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Article

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Determinants of household electrical energy consumption: Evidences and suggestions with application to Montenegro

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Abstract

The aim of this paper is to examine various socio-economic, dwelling-related and appliance-related factors which influence electricity consumption in Montenegro. Data was collected via questionnaires completed by 964 households in the second quarter of 2019 in Montenegro. Structural Equation Modelling (SEM) was applied in order to simultaneously examine the causal relationships between multiple factors, using a series of equations. The obtained results indicate the importance of income, dwelling size, family composition and routines, appliance age and region in determining household electricity consumption in Montenegro. The results show that the determinant which influences the electricity bill the most is the dwelling size, followed by the family composition and routines. On average, during winter and summer, dwelling size contributes to the energy consumption with 95%, while family composition and routines contribute with 56.85%. These determinants exert the same influence in winter and in summer, with the only statistically significant difference being observed in the variables that describe the types of heating or cooling.

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Keywords: Household electricity consumption; SEM; Montenegro

1. Introduction

Electricity consumption has a major impact on economic development, but it is of particular importance for households too. The concept of sustainable development, based on the rational use of resources, is an integral part of modern society. Electricity is not an exception to this concept; there is a trend of growth in electricity consumption all over the world. Predicting electricity consumption and identifying the determinants that have a significant impact on electricity consumption is of great importance for those who develop energy strategies. Numerous studies conducted in different countries have addressed this problem in order to determine and measure the impact of certain determinants and create an appropriate strategy (e.g. [1–5]). In Montenegro, as a developing country, and even in the Western Balkans, no similar study has been conducted so far, which was the main motive for selecting this topic. One of the main contributions of this paper lies in the fact that its results can be used in

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developing and creating energy strategies, which are based on the principles of sustainable development. Also, a valuable contribution of this paper is having this analysis applied for the first time on the data from Montenegro, which contains the conclusions regarding the discovery of electricity consumption determinants of a small and developing market, such as Montenegro.

For the purpose of this study, we developed a questionnaire based on a literature review and on previous research — primarily a research by Jones et al. [6]. Detailed information on our survey are given in the Methodology and Data section of this paper. Using an SEM (Structural Equation Modelling) model, we determined the impact of: dwelling size, household size, region, appliance age, routines in using appliances, and modes of heating and cooling on electricity consumption. We were also interested in whether there was a statistically significant difference in the impact of these determinants on electricity consumption during the summer months in relation to the winter period. To this end, we developed two separate econometric models.

The paper is structured as follows: an introductory section is followed by an overview of the relevant research on the topic. The third section of the paper explains the methodology and data used in the study. After the discussion of the results presented in the fifth section, the conclusion is presented as the final section of the paper.

2. Literature review

Understanding the determinants of electricity consumption is a precondition for implementing an effective energy policy, as well as for predicting future electricity consumption. Therefore, a vast body of studies, using different methods on data from different countries and groups of countries, is attempting to identify and explain the determinants that have the greatest impact on electricity consumption. According to Jones et al. [6], there are at least 62 factors that affect household electricity consumption, with 13 being socio-economic factors, 12 dwelling-related factors and 37 appliance-related factors. However, in different countries, whether these are developed or developing countries, there are various factors that determine electricity consumption.

