Methodology for Selecting the Best Model for Forecasts: The Case Study of Forest Bioenergy

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Abstract: The aim of this paper is the analysis of methodology for selecting the best model for forecasting of fuelwood demand in Greece for the years 2020, 2025 and 2030 with a final objective the decision-making in the sector of forest bioenergy. A complete time series of historical data exists that concerns: (a) the consumption of fuelwood and (b) the six most important from the independent variables that could influence the consumption of fuelwood, whose data cover the time period 1989-2010. The evaluation and choice of the best model was realized with the help of the following six statistical criteria: (a) the size of standard error of theoretical values of dependant variable, S. E.; (b) the value of adjusted R square (R^2); (c) the non-existence of autocorrelation among the residuals (ϵ_i) through the criterion Durbin-Watson; (d) the statistical significance of models coefficients through t criterion; (e) the statistical significance of models through F criterion and (f) the non-existence of multicollinearity through the values of Variance Inflation Factor.

Key words: Evaluation of models, choice of the best model, statistical criteria.

1. Introduction

The time series (data) that they concern in consumption of fuelwood and they are used in this research have been taken by the statements of the Ministry of Agriculture of Greece [1], they concern in the time period 1989-2010 (Table 1). The time series (data) of the independent variables (population of Greece, per capita income of a Greek, consumer price index, price of fuelwood, price of charcoal and price of heating oil) have been taken by the Yearbooks of National Statistical Authority of Greece [2] (Table 2). A complete time series of historical data exists that concerns: (a) the consumption of fuelwood and (b) the six independent variables, which cover the time period 1989-2010.

2. Models of Fuelwood Consumption: The Theory and Building

The authors used a linear multivariate model of

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Table 1 Time series (data) of fuelwood consumption in the period 1989-2010.

Year	Consumption of fuelwood (in tons)
1989	2,479,841
1990	2,453,231
1991	2,434,326
1992	2,395,678
1993	2,378,456
1994	2,339,892
1995	2,312,956
1996	2,298,743
1997	2,275,654
1998	2,256,789
1999	2,231,213
2000	2,215,579
2001	2,209,620
2002	2,201,025
2003	2,189,027
2004	2,225,933
2005	2,278,091
2006	2,292,887
2007	2,343,035
2008	2,361,561
2009	2,379,430
2010	2,395,564

Table 2 Data of independent variables for the time period 1989-2010.

Year	Population of Greece (PG)	Per capita income of a Greek (euros in current values, PCIG)	Consumer price index (CPI) (year as a base: 2002 = 100.0)	Price of fuelwood (PF) euros/ton	Price of charcoal (PCh) euros/ton	Price of heating oil (PO) euros/1000 lt
1989	10,154,338	9,532	78.4	115	795	410
1990	10,206,352	9,895	79.8	118	825	440
1991	10,258,364	10,258	80.1	120	850	480
1992	10,325,937	10,849	81.6	120	890	500
1993	10,393,510	11,028	82.3	122	905	560
1994	10,461,083	11,279	82.5	125	920	600
1995	10,528,655	11,346	84.8	130	935	650
1996	10,596,228	11,658	86.3	130	950	680
1997	10,663,801	11,763	88.3	135	960	720
1998	10,731,374	11,954	92.7	135	967	760
1999	10,798,947	12,103	94.3	138	972	790
2000	10,866,521	12,212	94.6	140	975	840
2001	10,934,097	12,275	96.8	140	975	880
2002	10,922,209	12,321	100.0	142	980	910
2003	10,910,318	12,392	113.7	143	987	960
2004	10,898,428	12,151	136.9	144	990	1,000
2005	10,886,541	11,943	163.6	144	995	1,050
2006	10,874,653	11,712	189.5	145	1,000	1,090
2007	10,862,759	11,648	216.8	146	1,005	1,120
2008	10,850,867	11,383	240.5	148	1,012	1,170
2009	10,838,973	11,125	262.8	150	1,017	1,210
2010	10,815,197	10,878	285.2	152	1,022	1,270

regression (linear multiple regression model) (Eq. (1)) with the general form [3-5]:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_k X_{ik} + \varepsilon_i \quad (1)$$

Where, Y_i : the dependant variable;

$X_{i1}, X_{i2}, \dots, X_{ik}$: the independent variables;

$\beta_0, \beta_1, \dots, \beta_k$: the (unknown parameters) coefficients of regression;

ε_i : the error or term of error or disorderly term.

