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Efficiency of daylight saving time on electricity consumption in Slovakia

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Abstract: This paper examines the impact of daylight saving time (DST) on electricity consumption in Slovakia. As DST was implemented in 1996, we do not have the possibility to have a control period to identify the impact of DST directly with before and after or with and without analysis. This problem in the study is resolved by creating a proxy control group of unaffected hours to identify the impact of DST. The difference-in-difference (DID) average treatment effects model suggests an annual reduction of about 0,4 percent in electricity consumption due to DST. These results favor DST policy on the basis of its impacts on electricity consumption.

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1. INTRODUCTION

Daylight saving time (DST) is a practice of changing clocks twice a year - once in spring and once in autumn. Its idea is to maximize sunlight during the day, especially in the northern hemisphere, leading to possible energy consumption savings. Its economic effect is however questionable - introduction of new energy-efficient technology in the past decade, such as LED light bulbs, popularization of electric heating, air-conditioning, or electric cars, has changed the overall demand. Moreover, thorough the years, DST faced many criticism. Hence, the EU decided to take steps towards abolishment of DST. Our motivation is to address its potential economic implication, especially in case of Slovakia where DST is used since 1996. Using the aggregated hourly data for total electricity consumption and meteorological data, such as temperature or humidity, we create a proxy control group of unaffected hours for our regression. Using difference-in-difference approach, we obtain the required coefficient of the impact of DST and so determine the efficiency of DST policy.

2. LITERATURE REVIEW

Ideas of optimal utilization of natural sunlight date back to as far as the 18th century when possible reduction on usage of tallow and wax was suggested by Benjamin Franklin (1784) in the

Journal of Paris. The concept of DST was further developed in the beginning of 21st century leading to the first implementation of DST in 1916 in some European countries, although it was dropped after two years. Since then, there were various research conducted on the efficiency and usefulness of DST. The researches focused of various aspects, such as impact on health, efficacy of labor, risks of accidents or economic factors, mostly optimization of energy consumption.

There exist many research on impact of DST on electricity consumption worldwide. An evidence from Jordan suggests possible reduction of demand for electricity by implementation of DST from April to the end of August (Momani et al., 2009), while a 30-minute forward shift from April to October has been shown to be most efficient in Turkey (Karasu, 2010). A research conducted on Western Australia proves a very little effect of DST on overall electricity consumption and production (Choi et al., 2017), while Kotchen and Grant (2011) have shown that DST actually increases electricity demand by roughly 1% in the case of northeast Indiana. In southern Norway and Sweden, there exists an evidence of an annual reduction of at least 1% in electricity consumption for both Norway and Sweden due to DST, resulting in an annual financial saving of 16.1 million Euros and 30.1 million Euros, respectively (Mirza and Bergland, 2011). Most importantly, meta-analysis evidence in case of Slovakian energy consumption suggests that the effect of DST should not decrease the consumption by more than 0.5 percent (Havranek et al., 2018). Regression results of Kudela et al. (2020), however, estimates the effect to be 0.8 percent in case of Slovakia.

Other non-economy related researches, such as Kantermann et al. (2007) about the human circadian clock indicates that the human circadian system does not adjust to DST and that its seasonal adaptation to the changing photoperiods is disrupted by the introduction of summer time. Barnes and Wagner (2009) found that in comparison with other days, on Mondays directly following the switch to DST workers sustain more workplace injuries and injuries of greater severity and they found indirect evidence for the mediating role of sleep in the DSTâ€“injuries relationship, showing that on Mondays directly following the switch, workers sleep on average 40 min less than on other days.

3. RESEARCH QUESTIONS AND HYPOTHESIS

In recent years, there has been a resurge in studying the impact of DST on energy consumption in different countries due to the current global economic crisis, high energy prices, climatic change and supply security considerations. Some of these studies even aim at DST extension during the winter period to quantify its impact on aggregate energy use. Contrary to this renewed interest in studying the potential impacts of DST policy in energy consumption, this policy has also been criticized in many countries. Parts of the general public have been very critical to the idea of DST adaptation due to the inconvenience when the switch between DST and standard time occurs. Furthermore, though DST policy is being implemented in most of developed countries, the evidence about its exact impacts on electricity consumption is still inconclusive and the estimates across the studies vary.

