THE AMBIENT AIR TEMPERATURE AND THE ELECTRICITY CONSUMPTION IN MACEDONIA FOR THE PERIOD 1992-1998

Marjan Nikolov[1]

Abstract

This research is an attempt to find a proper model where the ambient air temperature fluctuations can explain the electricity consumption fluctuations. The period under observation will be 1992-1998 on monthly data. I'll use an Ordinary Least Square Estimation method on static models. The results from the estimation show statistical significance in seasonal temperature impact on electricity consumption fluctuations. The impact is in the approximate range of 33-36 GWh per season and accounts for approximately 11 % of the mean monthly electricity consumption in the same period

THE RATIONALE FOR THE RESEARCH

The electricity consumption fluctuations are closely related to the ambient air temperature fluctuations. The end use of electricity for heating and/or cooling provides for the correlation between those two variables. Estimating proper statistical models will help in planning electricity consumption by the power utilities and/or by other stakeholders.

THE DATA

The data used for this research are courtesy of the ESM (The Macedonian Electric Power Company) for the electricity consumption time series; and the Macedonian Statistical Bureau for the time series on the average mean, maximum and minimum temperature in the Republic of Macedonia. The period under monthly observation is 1992-1998. Basic information about the time series are reported in the next Table 1

---

[1] Marjan Nikolov M.Sc.; Assistant/Interpreter to the resident IMF VAT expert.

Statistical basics	Average mean temperature (degree Celsius)	Average maximal temperature (degree Celsius)	Average minimal temperature (degree Celsius)	Electricity consumption in (GWh)	
mean	11.6	25.2	-0.8	303.6	
maximum	24.2	38.9	12.5	473.2	
minimum	-2.3	10.5	-20.2	165.3	
st. dev.	7.97	8.09	7.91	66.0	
Value interval	**%**	**%**	**%**	**Value interval**	**%**
[-30, -20)	-	-	1.19	**[100, 200)**	1.19
[-20, -10)	-	-	11.90	**[200, 300)**	50.00
[-10, 0)	4.76	-	39.29	**[300, 400)**	38.10
[0, 10)	39.29	-	39.29	**[400, 500)**	10.71
[10, 20)	32.14	30.95	8.33	-	-
[20, 30)	23.81	33.33	-	-	-
[30, 40)	-	35.72	-	-	-

Table 1

From the next Figure 1 we can note:

- Short run seasonal fluctuations in the electricity consumption;
- Long run progressive trend tendency in the electricity consumption;
- The positive peaks in electricity consumption are matching the negative peaks from the average mean air temperatures. The same holds true for the negative peaks in electricity consumption matching positive peaks in the average mean air temperatures.

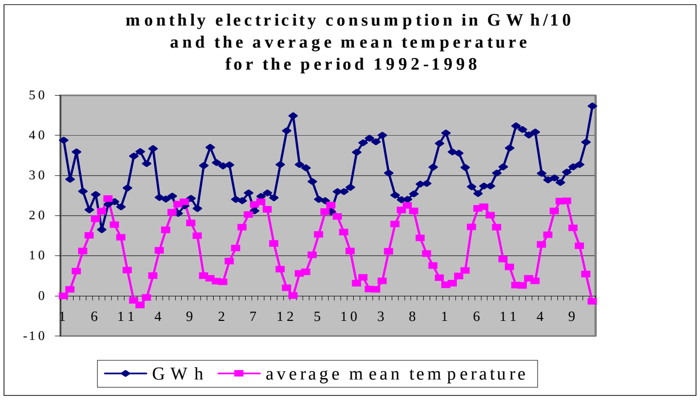

Figure 1

THE METHOD AND THE MODELS

In this research an Ordinary Least Squares estimation method on a static statistical models is used. The electricity consumption will be the dependent variable and the explanatory variables will be the temperature, the time and the four seasonal dummies. The seasonal dummies will cover the full seasonal effects and the time will cover the long run trend tendency in the electricity consumption. The functional dependence among the variables will be assumed cubical as a reasonable approximation with reference to the Figure's 1 fluctuations.