The error ε_i contains each deviation of model from the real situation. Thus, apart from the likely errors of measurements, it also contains errors of adaptation that they due either to omission of variables or to use of variables that they are not related to the dependant variable [6, 7].

The dependant variable which is studied here is the annual consumption of fuelwood in tons.

The assumptions that the authors make here in the multiple linear regression are the followings [8]:

(a) The variances of distributions of the random dependant variable Y_i are all equal each other and they are equal to σ^2 ;

(b) The values of dependant variable Y_i are all independent each other;

(c) The values of k independent variables are known constant, where they could be measured without some error. This means that the authors are reported to a model of regression where the independent variables X_i are not random;

(d) In each total of values of independent variables X_i corresponds a distribution of the random variable Y_i . The distributions of the dependant variable Y_i it is supposed that they follow the normal distribution.

A model (equation) in order to be more reliable it should include the most and mainly the most important from the independent variables $X_{i1}, X_{i2}, \dots, X_{ik}$ which influence the dependant variable Y_i . In other words, at the process of search of the best

relatively equation (model), the independent variables (factors) which actually practice a significant impact on the dependant variable Y_i should be not omitted by the equation. Moreover, it is required the variables to be quantitative, that is to say they should describe measurable sizes [9]. The independent variables it is able in this case to be: the population of Greece (PG), the per capita income of a Greek (PCIG), the consumer price index (CPI), the price of fuelwood (PF), the price of charcoal (PCh) and the price of heating oil (PO).

The larger the sample of observations the more accurate will be the estimate of the equation, but provided that a complete time series of data exists. Events which would have as a consequence the disturbance of interaction of the correlated to the equation variables did not take place at the corresponding time period of sample [7]. The time period 1989-2010 can be characterized as a period relatively normal, without significant disturbances and consequently the probability for change of equation structure is low.

The authors gathered data from all the factors (independent variables) which it is supposed that they practice a more or less significant influence on the consumption of fuelwood. Thus, the authors collected data for the time period 1989-2010 for six factors, as the population of Greece (PG), the per capita income of a Greek (PCIG), the consumer price index (CPI), the price of fuelwood (PF), the price of charcoal (PCh) and the price of heating oil (PO) (Table 2).

The authors suppose for the error or disorderly term ε_i that [6, 7, 10-12]:

- (a) It is a random variable (it takes positive and negative values and it follows normal distribution);
- (b) It has a mean equal to zero, $\mu = 0$ and a constant variance σ^2 , that is to say $\varepsilon_i \sim N(0, \sigma^2)$;
- (c) The values ε_i and ε_j for i, j are uncorrelated, that is to say $\text{cov}(\varepsilon_i, \varepsilon_j) = 0, i, j$;
- (d) The residuals ε_i are independent each other.

The following two suppositions are additionally

required for the estimate of the preceding linear multivariate model [11]:

- (a) The number of observations of sample is higher than the number of coefficients of model that the authors want to estimate, namely that $n > k + 1$ ($22 > 7$). This supposition ensures the essential degrees of freedom for the estimate as well as for the control of model;

- (b) Among the independent (interpretative) variables do not exist accurate linear relations, that is to say multicollinearity does not exist.

The estimate of regression coefficients became with the help of subprogram Stepwise Regression of SPSS for Windows [13, 14]. All the possible variables k were imported which it was judged that they could influence the dependant variable as well as all the possible combinations of them ($2^k - 1$).

