Does Daylight Saving Time Save Electricity? Evidence from Slovakia*

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Abstract

The European Union has recently decided to stop the policy of biannual clock changes in 2021. One reason is that the original rationale for the policy, energy savings, is not supported by a large portion of recent empirical studies. Whether the new permanent time will be standard time or the former daylight saving time has not been decided. Evidence on energy savings from daylight saving time is country-specific, and each country may choose its own time. We examine the effects of the policy in a country for which no studies on daylight saving exist, Slovakia. Using hourly data from the 2010–2017 period, we apply a difference-in-differences approach and estimate energy savings to equal 1% of annual electricity consumption. Alternatively, extrapolating the effect from the results of a previous meta-analysis on different countries, for Slovakia we obtain a smaller estimate, unlikely to exceed 0.5%. Moreover, our findings suggest that daylight saving time smooths the electricity demand curve.

Keywords: Daylight saving time, electricity consumption, energy savings, peak demand, Slovakia

JEL Codes: C54, Q41, Q48

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1 Introduction

Daylight saving time (DST) refers to the practice of setting clocks one hour forward in the spring and back again in the fall. Historically, the main reason for doing so has been to synchronize human activity with natural daylight at the peak hours of energy consumption. As of today, all member states of the European Union shift their clocks twice a year; although recently, the European Parliament endorsed a proposal to stop the seasonal clock changes starting in 2021 (EC, 2019).

The decision on the resulting permanent time will, however, be made individually by each EU member, and some studies (such as Havranek *et al.*, 2018a) indicate that the impact of DST is likely to be country-specific: some EU countries benefit from DST, whereas others consume more electricity because of the policy. Bergland & Mirza (2017) provide insight into the effects of DST in EU member states and show that the effects do indeed differ by state. Recent evidence from other continents indicates energy *costs* due to the policy (Kellogg & Wolff, 2008; Kotchen & Grant, 2011). In this paper, we provide the first detailed analysis of the effect of DST in Slovakia, an EU member state with one of the lowest carbon intensities in electricity production.

A common problem with studies that focus on DST in EU countries is the lack of natural experiment data. Part of our estimation strategy is based on a difference-in-differences model that exploits the fact that DST does not affect electricity demand during the midday hours (Ebersole *et al.*, 1975). We extend the model of Bergland & Mirza (2017) and analyze the overall and hourly effects, accounting for different sets of control groups, various weather conditions, temperature specifications, macroeconomic indicators, cyclicities, and seasonalities. The second part of our analysis uses the results of a meta-analysis by Havranek *et al.* (2018a), who construct a synthetic best-practice study to estimate the overall DST effect. We extrapolate their Bayesian model averaging benchmark results and the preferred design of the best-practice study on the Slovak electricity market.

Our results show that the DST policy in Slovakia conserves some electricity. While the difference-in-differences method shows an effect of approximately 1% on yearly electricity consumption, the best-practice specification extrapolated from the meta-analysis pushes the estimate downwards and suggests the overall effect is unlikely to exceed 0.5%. Importantly, the

DST policy lowers the peak consumption during the early morning and early evening hours while slightly increasing consumption before midnight, thus redistributing electricity consumption more evenly during the day.

The rest of this paper is structured as follows: Section 2 mentions some studies estimating the DST effect in Europe and introduces the Slovak electricity market in relation to DST policy, Section 3 describes the data and methodology used to evaluate different effects, Section 5 discusses the results of the analyses, and Section 6 concludes.

2 Related Literature and Electricity Market in Slovakia

The estimates of energy savings from DST focusing on European markets are scarce and somewhat contradictory. Many come from reports of government or electricity companies rather than academic peer-reviewed articles. HMSO (1970), Hillman (1993), and Hill *et al.* (2010) report the savings for the United Kingdom; Wanko & Ingeborg (1983) and EVA (1978) report the savings for Austria; Danish Government Report (1974) and ELTRA (1984) for Denmark; Bouillon (1983), Ebersbach & Schaefer (1980), and Fischer (2000) for Germany (these estimates are contradictory to later studies, such as TAB, 2016, showing some costs from DST in Germany); EnergieNed (1995) and SEP (1995) provide the estimates for Netherlands, Bellere (1996), ENEL (1999), and Terna (2016) for Italy; Mirza & Bergland (2011) for Norway and Sweden; ADEME (1995) and ADEME (2010) for France; and finally Castoralova (2019), who to some extent contradicts the findings of Kozuskova (2011), for the Czech Republic electricity market. Negative savings (i.e., costs) of the DST policy are not unheard of, especially for the US (Kotchen & Grant, 2011) and Australian markets (Kellogg & Wolff, 2008).

Only one known estimate of the electricity savings from DST in Slovakia exists: the cross-country study of Bergland & Mirza (2017), who evaluate the savings because of DST at 1% of power consumption (and provide estimates for many countries, without focusing on Slovakia). The estimates of the effect of DST for the structurally most similar economy to Slovakia would be those of the Czech Republic, the average of which is close to 0% in terms of overall electricity consumption (Kozuskova, 2011; Castoralova, 2019; Havranek *et al.*, 2018a; Bergland & Mirza, 2017; Jilek, 2000). Havranek *et al.* (2018a) and Bergland & Mirza (2017) find large country heterogeneity in the literature on DST effects on energy savings. They also reveal the estimates to be strongly dependent on latitude. Moreover, the patterns of national demand for electricity change over time as new technologies penetrate European markets (Bossmann & Staffell, 2015). Electronic home appliances with stand-by modes, energy-efficient light bulbs, the transition to electric heating systems, increasing occurrence of air-conditioning, smart-homes, and even electronic cars are changing the national load curves.[1] The discussions of DST in the EU is even more problematic since, legally, the EU regulatory bodies cannot oblige a member state to select a dedicated time zone.