Three model types will be estimated:

MODEL 1: $E = \beta_0 + \beta_1 M + \beta_2 M^2 + \beta_3 M^3 + \beta_4 D1 + \beta_5 D2 + \beta_6 D3 + \beta_8 T$

MODEL 2: $E = \beta_0 + \beta_1 MAX + \beta_2 MAX^2 + \beta_3 MAX^3 + \beta_4 D1 + \beta_5 D2 + \beta_6 D3 + \beta_8 T$

MODEL 3: $E = \beta_0 + \beta_1 MIN + \beta_2 MIN^2 + \beta_3 MIN^3 + \beta_4 D1 + \beta_5 D2 + \beta_6 D3 + \beta_8 T$

	Explanatory variable
Model 1	Average mean temperature-**M**
Model 2	Average maximum temperature-**MAX**
Model 3	Average minimum temperature-**MIN**

The description of the parameters in the models is in the Table 2.

PARAMETERS DESCRIPTION	
β_0	**constant**
β_1	**linear dependence**
β_2	**quadratic dependence**
β_3	**cubic dependence**
$\beta_4, \beta_5, \beta_6, \beta_7$ [2]	**Winter dummy (months: 12; 1; 2) and/or** **Spring dummy (months: 3; 4; 5) and/or** **Summer dummy (months: 6; 7; 8) and/or** **Autumn dummy (months: 9; 10; 11)**
β_8	**time**

Table 2

---

[2] One dummy is omitted always to avoid multicollinearity and singularity in estimation.

For each model all variations were estimated with one dummy excluded in order to find what is the most significant dummy. Then, by examination of the parameter's t-statistics, it was determined what are the most significant functional forms and what are the significant dummies. This is illustrated in the following section for the Model 1 with the mean average temperature.

THE MEAN AVERAGE TEMPERATURE-MODEL 1 TYPE ESTIMATIONS

Qualitative results were achieved by estimation where D4 (autumn) was excluded from the model 1and another estimation where D3 (summer) was excluded from the model 1. In a model where only D3 and D4 were involved together, the D4 parameter was not statistically significant. The dummies D1 and D2 were not statistically significant.

The results from the estimation are reported in the following Table 3. First we will look at the significance of the explanatory functional dependency parameters and then in the significance of the dummy's parameters.

THE MEAN AVERAGE TEMPERATURE MODEL 1			
	Estimation 1	**Estimation 1.1**	**Estimation 1.1.1**
β_0	**346.168 (24.800)**	**330.762 (27.584)**	**346.909 (47.311)**
β_1	**-8.529 (-2.857)**	**-7.377 (-9.668)**	**-**
β_2	**-0.253 (-0.921)**	**-**	**-**
β_3	**0.016 (1.905)**	**-**	**-8.349 (-15.614)**
β_4			
β_5	**7.714 (0.671)**	**19.225 (1.759)**	**-**
β_6	**5.080 (0.667)**	**3.788 (0.473)**	**-**
β_7	**-2.490 (-0.171)**	**30.775 (2.795)**	**36.335 (3.716)**
β_8	**1.070 (9.571)**	**1.065 (9.147)**	**1.054 (9.025)**
DW	**2.236**	**2.191**	**2.053**
R^2	**0.875**	**0.857**	**0.851**
ARCH-($n \cdot R^2$)	**-**	**-**	**2.967**

Note: t-statistic in parentheses.

Table 3

From the estimation of the full model 1 (estimation 1 from the Table 3), we can see that the parameters β_2 and β_3 are not statistically significant. Therefore in the next estimation 1.1 they will be excluded from the model 1. In this estimation 1.1 we can see that the parameters β_5 and β_6 are not significant and they will be excluded from the model 1. The final estimation 1.1.1 has as a result significant parameters. The Durbin-Watson test statistic in the estimation 1.1.1 shows no serial correlation in the residuals. The R^2 shows significant goodness of fit in the estimation 1.1.1. This estimation 1.1.1 accepts the null of no ARCH[3] effect in the model.

THE RESULTS FROM THE ESTIMATION

The very same method was applied to the other models and the final results of the estimation are reported in the Table 4.

ELECTRICITY CONSUMPTION AND AMBIENT TEMPERATURE MODELS			
	Model 1 average mean temperature	**Model 2 average maximum temperature**	**Model 3 average minimum temperature**
β_0	**346.909** **(47.311)**	**341.896** **(34.334)**	**230.832** **(33.591)**
β_1	**-**	**-**	**-7.081** **(-9.649)**
β_2	**-**	**-**	**0.183** **(2.933)**
β_3	**-8.349** **(-15.614)**	**-0.003** **(-13.439)**	**0.016** **(3.439)**
β_4	**-**	**-**	**34.047** **(3.729)**
β_5	**-**	**-34.724** **(-3.741)**	**-**
β_6	**36.335** **(3.716)**	**-**	**-**
β_7	**-**	**-33.468** **(-3.645)**	**-**
β_8	**1.054** **(9.025)**	**1.025** **(6.639)**	**1.099** **(8.936)**
DW	**2.053**	**2.004**	**2.018**
R^2	**0.851**	**0.745**	**0.868**
ARCH-($n \cdot R^2$)	**2.967**	**0.004**	**0.066**

Note: t-statistic in parentheses.