As regards developed countries, Kim [1] examined the determinants of electricity consumption in South Korea for two groups of households, those with the highest and those with the lowest consumption. The results show differences in socio-demographic, dwelling and consumption characteristics between these two groups, while the only factor that affects electricity consumption in both groups of households is the number of electrical appliances. Yalcintas and Kaya [7] compared electricity consumption in the Hawaiian Islands and showed that each island has a different electricity consumption pattern, which indicates the importance of the dwelling type, lifestyle and household size. Huebner et al. [8] showed that the total energy consumption in English households is largely explained by the dwelling characteristics, with a comparatively small contribution made by socio-demographics, self-reported behaviours, and attitudes towards environmentally significant behaviour and climate change. Huang [9] showed that the impact of demographic, socio-economic and dwelling characteristics on household electricity consumption in Taiwan can be distinguished through quantiles and changes over time. According to this study, the main characteristics of those households which are larger electricity consumers are higher income levels, more household members and the presence of senior citizens in the household. Similarly, Ndiaye and Gabriel [5] and Bartusch et al. [10] showed that household size is a significant determinant of electricity consumption in Canada and Sweden, respectively, that is, higher electricity consumption is characteristic for households with a larger number of members. The study conducted by Blázquez et al. [11] using aggregate panel data cited price, income and weather conditions as the most important electricity consumption factors in Spain, with weather variables having the most significant impact on consumption. Kavousian et al. [3] indicated time, location and dwelling size as the main variables that affect household electricity consumption in the US. Unlike other studies, they did not find a correlation between electricity consumption and income level, building ownership and the year of construction. Bedir et al. [2] estimated three models of electricity consumption in households in the Netherlands and showed that the duration of appliance use and dwelling and household characteristics are important predictors in electricity consumption models. McLoughlin et al. [4] examined the impact of dwelling and socio-economic characteristics on the consumption of electricity in Irish households. The results showed that the dwelling type, number of bedrooms, age of the head of the household, household composition, social class, water heating and cooking type have a significant impact on electricity consumption. Wiesmann et al. [12] showed that the direct effect of income on electricity consumption in Portugal is low and becomes even smaller when more relevant control variables are included in the analysis. Future demand for electricity in Portugal will be significantly influenced by trends in socioeconomic factors as well as by changes in the building stock.

Unlike in developed countries, the number of such studies in developing countries is not so large. In Nigeria, Babatunde and Enehe [13] indicated the importance of socioeconomic variables such as household size, number of rooms in the household and hours of power supply for determining electricity consumption. In addition, the income inelasticity of electricity consumption points to the importance of electricity as a necessity in Nigerian households. Ye et al. [14] showed that household income and electricity prices are important determinants of electricity consumption in developing countries such as South Africa. In addition, their study showed that electricity consumption is higher in appliance-rich households in urban areas, especially if there are more household members and they live in larger dwellings. Al-Bajjali and Shamayleh [15] examined the determinants of electricity consumption in Jordan and came to the conclusion that GDP, urbanisation, the structure of the economy and aggregate water consumption are significant and positively correlated to electricity consumption, while electricity prices are significant and negatively correlated to electricity consumption. Sakah et al. [16] showed that owning an air conditioner, freezer, fan, refrigerator and television; and, changes in socio-economic and building factors such as energy efficiency awareness and practise, income, household size and floor space have a high statistical significance in Ghana, and collectively account for 57% of the variance in total electricity consumption in households.

Finally, it can be concluded that every country, regardless of its level of development, has its own factors that influence electricity consumption. To date, there is still no study in the literature on the determinants of electricity consumption in Montenegro. Therefore the aim of this study is to fill that gap in the literature.

3. Methodology and data

Our aim was to examine the determinants of energy consumption in Montenegro. More specifically, we wanted to investigate whether there are different determinants that affect energy consumption during the summer and winter months. In order to do so, we conducted an SEM model analysis using the R package. SEM is a statistical multivariate analysis method used to simultaneously examine causal relationships between multiple factors. In doing so, it investigates the structure of interrelationships expressed in a series of equations.

An online survey was conducted in the second quarter of 2019. The sample consisted of 964 anonymous respondents from Montenegro. The survey was designed according to Jones et al. [6]. All 964 responses were valid, and the survey data could be considered valid only if the survey was completed in its entirety. In order to examine the perceptions, awareness and attitudes, the respondents were asked to rank the specified statements on a Likert scale.

As for the structure of the sample, the largest number of households consisted of four members (34.7%), followed by households with five or more members (27.4%). As regards household structure, 52.8% of households consisted of a couple with children, while the least number of households consisted of couples only (11.6%). The results showed that the average monthly household income in the sample had a fairly uniform distribution, with the majority of households claiming a monthly income of between €701 and €1000 (23.3%). Finally, the largest proportion of respondents live in the central region (75.9%), which is explained by internal migration of the population within Montenegro. The sample was representative and well structured.

Our basic hypothesised structural model contained the following two constructs – family composition and routines, and the age of the appliances – together with variables concerning household income, the region of the state to which the household belongs, the size of the house/flat, the heating type and air conditioning type that the household uses and energy consumption reflected in electricity bills during the summer and winter months.