In recent years, following increasing economic growth and standards of living after entering the European Union, Slovakia recorded an increase in the demand for electricity—the net consumption was over 30 TWh in 2018 (Table 1). Overall energy consumption has also increased; thus, any tool for energy conservation and greenhouse gas emissions reduction is relevant. The electricity mix, however, is focused on indigenous energy sources and low-carbon technologies, such as nuclear energy (54% of the electricity generated in 2017) and renewable sources (26% of the electricity generated in 2017, of which 17% is hydro power), with the remaining 20% of energy obtained from fossil fuels (SEPS, 2017). Since 2005, the Slovak electricity market has undergone full liberalization. In 2009, Slovakia joined a market coupling project with the Czech Republic: Hungary and Romania later joined in 2012 and 2014, respectively. Market coupling resulted in more efficient utilization of cross-border capacities, which currently amount to a respectable 40% of the generating capacity (IEA, 2018). Table 1 shows that the electricity production deficit in Slovakia is being covered from imported volumes. Net imports, however, do not generally cover supply limitations but rather regional business opportunities (IEA, 2018). The upcoming finalization of two units of the nuclear plant Mochovce will cover approximately 26% of the Slovak national electricity consumption (and will reduce the high carbon-intense production from coal and imports), amounting to approximately 7 billion tons of CO2 emissions (Janda, 2018).

Liberalization of the market made wholesale and retail open for competition. Retail prices, however, are regulated by a price cap for all households and small enterprises. Household consumption has increased over time at a pace similar to that of overall consumption: the share of households has remained steady at 20% of overall consumption. Still, it is safe to assume that

[1] Paradoxically, more efficient devices may actually *increase* energy consumption, as Madlener & Alcott (2009) discuss in detail.

Table 1: Electricity production deficit covered by imports

	2010	2011	2012	2013	2014	2015	2016	2017
Production	27.7	28.1	28.4	28.6	27.3	27.2	27.5	28.0
Export	6.3	10.5	13.1	10.6	11.9	12.6	10.6	12.5
Import	6.7	10.9	13.4	10.7	12.9	15.0	13.2	15.6
Consumption	28.8	28.9	28.8	28.7	28.4	29.5	30.1	31.1
Consumption by:								
Industry [%]	*45*	*45*	*50*	*47*	*51*	*44*	*48*	*48*
Agriculture, commerce, services [%]	*34*	*34*	*28*	*31*	*27*	*35*	*29*	*31*
Households [%]	*18*	*18*	*20*	*20*	*20*	*19*	*20*	*19*
Transportation [%]	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*

Notes: Numbers in TWh taken from SEPS (2019). Sectoral distribution of consumption in percentages (in italics) taken from SOSR (2019).

the price cap discourages, to some extent, energy-efficient behavior. Moreover, market coupling is responsible for the decrease in price volatility (Janda, 2018), even though IEA (2018) reports Slovakia to have comparatively higher electricity prices than neighboring countries, especially in the industrial sector. IEA (2018) suggests a number of policy improvements to increase efficiency in energy consumption and to support competition in the market. This becomes highly relevant given the dominant trend of increasing electricity consumption in Slovakia, which according to the prognosis of SEPS (2018), has an average year-on-year growth of 1.3%, for an estimated consumption of 33.8 TWh in 2025.

3 Data

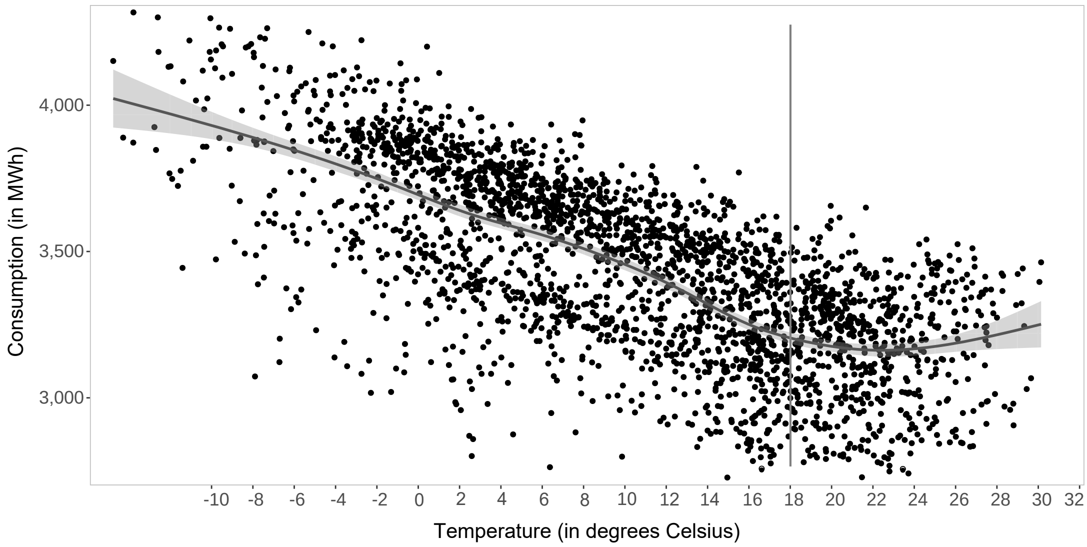
The literature recognizes two different approaches to estimate the savings from DST: simulation and regression. In simulation studies, authors (such as Fong *et al.*, 2007; Pout, 2006; Shimoda *et al.*, 2007) usually develop an energy consumption model of different types of buildings, such as households, industrial, and commercial buildings, and extrapolate the model to the country level. The difference-in-differences regression method, on the other hand, is widely applied for assessing the impact of certain policies (see, for example Choi *et al.*, 2017; Verdejo *et al.*, 2016). The idea is a comparison between the control group of data before the policy change and the treatment group of data after the policy change. In case of Slovak electricity market, both approaches face the problem of data availability. The only public source of electricity consumption data, ENTSO-E (2017), provides hourly load curves since January 2005. Given that the last DST policy change in Slovakia occurred in 1996, we have no obvious control group for the estimation. Ebersole *et al.* (1975), however, propose a compelling technique to address this issue: they divide the 24 hours of the day into those affected by DST policy (treatment group) and those unaffected by DST policy (control group). We will follow this approach in the footsteps of Kotchen & Grant (2011) and Mirza & Bergland (2011).