The choice of interpretative variables for the building of models became progressively with the method of Stepwise Regression which is based on the maximization of (R^2) adjusted R Square. This method combines the choice of interpretative variables with the technique of their addition in the regression as well as with the technique of omission of variables that they previously had been imported [7, 9].

3. Models of Fuelwood Consumption: The Output

3.1 Models of Fuelwood

In the stepwise multiple regression, initially the authors registered the per capita income which is responsible for the 77.4% of variance on the consumption of fuelwood ($F_{1, 20} = 113.786, p < 0.001$) (Table 3). Afterwards, the price of fuelwood was added and it is responsible for an additional 3.9% of variance on the consumption of fuelwood ($F_{1, 19} = 41.514, p = 0.012$) (Table 3). Afterwards, the price of heating oil was added and it is responsible for an additional 0.9% of variance on the consumption of fuelwood ($F_{3, 18} = 27.852, p = 0.016$) (Table 3).

The model 3 was selected which has the highest value of Adjusted R Square (R^2), equal to 0.818 (Table 3). The predictors per capita income, price of fuelwood and price of heating oil influence significantly the dependent variable consumption of fuelwood (Table 3). The values of the column “Sig. F Change” show that the improvement of adaptation for the three models is significant (Table 3). The t values (t_1 , t_2 and t_3) show that the three independent variables contribute significantly to the prediction (Table 4).

The best model of fuelwood consumption is the model 3 which is expressed as in Eq. (2) (Table 4):

$$C_f = 2,485,497.561 - 0.672PCIG - 0.215PF + 1.887PO \quad (2)$$

$$R^2 = 0.818 \text{ S. E.} = 9.681 \text{ D. W.} = 1.93$$

$$t_1 = 8.096 > t_{0.05, 18} = 1.734;$$

$$t_2 = 8.958 > t_{0.05, 18} = 1.734;$$

$$t_3 = 12.096 > t_{0.05, 18} = 1.734;$$

$$F = 27.852 > F_{0.05, 3, 18} = 3.16;$$

$$VIF_{(PCIG, PF)} = 3.352;$$

$$VIF_{(PCIG, PO)} = 2.136;$$

$$VIF_{(PF, PO)} = 2.748.$$

Where, the values in the parentheses depict the standard errors of constant and the coefficients (bi) of independent variables of the model:

R^2 : The value of Adjusted R Square;

S. E.: The standard error of theoretical values of dependant variable;

D. W.: The Durbin-Watson test;

VIF: The values of Variance Inflation Factor for the various pairs of independent variables of a selected model by which the existence of multicollinearity is tested;

The authors define level of significance $\alpha = 0.05$. The authors realize unilateral control;

C_f : The variable that declares the consumption of fuelwood (dependent variable);

Table 3 Model summary.

Model	R	R square	Adjusted R square	Std. error of the estimate	Change statistics				
					R square change	F change	df1	df2	Sig. F change
1	0.880a	0.774	0.770	25.232	0.774	113.786	1	20	0.000
2	0.902b	0.813	0.804	13.324	0.039	41.514	1	19	0.012
3	0.907c	0.822	0.818	9.681	0.009	27.852	2	17	0.016

*a. Predictors: (constant), per capita income;

b. Predictors: (constant), per capita income, price of fuelwood;

c. Predictors: (constant), per capita income, price of fuelwood, price of heating oil.

Table 4 Regression coefficients.

Model	Unstandardized coefficients		Standardized coefficients		
	B	Std. error	Beta	t	Sig.
1 (Constant)	2,503,224.136	145.338		17,223.466	0.634
Per capita income	-0.412	0.132	0.880	3.121	0.000
2 (Constant)	2,497,586.423	103.514		24,128.006	0.523
Per capita income	-0.524	0.198	0.687	2.646	0.000
Price of fuelwood	-0.138	0.049	0.262	2.816	0.012
3 (Constant)	2,485,497.561	78.327		31,732.321	0.474
Per capita income	-0.672	0.083	0.626	8.096	0.000
Price of fuelwood	-0.215	0.024	0.214	8.958	0.012
Price of heating oil	1.887	0.156	0.127	12.096	0.016

* Dependent variable: consumption of fuelwood.