The family composition and routines were measured by seven properties of households regarding the number of family members and their routines in terms of appliance usage. The first variable is coded as family_no and relates to the number of household members. The other four variables (oven_t, dishw_t, washm_t, and dryer_t) relate to how many times per week the appliance is used and has a value of 1 in cases where the respondents confirm that it is used 1–3 times per week; 2 when it is used 4–7 times per week; and 3 if the appliance is used eight times or more per week. The last two variables from this construct (tv_t and pc_t) are formed on a 5-point Likert scale by asking the respondents to rank the number of hours per day that the television or personal computer is on. A value of 1 is used for 0–3 h per day, 2 for 4–6 h per day, 3 for 7–10 h per day and 4 for 11 h or more per day that the television/personal computer is on. A value of zero is used if the respondent explicitly mentions that household members did not use the appliances at all.

For this group of variables, we performed a reliability analysis applying Cronbach's alpha coefficient, which was 0.701.

The appliance age was evaluated by the average age of kitchen appliances, the washing machine/dryer and the heating/cooling device. The appliance age was ranked as follows: a value of 1 was used if the age of an appliance was less than one year; 2 was used where the age was between 1 and 5 years; 3 was used for an age between 5 and 10 years; and a value of 4 for an age greater than 10 years. Cronbach's alpha coefficient was 0.807.

Following the aforementioned latent variables, we used further variables that were evaluated in the survey. Variable income stood for the average monthly income of the household and was evaluated on a scale of 1 to 6 (1 – less than €200; 2 – from €201 to €500; 3 – from €501 to €700; 4 – from €701 to €1000; 5 – from €1001 to €1500; 6 – more than €1500). The variable named 'region' represents the region in the state where the household is located (the value for the northern region is 1, for the central region 2, and a value of 3 for the southern region of the country). The next variable considered was the size of the flat/house expressed in square metres. And this variable is evaluated on a scale of 1 to 5 (1 – less than 35 m^2; 2 – from 36 m^2 to 50 m^2; 3 – from 51 m^2 to 65 m^2; 4 – from 66 m^2 to 100 m^2; 5 – more than 100 m^2). The final two independent variables that potentially affect household electricity consumption are the types of heating and cooling in households. There are seven potential heating methods (1 – electricity (central heating); 2 – electricity (air conditioning); 3 – electricity (radiators/heaters); 4 – wood; 5 – wood pellets; 6 – coal; 7 – solar panels), and four cooling methods (0 – I do not use cooling devices; 1 – air conditioning; 2 – fan; 3 – air conditioning and fan).

Finally, the dependent variable of electricity consumption was measured by two indicators: the average monthly bills during the summer and winter. These two variables were evaluated on a scale of 0 to 5 (0 – no answer; 1 – less than €20; 2 – from €21 to €40; 3 – from €41 to €60; 4 – from €61 to €100; more than €100). The descriptive statistics of all the above variables are presented in Table 1.

Table 1. Variable measurement and descriptive statistics.

Latent variables	Code	Observed variable definition	Mean	S.D.	Min.	Max.
Family composition and routines	family_no	Number of household members	3.5394	1.27455	1	5
	oven_t	Times per week oven is used	1.7261	0.85129	0	3
	dishw_t	Times per week dishwasher is used	1.3402	1.05297	0	3
	washm_t	Times per week washing machine is used	1.8880	0.78522	0	3
	dryer_t	Times per week dryer is used	0.4357	0.81459	0	3
	tv_t	Hours per day television is on	2.4855	1.22168	0	4
	pc_t	Hours per day personal computer is on	1.7842	1.06611	1	4
Appliance age	kitchen_age	Average age of kitchen appliances	2.4025	0.70698	1	4
	machine_age	Average age of washing machine and/or dryer	2.3568	0.73403	1	4
	cool/heat_age	Average age of heating/cooling device	2.3195	0.75938	0	4
Income	income	Average monthly income of household	3.8714	1.52345	1	6
Region	region	Region of state	1.9917	0.49153	1	3
Size	size	Size of house/flat (in square metres)	3.5353	1.08772	1	5
Heating type	heat_t	Type of heating the household uses	2.9336	1.11605	0	6
Air conditioning type	cool_t	Type of air conditioning the household uses	0.9876	0.69810	0	3
Summer electricity bill	e_bill_summer	Average electricity bill in summer	2.9627	1.04615	0	5
Winter electricity bill	e_bill_winter	Average electricity bill in winter	3.4979	0.98795	0	5

Notes: Latent variables include several factors, marked by codes. Every variable (factor) has its definition shown in column 3, and the mean value (Mean) and standard deviation (SD) are calculated in columns 4 and 5. Min and Max are abbreviations for the minimum and maximum observed value.