Several factors could systematically influence the consumption patterns in our data and need to be controlled for. The most pronounced controls are weather and light conditions, seasonality, holidays, heterogeneity among consumption units, and related macroeconomic conditions. We obtained the weather data from the Slovak Hydro-Meteorological Institute for four representative meteorological stations: Bratislava airport (western Slovakia), Sliac (central Slovakia), Kamenica nad Cirochou (eastern Slovakia), and Poprad (representative of the cooler northern mountain climate). Given that our consumption data are a country aggregation, we construct a weighted average for all weather variables, where the weights are represented by time-respective regional industry consumption (annual industrial data taken from SOSR, 2019).[2] Slovakia lies between the temperate and continental climate zones and has relatively warm summers (reaching 35 degrees Celsius in extreme conditions according to SHMU, 2019) and relatively cold winters (reaching -15 degrees Celsius in extreme conditions), making Slovak electricity consumption likely to be strongly related to heating and cooling.

Research, such as that by Choi *et al.* (2017), Hill *et al.* (2010), and Rock (1997), has shown that the relationship between temperature and electricity consumption is not necessarily linear but either U-shaped or V-shaped. Plotting the relationship of consumption and temperature in Figure 1 for the twelfth hour in the middle of the day, the data appear to follow a U-shaped relationship. Therefore, we create another variable to capture this nonlinearity, a quadratic form of temperature (*Temperature squared*). Following Choi *et al.* (2017), Kotchen & Grant (2011), and Kellogg & Wolff (2008), we also capture the relationship between electricity consumption and temperature with the variables *Cooling degrees*, defined as $max\{Temperature - 18°C, 0\}$, and *Heating degrees*, defined as $max\{18°C - Temperature, 0\}$. Here, 18°C is the base temperature that also represents the average turning point where Slovak consumption stops to decrease

[2]Based on geographical location, average regional weather, and demographics, we have assigned Bratislava airport weather conditions to the Slovak regions of Bratislava, Trnava, and Nitra; Sliac weather conditions to the regions of Banska Bystrica and Trencin; Poprad weather conditions to the regions of Zilina and Presov; and Kamenica nad Cirochou weather conditions to the Kosice region.

Figure 1: The relationship between consumption and temperature is not linear



Notes: Figure is a scatter plot of electricity consumption and average temperature at 12 AM. The vertical line represents 18 degrees Celsius, the base temperature for the calculation of heating and cooling degrees (see Table 2)—although for this hour of the day, the base temperature is actually approximately 22 degrees Celsius.

and starts to increase with an increasing temperature. This inflection point appears in Figure 1 between 21°C and 22°C at noon but varies from 15°C around midnight to 22°C in the afternoon hours.

Electricity Price is not a common variable in the regression for DST effects as it introduces endogeneity and is believed not to influence the estimated effect of DST savings. We think, however, that a good representation of the electricity price could help to filter out the residual variations in demand; thus, we follow Mirza & Bergland (2011) in this regard. We could not obtain a suitable instrument, but given that the incremental endogeneity should not decrease the validity of the estimated DST effect and given that the price elasticity of electricity demand in Slovakia is rather small (Bildirici & Kayikci, 2016), we use the hourly short-term market price from OKTE (2017). Moreover, given that retail prices in Slovakia are regulated, this price should not substantially affect the end-consumer behavior. In addition, to account for external macroeconomic conditions, we include the variable *Oil price*, which represents the daily (weekdays only) Brent oil spot prices collected from FRED (2017).

The last group of variables in the analysis is used to account for cyclicity, seasonality, and other time-related systematic patterns of electricity consumption. The electricity demand in our sample, irrespective of the DST policy, increases from year to year, varies from month to

Table 2: Summary statistics of explanatory variables

Variable	Description	Mean	SD	Min	Max
Consumption	= hourly aggregate electricity consumption [in MW]	3,207.9	426.7	2,119.0	4,541.0
Weather variables					
Humidity	= average hourly relative air humidity [in %]	73.8	16.8	18.7	98.7
Air pressure	= average hourly air pressure [in hPa]	982.8	13.0	828.3	1,007.5
Sunlight	= total duration of sunshine in an hour [in *minutes*]	9.9	15.1	0.0	60.0
Precipitation	= sum of hourly rainfall [in mm]	0.1	0.3	0.0	13.3
Radiation	= average hourly intensity of radiation [in J/cm^2]	36.5	51.4	0.0	328.4
Temperature variables					
Temperature	= average hourly air temperature [in °C]	10.2	9.2	-19.7	36.8
Cooling degrees	= hourly amount of cooling degrees [in °C]	1.0	2.6	0.0	18.8
Heating degrees	= hourly amount of heating degrees [in °C]	8.8	7.8	0.0	37.7
Price variables					
Electricity price	= average hourly price in a daily market [in EUR per MWh]	39.1	17.0	-150.0	200.0
Oil price	= Brent daily crude oil spot price [in USD per barrel]	83.9	29.0	26.0	128.1

Notes: SD = standard deviation. Data set is based on the period between April 2010 and July 2017. Weather variables were constructed as consumption-weighted averages from the selected areas: Bratislava, Sliac, Kamenica nad Cirochou, and Poprad.

month (decreasing in summer regardless of DST policy), jumps on non-working days and shows hourly patterns. We also include *Cyclicity*, a trigonometric sine function, to account for residual cyclical annual patterns in consumption (Mirza & Bergland, 2011). Furthermore, the variable *Holidays* represents a dummy variable with daily granularity for all public holidays in Slovakia, when there is a different pattern of consumption compared to working days. *Weekend* represents a dummy variable for weekends to distinguish between weekend and weekday patterns of consumption, and the *Seasonality* matrix includes dummy variables for hours, months, seasons, and years to account for several potential forms of seasonality and periodic patterns. Note that we include monthly variables as well as the variable *Summer* representing the months of June, July, and August. Slovakia tends to have much lower consumption of electricity in the summer months, according to SEPS (2019) by about 20% or more. The geography and climate of Slovakia ensures there is no need for heating during the summer, schools and school facilities are closed, and people are often abroad for vacation. Even the gradual increase in the usage of air-conditioning units, refrigeration equipment, and pool pumps during the summer months still does not compensate for the large differences in consumption throughout the year (SEPS, 2019).