PCIG: The variable that declares the per capita income of a Greek (predictor, independent variable);

PF: The variable that declares the price of fuelwood (predictor, independent variable);

PO: The variable that declares the price of heating oil (predictor, independent variable).

3.2 Evaluation of Models

3.2.1 Control of Models

After the completion of models building (Tables 3 and 4), the best model was selected according to the following statistical criteria-controls:

- The size of standard error of theoretical values of dependant variable, S. E.;
- The value of adjusted R square, R^2 ;
- The non-existence of autocorrelation among the residuals (ϵ_i) through the criterion Durbin-Watson;
- The statistical significance of models coefficients through t criterion;
- The statistical significance of models through F criterion;
- The non-existence of multicollinearity through the values of Variance Inflation Factor (VIF).

3.2.2 The Standard Error of Theoretical Values of Dependant Variable, S. E.

The standard error of theoretical values of dependant variable (S. E.) was used as one of the more basic criteria for the choice of each model. The lower the value of this standard error is the closer to the estimated line of model are found the real values of dependant variable in the population, that is to say the value of dependant variable for given values of independent variables is so much more accurate and consequently the model is so much better [6, 8].

The standard error (S. E.) of theoretical values of dependant variable for the model 3 is the lowest one than that of the other models and it comes to 9.681 (Table 3).

3.2.3 The Value of Adjusted R Square, R^2

The adjusted R square (R^2) is considered as a better indicator of a model adaptation than the R square (R^2)

if the size of sample and the number of independent variables differ. The adjusted R square (R^2) receives values between 0 and 1, but it can receive even negative value [7, 10, 12, 15, 16]. In this paper, the size of sample ($n = 22$, number of past years 1989-2010) and the number of independent variables (6) differ. On the basis of this criterion, it was selected the model 3 which has the highest value of Adjusted R Square (R^2) that runs to 0.818 (Table 3) and this means that model 3 interprets the 81.8% of scattering, that is to say it is adapted enough satisfactorily on the data.

3.2.4 Control of Autocorrelation

If the sequential errors of the estimate of a model are related, the authors say that autocorrelation of residuals or disorderly terms exist. The autocorrelation in the errors of the estimate is in general indication of a bad specialization of a model. For this control is used the criterion Durbin-Watson [5, 7]. If the value D. W. is close to the number 2, then the authors are sure that autocorrelation does not exist. If it is close to zero then the existence of autocorrelation is sure [17-19]. In different cases, the authors are compelled to resort to marginal values given from statistical tables and after comparison proportionally to decide [10]. In the case of model 3, the value D.W is equal to 1.93 and so the authors are sure that autocorrelation does not exist. This constitutes indication of a good specialization of the model.

3.2.5 Control of the Statistical Significance of Models Coefficients through T-criterion

This control becomes with the t-criterion with which is checked each coefficient (b_i) of the model, separately, if it is statistically significantly different from zero in level of significance $\alpha = 0.05$. This control concerns the statistical significance of each independent variable separately on the interpretation of changes of the dependant variable. Rejection of null hypothesis (H_0) means that the independent variable that the authors examine is statistically significant for the interpretation of the dependant variable, that is to

say it influences the dependant variable, namely linear relation exists between the Y and X [20, 21].

In the selected model 3, the values of t for each independent variable are higher than the corresponding critical value of $t_{\alpha, v}$ the given from the statistical tables in level of significance $\alpha = 5\%$ and for v degrees of freedom. Consequently, in level of significance 5%, the null hypothesis (H_0) is rejected and this means that the independent variable that the authors examine each time is statistically significant for the interpretation of dependant variable, that is to say it influences the dependant variable, namely linear relation between each particular independent variable and dependant variable exists. From the preceding, it results that for the selected model 3 each one from the independent variables influences the dependant variable and at the same time that the coefficients (b_i) are significantly different from zero.