4. Results and discussions

We estimated the structural equation model by the maximum likelihood estimation method with the R package. The results of the SEM model are presented in Tables 2 and 3 according to the dependent variable. The first model looked at electricity consumption during the summer months, so the dependent variable is the summer electricity bill (Table 2). The goodness of fit is measured by the chi-squared (χ^2) statistic and the CFI. The chi-squared statistic is 754.381 with 75 degrees of freedom ($p = 0$), and the CFI (comparative fit index) is 0.917, which shows a sufficiently good fit. In addition, the root mean square error of approximation statistic (RMSEA) is 0.091, which is below the upper acceptable boundary of 0.1 [17,18]. The estimated results and standardised path coefficients are

Table 2. Estimation results of SEM model — the summer electricity bill is the dependent variable.
Source: Authors' calculation.

Causal relationship	Non-normalised path coefficient	S.E.	P	Normalised path coefficient
Summer electricity bill ← income	1.000	–	–	0.495
Summer electricity bill ← family composition and routines	0.671	0.080	0.000***	0.674
Summer electricity bill ← appliance age	0.062	0.038	0.099*	0.080
Summer electricity bill ← region	0.056	0.029	0.051*	0.087
Summer electricity bill ← size	1.140	0.139	0.000***	0.791
Summer electricity bill ← air conditioning type	0.043	0.041	0.292	0.047
family_no ← family composition and routines	1.000	–	–	0.589
oven_t ← family composition and routines	0.616	0.057	0.000***	0.543
dishw_t ← family composition and routines	0.832	0.073	0.000***	0.594
washm_t ← family composition and routines	0.624	0.054	0.000***	0.597
dryer_t ← family composition and routines	0.467	0.052	0.000***	0.430
tv_t ← family composition and routines	0.759	0.079	0.000***	0.467
pc_t ← family composition and routines	0.528	0.066	0.000***	0.372
kitchen_age ← appliances age	1.000	–	–	0.827
machine_age ← appliances age	1.029	0.057	0.000***	0.820
cool/heat_age ← appliances age	0.852	0.052	0.000***	0.656
χ^2	754.381			
Df	75			
RMSEA	0.091			
CFI (Comparative Fit Index)	0.917			
TFI (Tucker–Lewis Index)	0.857			

Notes: Independent variables (direct and indirect) are indicated in column 1, after the symbol "←";
For example, the abbreviation "summer electricity bill ← income" means measuring the path coefficient that indicate the influence of income to the summer electricity bill;
***, ** and * indicate significance at the level of 1%, 5 % and 10% respectively. P represents the p-value. S.E. is the abbreviation for calculated standard errors.

also shown in Fig. 1 as a flow diagram, in order to graphically illustrate the interrelations obtained between the used variables.

In our model, the standardised factor loadings that were statistically significant to 0.01 are those for dwelling size and for family composition and routines. This implies that, all other conditions remaining constant, the contributions of dwelling size and of family composition and routines to electricity consumption during the summer months were 79.1% and 67.4%, respectively. So, the results indicate that size of flat/house played a more important role than family routines in energy consumption in the summer months.

The factor loadings of appliance age and region were statistically significant to 0.1, indicating that appliance age positively contributes to energy consumption in the summer months with 8% and that the region positively contributes to it with 8.7%. The type of air conditioning in the households is not statistically significant for energy consumption in the summer months since the p-value for its factor loading is large, while income positively contributes to energy consumption in the summer months with 49.5%.

All of the seven exogenous variables of family composition and routines are statistically significant at a significance level of 0.01 and have a positive correlation with family composition and routines. The standardised path coefficients of washing machine time, dishwasher time, number of family members, oven time, television time, dryer time and personal computer time are 0.597, 0.594, 0.589, 0.543, 0.467, 0.430 and 0.372, respectively. These results mean that the time appliances are turned on positively contributes to family composition and routines, and indirectly affects energy consumption in the summer months.