Table 2 provides the descriptive statistics for the final set of data used in this analysis: electricity *Consumption* with hourly granularity, the hourly amount of *Cooling degrees* and

Heating degrees, macro variables such as *Electricity price* and *Oil Price*, and hourly data on weather conditions such as *Humidity*, *Air Pressure*, *Sunlight*, *Precipitation*, sun *Radiation*, and *Temperature*. Given the data availability for other explanatory variables, we obtain hourly aggregate electricity *Consumption* for Slovakia for the period between April 1st, 2010, and July 31th, 2017 (downloaded from ENTSO-E, 2017). Data are collected in Central European Time, which means the last Sunday in March has 23 hours and the last Sunday in October has 25 hours. The time zone is important in order to match local temperature and pricing with the time stamp used in the ENTSO-E database.

4 Research Design

Given the availability of data and variables described in Section 3, our central approach to estimate the DST effect is the difference-in-differences technique. The first step is to identify the control group in a data set without the change in the DST policy. Mirza & Bergland (2011) and Kotchen & Grant (2011) dealt with the problem in the following way: they pronounced the midday hours from 12 AM to 2 PM and the midnight hours from 12 PM to 2 AM to be unaffected by the policy, thus the control group, because these hours have practically the same amount of natural daylight regardless of the DST policy. The authors considered the remaining hours to be affected by the policy and set them to serve as the treatment group. We will apply similar techniques in this study.

Before presenting the formal tests for validity of the control hours, we follow Belzer *et al.* (2008) and provide the visualization of changes in hourly patterns in consumption before and after the time shift. We compute the average consumption for each hour of the day for two different samples: consumption five days prior to the time shift and consumption five days after the time shift, both in March 2014 (since it is a data sample with no holidays around the time shift). Figure 2 presents the variation in consumption throughout the hours of the day with two peaks, one in the morning hours and one in the evening hours. The morning peak remains approximately the same for both data samples at 9 AM, while the evening peak shifts after the DST transition from 7 PM to 8 PM.

This result is in line with intuition: because people wake up with an alarm clock at the same time and have the same morning routine, the morning peak occurs at approximately the same time, regardless of the DST policy. By contrast, the shift in the evening hours corresponds to the logic that adding additional hour of natural light shifts evening consumption by an hour. The direction of the consumption change in Figure 2 suggests a decrease in consumption after the time shift. Moreover, the difference in consumption after the time shift is smaller in the morning and in the late evening hours and the largest in the early evening hours. A similar pattern is observed for other investigated years (except those where the analyzed sample includes holidays). During the Autumn time shift, the opposite pattern is observed.

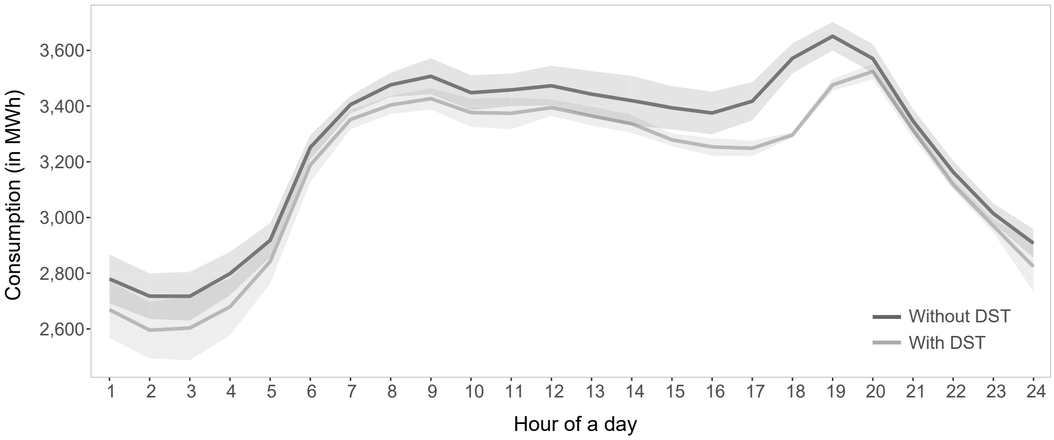
Even more revealing is Figure 3, which visualizes the pattern of electricity consumption by means of the ratio of hourly electricity consumption to the average consumption during the control hours of 12 AM to 2 PM and 12 PM to 2 AM (here, we follow Mirza & Bergland, 2011). One clear pattern is the increased morning consumption after the shift to DST, possibly because throughout the darker mornings after the shift, people still need artificial light and heating (Kotchen & Grant, 2011; Momani *et al.*, 2009). On the other hand, the decrease in consumption during the early evening hours is followed by an increase later in the evening (consistent with the findings of, for example, Karasu, 2010).