In case of Slovakia, there exist already a research paper on DST and electricity savings, however, authors use prices of electricity as one of the regressors, which can be potentially endogenous. Thus, in this paper we are asking if electricity consumption goes down even if we exclude prices as an effect of DST policy and how does the estimate change.

According to the previous research, we expect to find that DST generally reduces the energy consumption in Slovakia. The exact impact of DST is harder to guess, as it is very likely that DST offsets peak consumption hours during the day. Generally, DST reduces the amount of sunlight during morning hours, during which there is an intensive demand for electricity. As DST usually does not affect people's schedules (work schedules, transport schedules etc. stay the same regardless of daylight), we expect a shift in morning peak demand to occur earlier around the date of DST start. A reverse effect is expected during evening hours with the peak in demand occurring later due to more light during evening hours and later sunset. Another important factor in the change of demand is the weather. With the strong relation of power consumption in Slovakia with heating and cooling due to climate, we expect overall increase in demand during winter months, i.e. the hours when DST is not applied. The change in winter months is expected to be more significant than during summer, as air conditioning is not that common in Slovakian households. Moreover, energy consumption is expected to be higher during weekends and public holidays, since people are at home their electricity consumption is higher than on weekdays when at work.

4. DATA AND METHODOLOGY

The only available source of hourly consumption data of electricity is the ENTSO-E, which gathers data from national transmission system operators, Slovenská elektrizačná prenosová sústava (SEPS) for the case of Slovakia. We extend the data set ranging from 1.1.2006 up to 31.12.2017. From this database we can obtain hourly load values in MW for every day and every hour for each EU state, as well as the total coverage. Thus, we work with panel data of 103519 observations, out of which 78126 are used for our analysis. Below table depicts summary statistics on variables where appropriate:

Variable	Min.	1st Qu.	Median	Mean	3rd Qu.	Max
Energy consumption (in MW)	2039	2911	3229	3233	3528	4541
Average temperature (in degrees)	-22.100	1.667	8.267	8.333	14.967	35.000
Pressure (in Pa)	977	1012	1017	1017	1022	1048
Relative humidity (in oz/m3%)	15	67	81	76.92	90	100

Table 1: Descriptive statistics

The weather data can be obtained at Meteostat, which seems to be the only provider of free hourly meteorological data. The data is gathered from official meteorological stations administrated by respective national meteorological authorities. The data for Slovakia come from Slovenský hydrometeorologický ústav (SHMÚ), where we chose three stations: Bratislava-Ivanka, Poprad and Kamenica and Cirochou, which come from different parts of the country and can, in average, represent general climate conditions in Slovakia. The weather data consist of temperature, dew point, atmospheric pressure, relative humidity, wind speed and direction. In this work we choose the temperature, atmospheric pressure, and relative humidity as weather variables included in the model. The database is not complete for each of the meteorological stations, as observation for some hours are missing. For 105 192 hours between 1.1.2006 and 31.12.2017, the Kamenica station has the least observations (103 532), with missing hours spread randomly throughout the years and days. The data from other stations and for consumption were accordingly adjusted with hours with missing data being dropped from regression.

By plotting the relationship of consumption and temperature, the data do not appear to follow a linear relationship (Figure 1.). Therefore, we create another variable to capture this non-linearity, a quadratic form of temperature ($Temperature^2$).