The same goes for appliance age. This construct has three exogenous variables that are listed in Table 1 (kitchen age, machine age and cooling/heating age). Of all these variables, the largest contribution to appliances age is made by the variable kitchen age – 0.827. This implies that the age of kitchen appliances exerted a stronger influence on energy consumption on summer nights, indirectly, and this contribution was estimated at 90.7% (0.827+0.080), while other conditions remained constant. This is followed by the contributions of the variables machine age and cooling/heating age, with standardised path coefficients of 0.820 and 0.656, respectively. Its contributions to energy consumption on summer nights were estimated at 90% and 73.6%, respectively.

Table 3. Estimation results of a SEM model — the winter electricity bill is the dependent variable.
Source: Authors' calculation.

Causal relationship	Non-normalised path coefficient	S.E.	P	Normalised path coefficient
winter electricity bill ← income	1.000	–	–	0.349
winter electricity bill ← family composition and routines	0.654	0.086	0.000***	0.463
winter electricity bill ← appliances age	0.104	0.041	0.011**	0.095
winter electricity bill ← region	0.092	0.032	0.004***	0.099
winter electricity bill ← size	2.271	0.430	0.000***	1.109
winter electricity bill ← heating type	0.467	0.080	0.000***	0.222
family_no ← family composition and routines	1.000	–	–	0.589
oven_t ← family composition and routines	0.629	0.058	0.000***	0.555
dishw_t ← family composition and routines	0.808	0.072	0.000***	0.576
washm_t ← family composition and routines	0.640	0.055	0.000***	0.612
dryer_t ← family composition and routines	0.447	0.051	0.000***	0.412
tv_t ← family composition and routines	0.766	0.079	0.000***	0.471
pc_t ← family composition and routines	0.539	0.066	0.000***	0.379
kitchen_age ← appliance age	1.000	–	–	0.823
machine_age ← appliance age	1.038	0.057	0.000***	0.823
cool/heat_age ← appliance age	0.857	0.052	0.000***	0.656
χ^2	785.418			
Df	75			
RMSEA	0.094			
CFI (Comparative Fit Index)	0.911			
TFI (Tucker–Lewis Index)	0.850			

Notes: Independent variables (direct and indirect) are indicated in column 1, after the symbol "←";
For example, the abbreviation "winter electricity bill ← income" means measuring the path coefficient that indicates the influence of income on the summer electricity bill;
***, ** and * indicate significance at the levels of 1%, 5 % and 10% respectively. P represents the p-value. S.E. is the abbreviation for calculated standard errors.