Figure 3 also shows a small increase in consumption during midday hours. During the midnight hours and early morning hours, however, a decrease in consumption is observed, which indicates that using midnight hours as a control group might underestimate the DST effect, whereas using midday hours might overestimate the effect. Conclusions drawn solely from Figure 2 and Figure 3, however, might be misleading because these figures do not account for other important factors that could influence consumption patterns. We test for the validity of the hours more formally, by constructing 24 regressions (one regression for every hour) in the form of

$$
\begin{aligned}
log(Consumption)_d = & \beta_0 + \beta_1 \text{DST}_d + \gamma' \text{Temperature variables}_d + \\
& + \beta_2 \text{Electricity price}_d + \delta' \text{Weather variables}_d + \\
& + \phi'(Cyclicity, Holidays, Weekend, Seasonality)_d + u_d, \qquad (1)
\end{aligned}
$$

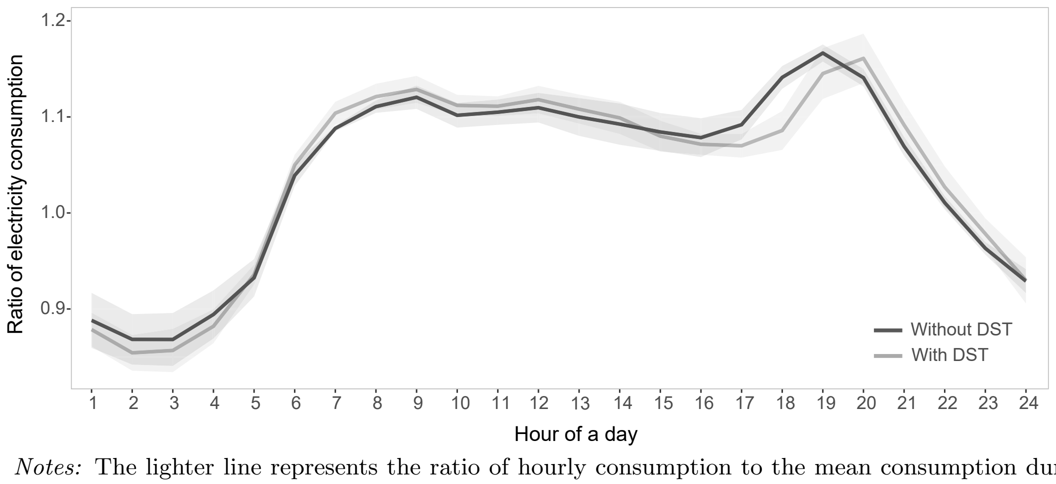
to estimate the coefficient β_1 of the DST_d variable. DST_d is a dummy variable equal to 1 when the DST policy is applied in day d. The group of Temperature variables represents either the pair of variables *Temperature* and *Temperature squared* or the pair of variables *Cooling*

Figure 2: Largest difference in consumption before and after the DST change probably occurs in the evening hours



Notes: The lighter line represents the average consumption during the five days following the transition in March 2014. The darker line represents the average consumption during the five days prior to the transition in March 2014. Shaded areas represent the 95% confidence intervals.

Figure 3: During natural daylight hours, the DST policy might have slightly increased electricity consumption



Notes: The lighter line represents the ratio of hourly consumption to the mean consumption during the control hours averaged throughout the five days following the transition in March 2014. The darker line presents the same ratio based on the data of five days after the transition in March 2014. We consider the control group of midday hours (from 12 AM to 2 PM) and midnight hours (from 12 PM to 2 AM). Shaded areas represent 95% confidence intervals.

degrees and *Heating degrees*. The group of *Weather variables* represents *Humidity*, *Air Pressure*, *Sunlight*, *Precipitation*, and *Radiation*. The rest of the variables follows the definition in Table 2. Table 7 provides an overview for hours where the coefficient of DST was statistically insignificant, including those hours that we originally considered for a control group. The results suggest that in our data sample, DST does not affect consumption during the hours of 11 AM to 1 PM, and we use these hours as the control group in our benchmark model specification (but provide several robustness checks utilizing common practice in the literature set by Kotchen & Grant, 2011):

$$\begin{aligned} log(Consumption)_{hd} = \beta_0 + \beta_1 \text{DST}_{hd} + \beta_2 \text{Treatment}_{hd} + \\ + \beta_3(\text{DST}_{hd} * \text{Treatment}_{hd}) + \\ + \gamma' \text{Temperature variables}_{hd} + \delta' \text{Weather variables}_{hd} + \\ + \phi'(\text{Cyclicity, Holidays, Weekend, Seasonality})_{hd} + \\ + \epsilon' \text{Price variables}_{hd} + u_{hd}, \end{aligned} \tag{2}$$

where DST_d is a dummy variable equal 1 when DST policy is active at hour h of day d and $Treatment_{hd}$ is a dummy variable equal 1 if the hour h of day d belongs to the treatment group. The interaction term $DST_{hd} * Treatment_{hd}$ is the variable of interest that captures the DST policy effect in percentage points for days when the policy is in place. The group of *Temperature variables* represents either the pair of variables *Temperature* and *Temperature squared* or the pair of variables *Cooling degrees* and *Heating degrees*. The group of *Weather variables* represents *Humidity*, *Air Pressure*, *Sunlight*, *Precipitation*, and *Radiation*. The group of *Price variables* represents *Electricity price* and *Oil price*. The remaining dummy variables representing weekends, holidays, and hours of the day are used to control for the different time-invariant fixed effects. Cyclical and seasonal patterns are accounted for. The identifying assumption is that once controlling for observables such as weather, fixed effects, and DST observance, the evolution of electricity consumption in the control and treatment groups should be the same and the expected residual in electricity consumption is zero. The coefficient of the interaction variable β_3 can thus provide a measure for the estimated change in electricity consumption, looking at the differences between periods before the DST transition and after the DST transition in the difference of consumption in the DST-affected and DST-non-affected hours, while controlling for other systematic effects on consumption.

We estimate our benchmark (2) model based on the selection of the empirically validated control hours. To provide robustness checks for the benchmark model, we estimate the models for different sets of control groups. Furthermore, we utilize the meta-analysis data set of Havranek *et al.* (2018a), as well as their Bayesian model averaging results from the meta-regression analysis and their specification of the best-practice study design in the DST literature, to create a synthetic study tailored for Slovakia. Although this estimate is expected to have relatively large confidence intervals, it has significant informational value given the breadth of data included and can provide further support to the validity of our benchmark model results.