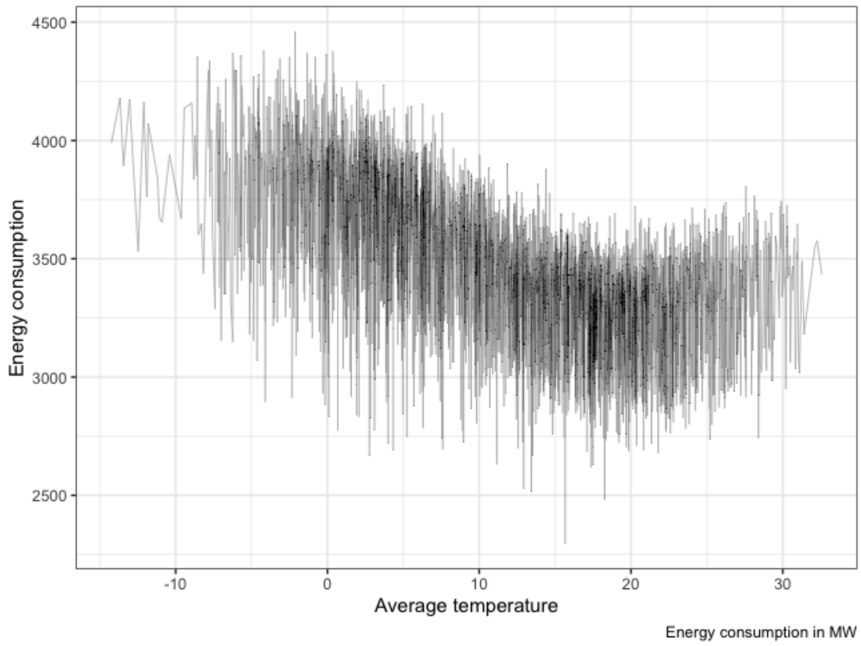

Figure 1: Nonlinear relationship between energy consumption and average temperature at 12AM

We estimate the standard difference-in-difference (DID) treatment effect model to evaluate the impact of DST on electricity consumption in Slovakia. In case of Slovakia, it is nearly impossible to find data on electricity consumption before the EU entry in 2004. Therefore, it is difficult to obtain data from both periods of practicing and not practicing DST. Thus, we have no control group for the estimation. This can be solved by dividing the 24 hours those affected by DST policy (treatment group) and those unaffected by DST policy (control group). This approach has been used in similar studies with the same problem of creating control group (Mirza and Bergland, 2011; Kudela et al., 2019). We pronounce midday hours from 11AM to 1PM to be unaffected by DST policy, as they get the same amount of natural daylight regardless of DST policy. The remaining hours serve as the treatment group.

Given the variables and chosen econometric method, we construct the following difference-in-difference model:

$$log(Consumption)_{hd} = \beta_0 + \beta_1 DST_{hd} + \beta_2 Treatment_{hd} + \beta_3 (DST_{hd} * Treatment_{hd}) + \beta_4 Temperature_{hd} + \beta_4 Temperature^2_{hd} + \delta Weathervariables_{hd} + \gamma(Weekend, Holidays)_{hd} + u_{hd}$$

where DST_{hd} is a dummy variable equal 1 when DST policy is active at hour h of day d, $Treatment_{hd}$ is a dummy variable equal 1 if the hour h of day d belongs to the treatment group, and the interaction term $DST_{hd} * Treatment_{hd}$ captures the DST policy effect, $Temperature_{hd}$ is the average temperature of an hour h of a day d, $Weathervariables_{hd}$ are the values of atmospheric pressure and relative humidity of an hour h of a day d, $(Weekend, Holidays)_{hd}$ represents dummy variables taking value 1 for public holiday or weekend of an hour h of a day d, u_{hd} represents the error term.

We perform also robustness check using heating and cooling degrees variables instead of average temperature. Variable "Heating degrees" depicts average temperature in Slovakia lower than 18 degrees, 0 otherwise, while variable "Cooling degrees" represents average temperature in Slovakia higher than 18 degrees, 0 otherwise. These variables are created as dummies for seasonality, where deviations from standard comfortable temperature (in our case 18 degrees, since as depicted in Figure 1., turning point appears to be around this number) can be observed requiring heating or cooling.

5. RESULTS

The estimate of the $DST_{hd} * Treatment_{hd}$ suggests a decrease in electricity consumption in Slovakia of about 0.4% significant at 90% significance level. The coefficient of the variable $Temperature_{hd}$ suggests that during our chosen control hours, consumption is lower, regardless of the DST policy. Robustness check confirms the reduction in electricity consumption, however, the magnitude is larger, specifically by 0.01%. During cooling and heating degrees, as expected, electricity consumption increases significantly by 0.5% and 0.3% respectively.

The results of a DST reducing electricity consumption are consistent with the logic of DST and results of other conducted researches, though, according to our results, the impact is not as big as 0,8% in case of Slovakia (Kudela et al., 2020) or 1% in Norway and Sweden (Mirza and Bergland, 2011). Thus, the magnitude of our estimate is closer to 0.5 percent as pronounced by Havranek et al. (2018) in their meta-analysis. On the other side, we obtain lower R^2 when compared to the difference in difference model of Kudela et al. (2020).