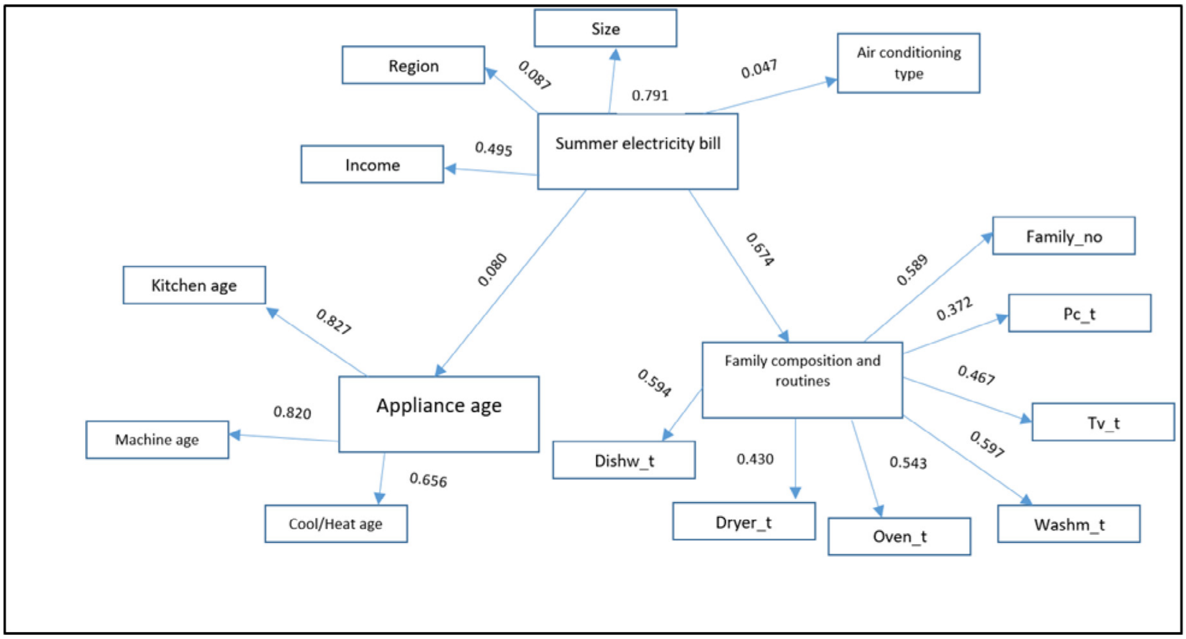

Fig. 1. SEM results for factors influencing energy consumption during the summer months.

The second model is based on energy consumption during the winter months, so the dependent variable is the winter electricity bill (Table 3). As can be seen from Table 3, the goodness of fit, as measured by the chi-squared statistic, is 785.418 with 75 degrees of freedom ($p = 0$), and the CFI (comparative fit index) is 0.911. The root mean square error of approximation statistic (RMSEA) is 0.094. The estimated results and standardised path coefficients are also shown in Fig. 2 as a flow diagram.

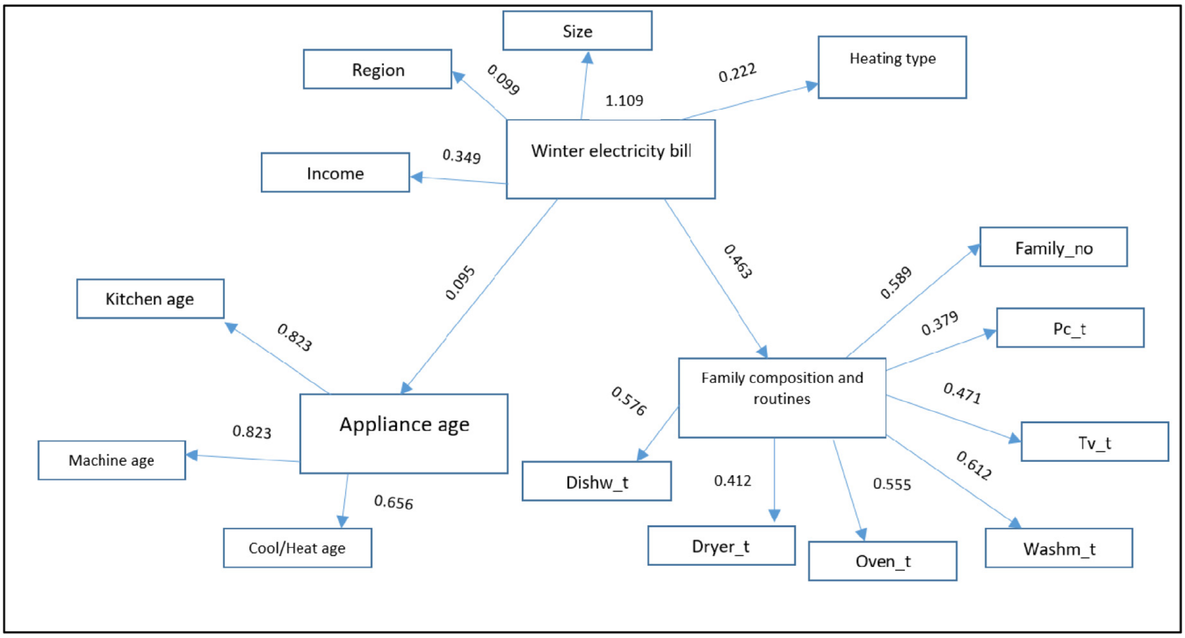

Fig. 2. SEM results for factors influencing energy consumption in the winter months.

Almost all standardised factor loadings were statistically significant to 0.01 in this second model. The size of the flat or house made the largest contribution to the winter electricity bill, and this contribution was 110.9% – all other conditions remaining unchanged. Family composition and routines had an impact of 46.3% measured by the normalised path coefficient. The average monthly income of the household positively contributed to electricity consumption in the winter months with 34.9%, as well as the type of heating, whose contribution amounted to 22.2% – all other conditions remaining unchanged. The region of the state made a positive contribution to electricity consumption in winter months, amounting to 9.9%. With a level of significance of 5% we can conclude that the age of household appliances positively contributed to electricity consumption in winter months, amounting to 9.5%.