Previous research has noted that the DST effect is not constant throughout the day (Mirza & Bergland, 2011; Karasu, 2010; Verdejo *et al.*, 2016). Some studies, such as Kellogg & Wolff (2008), suggest that the evening energy savings might be offset by increased morning consumption. To analyze the effect of DST on peak power demand, the following model is constructed:

$$\begin{aligned} log(Consumption)_{hd} = {} & \beta_0 + \beta_1 \mathrm{DST}_{hd} + \beta_2 \mathrm{Treatment}_{hd} + \\ & + \gamma' Hours * (\mathrm{DST} * \mathrm{Treatment, Temperature})_{hd} + \\ & + \delta' \mathrm{Weather\ variables}_{hd} + \\ & + \phi' (\mathrm{Cyclicity, Holidays, Weekend, Seasonality})_{hd} + \\ & + \epsilon' \mathrm{Price\ variables}_{hd} + u_{hd}, \end{aligned} \tag{3}$$

where DST_d is a dummy variable equal to 1 when DST policy is active at hour h of day d and $Treatment_{hd}$ is a dummy variable equal to 1 if the hour h of day d belongs to the treatment group. $\gamma'_{DST} Hours * DST_{hd} * Treatment_{hd}$ is representation of $\gamma^1_{DST}(hour_1 * DST_{hd} * Treatment_{hd}) + \gamma^2_{DST}(hour_2 * DST_{hd} * Treatment_{hd}) + \cdots + \gamma^{24}_{DST}(hour_{24} * DST_{hd} * Treatment_{hd})$ and variables $hour_1, \ldots, hour_{24}$ are dummy variables for each hour of the day. The definition of variable $\gamma'_{Temp} Hours * \mathrm{Temperature}_{hd}$ follows the same logic and represents the interactions between the temperature and the dummy variables for an hour. The rest of the variables follow (2). To avoid loosing too many degrees of freedom, and given that temperature is generally considered to be one of the most important explanatory variables in DST models, we do not include interactions of hours with explanatory variables other than *Temperature*. The variables of interest are given by the interaction terms of $Hours * DST_{hd} * Treatment_{hd}$, which represent the percentage change in electricity consumption for a specific hour of the day due to the DST policy if every other control factor is held constant.

5 Results

5.1 Benchmark Estimation

The first step in our analysis is to assess the validity of the chosen model. Given that our models suffer from both heteroskedasticity and serial correlation, we use standard errors robust to both heteroskedasticity and serial correlation with a lag of 24 (Verbeek, 2008; Mirza & Bergland, 2011). Second, given that the stationarity assumption does not hold for the variable *Oil price*, we drop the variable to avoid spurious regression. The results of our benchmark model using control hours from 11 AM to 1 PM can be found in Table 3. The estimates of the DST effect (coefficient of the variable *DST * Treatment*) suggest a decrease in electricity consumption in Slovakia of between 1.3% and 1.6% during the days when DST is applied, depending on how the relationship between temperature and consumption is modeled. In Slovakia, DST applies for 210 days of the year; thus, the yearly DST effect on electricity consumption amounts up to 0.9% ($= 1.3(1.6)\% * 210/365$) of energy savings in terms of yearly electricity consumption. These results are fairly consistent with the estimates from Bergland & Mirza (2017), which suggest a reduction in consumption due to DST of approximately 1%. Apart from the effect of the DST policy on consumption, a few other relationships should be discussed. The coefficient of the variable *Treatment* suggests that during our chosen control hours, consumption is lower, regardless of the DST policy (largely because the peaks in electricity consumption occur in the morning and in the evening).

Deviations from the base temperature (*Heating* and *Cooling degrees*) increase consumption, which, as Kellogg & Wolff (2008) state, is consistent with the effects of heating (when the temperature is below 18 degrees Celsius) and air-conditioning (when the temperature is above 18 degrees Celsius). Kotchen & Grant (2011) find the change in consumption greater for cooling than heating in Indiana, which is in contradiction to what we found for the Slovak data set—

Table 3: Results of the baseline model (2) using control hours from 11 AM to 1 PM

Variable	Benchmark using *Cooling/Heating degrees*	Benchmark using *Temperature squared*
Constant	8.180***	8.227***
	(0.016)	(0.016)
DST	−0.012***	−0.017***
	(0.002)	(0.002)
Treatment	−0.133***	−0.134***
	(0.001)	(0.001)
DST * Treatment	**−0.0156***	**−0.0127***
	(0.001)	**(0.001)**
Temperature variables		
Temperature		−0.005***
		(0.0001)
Temperature squared		0.0001***
		(0.00000)
Heating degrees	0.004***	
	(0.0001)	
Cooling degrees	0.002***	
	(0.0001)	
Weather variables		
Humidity	−0.0001***	0.00003
	(0.00002)	(0.00002)
Air pressure	−0.0001***	−0.0001***
	(0.00001)	(0.00001)
Sunlight	−0.001***	−0.001***
	(0.00002)	(0.00002)
Precipitation	0.003***	0.003***
	(0.001)	(0.001)
Radiation	0.00004***	0.0001***
	(0.00001)	(0.00001)
Price variable		
Electricity Price	0.002***	0.002***
	(0.00001)	(0.00001)
Cyclicity	−0.00001***	−0.00001***
	(0.00000)	(0.00000)
Holidays	−0.068***	−0.068***
	(0.001)	(0.001)
Weekend	−0.077***	−0.077***
	(0.0004)	(0.0004)
Seasonality		
Summer	−0.006***	−0.008***
	(0.001)	(0.001)
January	0.079***	0.084***
	(0.002)	(0.002)
February	0.090***	0.097***
	(0.002)	(0.002)
March	0.073***	0.082***
	(0.002)	(0.002)
April	0.034***	0.042***
	(0.001)	(0.001)
May	0.015***	0.017***
	(0.001)	(0.001)
June	0.017***	0.017***
	(0.001)	(0.001)
July	0.004***	0.004***
	(0.001)	(0.001)
September	0.026***	0.027***
	(0.001)	(0.001)
October	0.052***	0.060***
	(0.001)	(0.001)
November	0.059***	0.067***
	(0.002)	(0.002)
December	0.066***	0.074***
	(0.002)	(0.002)
Year 2010	−0.068***	−0.067***