Other results of the regression follow the expected logic behind them. A negative sign of the coefficient for the average temperature explains the increased use of electricity with drops in temperature (most importantly during winter months), what is caused by the effect of heating, widely spread in Slovak households. So do the negative coefficients of pressure and humidity, when decrease in these values means bad weather, cloudy weather and thus reducing the sunlight, what leads to increased use of electricity which is required for lighting. These finding are consistent with other researches using a similar model (Kudela et al., 2020; Mirza and Bergland, 2011). On the other side, electricity consumption on public holidays and weekends does not follow our expectations - this is probably due to the fact that the household effect during free days is negligible in comparison to the industrial effect. Since many firms minimize

Table 2: Regression Results

	Dependent variable:	
	Electricity consumption	
	Main model	Robustness check
DST	−0.107*** (−0.111, −0.103)	−0.101*** (−0.104, −0.097)
Treatment	−0.071*** (−0.074, −0.068)	−0.070*** (−0.073, −0.067)
DST*Treatment	−0.004* (−0.008, −0.001)	−0.005** (−0.009, −0.001)
Average temperature	−0.004*** (−0.004, −0.003)	
Temperature^2	0.0001*** (0.0001, 0.0001)	
Cooling degrees		0.005*** (0.005, 0.006)
Heating degrees		0.003*** (0.003, 0.003)
Pressure	−0.0002*** (−0.0003, −0.0001)	−0.0001*** (−0.0002, −0.0001)
Relative humidity	−0.001*** (−0.001, −0.001)	−0.001*** (−0.001, −0.001)
Weekend	−0.099*** (−0.100, −0.098)	−0.099*** (−0.100, −0.098)
Public holiday	−0.114*** (−0.117, −0.111)	−0.114*** (−0.117, −0.111)
Constant	8.542*** (8.458, 8.625)	8.442*** (8.359, 8.525)
Observations	78,126	78,126
R^2	0.437	0.438
Adjusted R^2	0.437	0.438
Residual Std. Error (df = 78116)	0.101	0.101
F Statistic (df = 9; 78116)	6,731.025***	6,771.818***
Note:		*p<0.1; **p<0.05; ***p<0.01

their workforce and workload especially during public holidays, the electricity consumption decreases by 11.4% whereas during weekends consumption lowers by 9.9%.

Overall, the findings of our research show that DST truly does save electricity, so the application of this policy makes sense, at least in the energy-consumption-wise way. DST can bring various disadvantages and risks in social and personal health sphere, but it is beneficial in environmental and economic area, reducing the electricity consumption. Smaller demand means less electricity generated, and because, in Slovakia, only small percentage is coming from renewable sources, it is beneficial for the environment to some extent. A reduction in electricity means also a positive financial impact on households. With an average Slovak household consuming about 20 MWh annually, the total savings can be as high as 3 million euro (Kudela et al., 2020), though, in reality, not only households benefit from this savings.

6. CONCLUSION

The DST policy in Europe was originally introduced for the purpose of energy savings. Recent academic evidence, such as Bergland and Mirza (2017) or Choi et al. (2017), suggests the policy has different impacts on the electricity consumption of the states, where it is in practice. The European Union in the recent years is favoring abolishment of DST, as it argues, that its impact is not that significant today and it causes other, socio-economic problems. This paper focuses on the case of Slovakia, a member of the EU, where DST is in practice since 1996. As there is lack of information on the electricity consumption in Slovakia before the application of DST, we do not have a control period to evaluate the impact of DST. In contrast to Kudela et al. (2020), using only midday control hours, enlarging the dataset, taking different sample for estimating average temperature in Slovakia and excluding potentially endogenous variables we find that the overall effect of DST leads to a reduction of electricity consumption of about 0,4%, when the DST is applied, even though our model does not explain such high variation in data as their model with electricity prices included. Our estimate is, however, in line with findings of meta-analysis of Havranek et al. (2018) which suggests that impact of DST on overall electricity consumption savings should not exceed 0.5 percent. For implementing this policy in other countries, policy makers should also take into account its other potential impacts on public health, transport, emission of greenhouse gases and the use of alternate energy sources.

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