Similar to electricity consumption in the summer months, in the winter months too, there were statistically significant positive contributions to the exogenous variables of the construct family composition and routines. These contributions were as follows: 0.612, 0.589, 0.576, 0.555, 0.471, 0.412 and 0.379, and were related to the working time of the washing machine, the number of household members, the dishwasher, the oven, the television, the dryer and the personal computer.

The impact of the age of appliances on energy consumption during the winter months was also positive, with a significance level of 0.01. The indirect influence of appliances age was 91.8% (0.823 + 0.095), the influence of the age of the washing and drying machines was also 91.8% (0.823 + 0.095), and the influence of the age of the cooling and heating devices was 75.1% (0.656 + 0.095).

Based on the previously explained results, it can be concluded that all the variables influence electricity consumption, with the expected sign, in both the winter and summer months. Namely, it is shown that the impact of household income on energy consumption is significant and positive, suggesting that an increase in the level of income is associated with higher household electricity consumption. Similarly, the number of family members has a positive correlation with electricity consumption, suggesting that as the household size increases, more electricity is consumed [2,3]. The amount of time appliances are turned on positively contributes to family composition and routines, and indirectly affects energy consumption during the summer and winter months. This is contrary to the findings of McLoughlin et al. [4] who determined that the use of major cooking appliances did not have a significant influence on electricity consumption, but this is in line with the findings of Bedir et al. [2], who established that the duration of use of appliances accounted for 37% of the variance in electricity consumption. In addition, it is not surprising that the appliance age had a positive impact on electricity consumption. In addition, previous-generation appliances require more energy to perform their functions and, therefore, they increase the electricity tariff. The results obtained point to the fact that electricity consumption is higher in dwellings with a larger floor area, which is contrary to the findings of Bedir et al. [2], who showed that a floor area has a very small influence on electricity consumption. The effects of region variables on household electricity consumption were largely significant. These results showed that household electricity consumption varied across regions, which was probably attributed to the climatic characteristics. According to the obtained data, the average winter electricity bill in the northern region was €20.61, while the average electricity bill in the southern region for the same period was €49.64. During the summer months, the average bill in the northern region amounted to €24.79, while in the southern region it amounted to €36.04.

The only difference found between the determinants of electricity consumption during the summer and winter months was the finding that the type of cooling during the summer months did not have a significant impact on consumption, while the type of heating was shown to be a significant determinant of electricity consumption in the winter months. Namely, 40% of households from the sample used wood, wood pellets or coal for heating, with their average electricity bill ranging from €41 to €60, while 60% of households used electricity for heating, and their average bill was between €61 and €100. According to the data obtained in the survey, air conditioning was the most dominant type of heating.

Generally, the primary determinant that contributes to the electricity consumption in summer and winter months in Montenegro is dwelling size. Its contribution amounts to 79.1% in summer and 110.9% in winter months. Second rated determinant is family composition and routines — its contribution is 67.4% in summer and 46.3% in winter months. Besides those, an important determinant for the electricity consumption is income, which is measured by normalised path coefficient of 49.5% in summer and 34.9% in winter months.

5. Conclusion

The aim of this paper was to analyse the determinants of energy consumption in Montenegro, i.e. to investigate whether there are different determinants that affect energy consumption in the country.

Using an SEM model on data collected in the second quarter of 2019, we came to the conclusion that the tested variables had an impact on the dependent variable (the monthly electricity bill) with the expected sign. In the summer months the contribution of dwelling size and family composition and routines to energy consumption was 79.1% and 67.4%, respectively. A similar trend was also proven for the winter period. Namely, dwelling size had the greatest impact in the winter period, amounting to 110.9%, while the second significant factor was family composition and routines (46.3%).

Since, to the best of our knowledge, similar studies have not been done so far for the Western Balkan countries, further studies could be done in which a comparative analysis could be performed of these determinants, including price as an important factor of demand. As regards political implications, the results of this study will make a special contribution to energy management especially in the field of forecasting and planning electricity consumption, with the aim of resource conservation, environmental protection, as well as financial savings.

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