Continued on next page

Table 3 – *Continued from previous page*

Variable	Benchmark using *Cooling/Heating degrees*	Benchmark using *Temperature squared*
	(0.001)	(0.001)
Year 2011	−0.072***	−0.070***
	(0.001)	(0.001)
Year 2012	−0.057***	−0.056***
	(0.001)	(0.001)
Year 2013	−0.049***	−0.046***
	(0.001)	(0.001)
Year 2014	−0.060***	−0.058***
	(0.001)	(0.001)
Year 2015	−0.033***	−0.030***
	(0.001)	(0.001)
Year 2016	−0.015***	−0.013***
	(0.001)	(0.001)
Hour 1	−0.034***	−0.033***
	(0.001)	(0.001)
Hour 2	−0.072***	−0.071***
	(0.001)	(0.001)
Hour 3	−0.092***	−0.092***
	(0.001)	(0.001)
Hour 4	−0.092***	−0.091***
	(0.001)	(0.001)
Hour 5	−0.080***	−0.079***
	(0.001)	(0.001)
Hour 6	−0.056***	−0.054***
	(0.001)	(0.001)
Hour 7	0.022***	0.023***
	(0.001)	(0.001)
Hour 8	0.066***	0.066***
	(0.001)	(0.001)
Hour 9	0.104***	0.104***
	(0.001)	(0.001)
Hour 10	0.132***	0.131***
	(0.001)	(0.001)
Hour 11	−0.003***	−0.003***
	(0.001)	(0.001)
Hour 12	0.003**	0.003**
	(0.001)	(0.001)
Hour 14	0.137***	0.136***
	(0.001)	(0.001)
Hour 15	0.125***	0.125***
	(0.001)	(0.001)
Hour 16	0.115***	0.115***
	(0.001)	(0.001)
Hour 17	0.115***	0.115***
	(0.001)	(0.001)
Hour 18	0.108***	0.108***
	(0.001)	(0.001)
Hour 19	0.102***	0.102***
	(0.001)	(0.001)
Hour 20	0.108***	0.108***
	(0.001)	(0.001)
Hour 21	0.110***	0.110***
	(0.001)	(0.001)
Hour 22	0.080***	0.080***
	(0.001)	(0.001)
Hour 23	0.037***	0.037***
	(0.001)	(0.001)
Observations	63,427	63,427
R^2	0.902	0.902
Adjusted R^2	0.902	0.902
Residual Std. Error (df = 63,371)	0.042	0.042
F Statistic (df = 55; 63,371)	10,607***	10,583***

Notes: The table presents the results of difference-in-differences regression of (2). HAC-robust standard errors in parentheses. *p<0.1; **p<0.05; ***p<0.01.

air-conditioning is less widespread in Slovakia and draws less electricity than heating, which is heavily used during the colder months. Moreover, the corresponding sign of the variables *Heating* and *Cooling degrees* suggests a U-shaped relationship between temperature and consumption, corroborating the evidence from the opposite signs of *Temperature* and *Temperature squared*. In addition, these results suggest that increasing the base temperature in Slovakia would also increase the savings from the DST policy.

The variables capturing general weather conditions (including temperature) are mostly statistically significant, and the direction of the estimated weather effects remains in line with intuition. An increase in the length of daylight in a single hour decreases electricity consumption, which is reflected in the negative coefficient of *Sunlight*, a result compatible with many studies, including Kellogg & Wolff (2008), Hancevic & Margulis (2016), and Choi *et al.* (2017). We report a similar trend for *Air Pressure*, corroborating the results of Hancevic & Margulis (2016), who also find a significantly negative but rather small effect on electricity consumption. *Humidity* does not play a crucial role in explaining energy consumption in Slovakia or has a rather negative effect, which could be due to the fact that higher air humidity in Slovakia is also associated with lower temperatures (an argument already used by Choi *et al.*, 2017). The remaining weather variables, *Precipitation* and *Radiation*, appear to have a positive effect on consumption—increasing precipitation could bring colder temperatures and therefore increase the necessity of heating. The intensity of sunshine is also at its highest in more extreme temperatures, corroborating the story of a positive effect on consumption, as well as a U-shaped relationship between temperature and consumption. Other important effects are related to *Seasonality* and non-working days.

Electricity consumption on *Holidays* and *Weekends* is lower, consistent with the findings of Kellogg & Wolff (2007) and Kandel (2007). It follows that during non-working days, people sleep longer, and the morning increase in demand is mitigated by fewer morning activities. We also find that electricity consumption is reduced during the summer (the coefficient for *Summer* is negative), and the DST policy is believed to play a role here: in the morning, the sun rises early enough for people to wake up in natural daylight, while in the evening, an extra hour of sunlight is provided. As soon as there are no early morning benefits, as happens when DST is prolonged to early spring or later autumn months, the argument looses its power (Kellogg &

Wolff, 2008). Similar reasoning applies to the coefficient of *DST*, which is active mostly during the summer: the coefficient represents the percentage difference in electricity consumption between the period of active and non-active DST policy use. The coefficient *Electricity Price* suggests positive partial correlation with consumption. However, it is most likely the result of endogeneity as the price is set to be highest value during the peak of electricity consumption. The variable could also be capturing seasonality or trend over and beyond other variables in the model due to possibly lower short-term demand flexibility of our data. To check whether our reliance on selected explanatory variables drives our conclusions, we calculate several robustness checks adapting the benchmark model to different assumptions about the best model design.