3.2.6 Control of the Statistical Significance of Models through F-criterion

By F-criterion the authors check the statistical significance of all together of the independent variables in the interpretation of changes of the dependant variable. The value of F for each model is checked if the particular relation between the dependant and the independent variables of model really exists [21]. Rejection of null hypothesis means that at least one of the independent variables is statistically significant for the interpretation of dependant variable, that is to say that at least one of the independent variables influences the dependant variable [21-23]. However, the model in order to be satisfactory, beyond the rejection of the null hypothesis (H_0), it should be in force $F > 4F_{\alpha, v_1, v_2}$ [3]. For the application of two preceding criteria it is supposed that the distribution of errors is normal with medium value zero and variance σ^2 , that is to say that $\varepsilon_i \sim N(0, \sigma^2)$ [11].

In the selected model 3, the value F is higher than the corresponding critical value F_{α, v_1, v_2} given from the statistical tables in level of significance $\alpha = 5\%$ and

for v_1 and v_2 degrees of freedom. Consequently, in level of significance 5%, the null hypothesis (H_0) is rejected, but likewise for the selected model 3 be in force $F > 4F_{\alpha, v_1, v_2}$ thing that means that this model is satisfactory.

3.2.7 Control of Multicollinearity

The values of Variance Inflation Factor (VIF) for the various pairs of independent variables of the selected model 3 are relatively low, thing that means that accurate linear relations among the independent variables do not exist, that is to say multicollinearity does not exist, but even if it exists, this is not harmful. Norusis [13] states that multicollinearity can be harmful if the VIF values are higher than 10.

4. Conclusion

The selected model 3 (Table 4) of fuelwood consumption is the best model (Eq. (2)) because it has the highest value of Adjusted R Square, thing that means that this model interprets a high percentage (81.8%) of deviations of theoretical from the real values, that is to say it is adapted enough satisfactorily on the data. The signs of independent variables are in conformity with the economic theory. The per capita income of a Greek influences negatively the consumption of fuelwood because fuelwood constitutes a product of cheapness. Concretely, as the per capita income increases, the standard of living rises and therefore the consumption of fuelwood decreases, with turn to mining fuels. The price of fuelwood influences negatively the consumption of fuelwood, namely as the price of fuelwood increases the consumption of fuelwood decreases. The price of heating oil influences positively the consumption of fuelwood, namely as the price of heating oil increases the consumption of fuelwood increases.

In the selected model 3, the standard errors of coefficients (b_i) are lower than the half of coefficients (b_i). The standard error (S. E.) of theoretical values of dependant variable for the model 3 is the lowest one than that of the other models and it comes to 9.681.

The Durbin-Watson test (D. W.) shows that autocorrelation among the residuals or disorderly terms ε_i does not exist. The values of Variance Inflation Factor (VIF) for the various pairs of independent variables of the selected model 3 are lower than 4, thing that means that multicollinearity does not exist.

In the selected model 3, the values of t for each independent variable are higher than the corresponding critical value of $t_{\alpha, v}$ given from the statistical tables in level of significance $\alpha = 5\%$ and for v degrees of freedom and this means that each one from the three independent variables is statistically significant for the interpretation of dependant variable, that is to say it influences the dependant variable.

In the selected model 3, the value F is higher than the corresponding critical value F_{α, v_1, v_2} given from the statistical tables in level of significance $\alpha = 5\%$ and for v_1 and v_2 degrees of freedom and besides $F > 4 F_{\alpha, v_1, v_2}$ be in force, thing that means that this model is satisfactory. After the relative controls it was ascertained that the basic assumptions are not violated by the selected model, thing that means that this model has a foreseeable ability. The selected model was used for the forecast of fuelwood consumption for the years 2020, 2025 and 2030. The reliability of these forecasts depends on the usable model. This paper could constitute a guide for those who would like to deal with the building of models for forecasts, because this paper provides a concentrated terminology for the building's conditions, the control and evaluation of the selected model.

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