Table 4

From the Table 4 we can see that:

- All models shows no serial correlation in the residuals[4] from the Durbin-Watson test statistic and no ARCH effect;
- Significant goodness of fit in the models.

---

[3] Under the null, the $n \cdot R^2$ has a χ^2 distribution with one degree of freedom. The critical value is 3.841.

[4] The Model 3 was adjusted for the ARCH effect in the residuals with a help of the following estimated equation: $\varepsilon_t = \rho_1\varepsilon_{t-1} + \rho_2\varepsilon_{t-2} + \rho_3\varepsilon_{t-3}$. See more in [ ].

- For the average mean temperature model 1, the cubic parameter is most significant, the time and the summer dummy;
- For the average maximum temperature model 2, the cubic parameter is most significant, the time and the spring and autumn dummies;
- For the average minimum temperature model 3, the linear, quadratic and cubic parameters are significant, the time and the winter dummy.

CONCLUSION

There is a statistical significance in the correlation between the electricity consumption and the ambient air temperature. The time trend dependence of the electricity consumption is significant probably because of the population growth and/or economic development. The cubic dependence of the electricity consumption level value from the mean, maximum and minimum temperature is statistically significant. Additionally, in the model 3 (average minimum temperature model) the electricity consumption is depending on the linear and quadratic value of that temperature as well.

From the estimated models we can conclude also the following:

- **Model 1.** If during the year the air temperature is on the average mean, the most significant season for the electricity consumption is the summer (months: June, July and August). This can be due to the cooling end use of electricity. The summer dummy is with positive value of 36.335 and that means that in summer the electricity consumption will be, beside the constant 346.909 GWh, higher for 36.335 GWh as a seasonal effect. The monthly trend increasing is 1.054 GWh for each following month in a year with average mean ambient temperature.
- **Model 2.** If during the year the air temperature is higher than the average means for the proper period of the year, meaning closer to the maximum averages, then the most significant seasons for the electricity consumption are spring and autumn (months: Mart, April, May, September, October and November). This is understandable because if the air temperatures are higher compare with the usual average means for that period, in those months the heating end use of the electricity will end earlier in spring and the start heating season will be prolonged in the autumn. The spring dummy is with negative value of -34.724 meaning that in spring the electricity consumption will be, beside the constant consumption of 341.896 GWh, lower for –34.724 GWh as a seasonal effect. The autumn dummy is with negative value of –33.468 meaning that in autumn the electricity consumption will be, beside the constant consumption of 341.896 GWh, lower for –33.468 GWh as a seasonal effect. The monthly trend increasing is 1.025 GWh for each following month in a year with average maximum ambient temperature.
- **Model 3.** If during the year the air temperature is under the average means for that period of the year, the most significant season for the electricity consumption is winter (months: December, January, and February). This is understandable because when the temperatures are lower than the averages for that period of the year the consumption of electricity is higher because the heating end use of electricity is on higher scale. The winter dummy is with positive value of 34.047 and that means that in winter the electricity consumption will be, beside the constant consumption of 230.832 GWh, higher for 34.047 GWh as a seasonal

effect. The monthly trend increasing is 1.099 GWh for each following month in a year with average minimum ambient temperature.

- The monthly increasing is highest in a year with average minimum temperatures and lowest in a year with average maximum temperatures. This can be a sign of biased end use of electricity toward heating compare to cooling end use in the observed period. The evidence for that was found in the signs of the winter, spring and autumn dummies. The monthly increasing of electricity consumption is approximately 1 GWh per month.
- The seasonal impact on electricity heating/cooling end use is in the approximate range of 33-36 GWh per season, depending on the average temperatures and it accounts for approximately 11 % of the mean monthly electricity consumption in the period 1992-1998.

LITERATURE

[1] R. L. Thomas (1997) “Modern Econometrics”, Addison-Wesley Ltd.
[2] Walter Enders (1995) “Applied Econometrics Time Series”, John Wiley & Sons.
[3] Dale J. Poirier (1995) “Intermediate Statistics and Econometrics”, MIT Press.
[4] R. Turvey and D. Anderson (1977) “Electricity Economics”, A World Bank P.