5.2 Robustness Checks

To validate the conclusions discussed in the previous subsection, we provide five more specifications addressing the impact of different structural changes to the baseline models captured by Table 3. The model adjustment concerns three major issues: the alternative definition of *Heating degrees* and *Cooling degrees*, the alternative definition of *Seasonality* and *Cyclicity*, and the usage of the *Electricity price* variable inside the model. Given that cooling and heating were repeatedly shown to change non-linearly with temperature (Bushnell & Mansur, 2005; Kellogg & Wolff, 2008), we construct a specification employing the squared variables of *Heating degrees* and *Cooling degrees*. The first model of Table 9 captures the adjustment resulting in a lower DST estimate of 1.4% of savings when DST is applied (i.e., 0.9% annually). Although some empirical evidence suggests that the non-linear pattern is less pronounced in colder countries such as Slovakia (see, for example, Bessec & Fouquau, 2008), it perseveres in our sample and is robustly significant for the cooling efforts related to electricity consumption.

Second, it can be the case that for some temperature interval neither heating nor cooling is necessary. In that case, the base temperature of 18°C would be different for both cooling and heating efforts. For the second specification of Table 9, we redefine *Cooling degrees* as $max\{Temperature{-}21°C, 0\}$, and *Heating degrees* as $max\{15°C{-}Temperature, 0\}$. The choice of the interval $\langle 15, 21\rangle$ of no electricity utilization for heating/cooling follows the temperature extremes of the indicative heating and cooling season in Slovakia (Lieskovsky *et al.*, 2019, provide monthly ranges for the seasons' duration). The range also roughly corresponds to the inflection points on the consumption-temperature curve throughout the day in our data set (displayed at noon in Figure 1). The resulting DST effect decreases to 1.4% again, and the additional assumption of non-linearity in the heating/cooling efforts (not reported in Table 9) in this case does not change the economic or statistical significance of the estimated DST effect.

Our representation of the seasonal or cyclical annual patterns includes months, summer, and a simple sinusoidal function capturing a possible residue in the annual pattern. A cyclical component of the electricity consumption may be, however, extracted from the data by a straightforward application of both the sine and cosine functions. Such application is often considered parsimonious relative to the use of many monthly dummies (Bergland & Mirza, 2017), it can better locate the consumption peaks, and increases the number of degrees of freedom compared to our baseline estimation. The third and fourth specification of Table 9 show the sensitivity of our baseline models when seasonalities and cyclicalities shaping the annual patterns are defined solely by trigonometric functions. In this case the DST effect rises to 1.9% of savings from the policy when DST is applied (i.e., to 1.1% of annual electricity consumption).

We do not have any strong instrument at disposal to account for the endogeneity the *Electricity price* variable most probably brings to our estimation. The price variable is likely associated with seasonality (high consumption periods are associated with high prices). Therefore, we analyze the sensitivity of our estimated DST effect to an estimate stemming from a model without *Electricity price*.[3] Discarding the variable from our baseline does not change the value of the DST effect (thus is not reported in Table 9). Our final specification in Model 5 of Table 9, however, shows what happens when all possible changes to the baseline are applied cumulatively: the model ignores *Electricity price*, uses redefined *Heating degrees* and *Cooling degrees* with their squared values, and employs trigonometric functions instead of *Seasonality* dummies. The resulting DST effect amounts to 2% of savings when DST is applied, equivalent to 1.2% of annual savings on total electricity consumption—very close to our baseline estimate of 1% with a similar and small standard error.

Previous studies using the "equivalent day normalization technique" on electricity consumption used the same set of control hours that, by common sense, should be unaffected by the DST policy. As a final robustness check, we show in Table 4 how the different sets of control

[3] An additional argument is the voluminous research that shows low sensitivity of energy demand to prices (see, for example, Havranek *et al.*, 2012).

Table 4: Selecting the correct group of control hours matters

	Benchmark using *Cooling/Heating degrees*	Benchmark using *Temperature squared*
Benchmark group (hours 11, 12, 13)	-0.0156	-0.0127
Control group 1 (hours 12, 13, 14)	-0.0165	-0.0137
Control group 2 (hours 24, 1, 2)	-0.0066	-0.0080
Control groups 1 & 2	-0.0126	-0.0118

Notes: This table summarizes the overall DST effect estimates using different control hour groups and temperature specifications. The "Benchmark group (hours 11, 12, 13)" is identical to the coefficients of variable *DST*Treatment* reported in Table 3. Negative coefficients represent energy consumption savings as a result of the DST policy. All reported coefficients are statistically significant at the 1% level.

hours and different approaches to capturing the effects of temperature could affect the estimated savings using our baseline set of models. We estimate the benchmark models for 1) group of control hours from 12 AM to 2 PM, 2) group of control hours from 12 PM to 2 AM, and 3) group of standard control hours from 12 PM to 2 AM and from 12 AM to 2 PM. It can be observed that using the midday hours as the control group slightly overestimates the reduction in consumption. On the other hand, if midnight hours serve as the control group, the results are underestimated. The standard set of control hours results in an estimate of 1.3% savings (0.8% annually). Considering all of our estimated models and their robustness checks, the annual estimate of DST savings on electricity consumption ranges between 0.8% and 1.2%. As Havranek *et al.* (2018a) show in a large meta-analysis, the estimated DST effect is sensitive to study design, model specification, and estimation method.

5.3 Meta-Analysis Estimate

To confront the empirical estimates of Table 4 and Table 9 with broader evidence based on international data, we employ the study of Havranek *et al.* (2018a) and replicate their best-practice approach to estimate the DST effect based on the literature covering the last 40 years of research. The data set in Havranek *et al.* (2018a) codes 162 independent estimates of the DST effect from various studies, their statistical measures of precision, and different aspects of study design, including method and publication characteristics. To show a systematic dependence between the DST effects and study design, the authors use state-of-the-art techniques to estimate the meta-regression, taking into account the publication bias often present in the economic literature (Havranek & Irsova, 2010; Babecky & Havranek, 2014; Havranek & Irsova, 2017; Havranek *et al.*, 2018b,c). We take the results of this estimation (posterior means from the Bayesian Model Averaging model of Havranek *et al.*, 2018a, from Table 5 on p. 49) and the best-practice specification of Havranek *et al.* (2018a) to remain consistent with their estimates.

The best-practice approach, according to Havranek *et al.* (2018a), is based on the difference-in-differences method covering large data sets and the latest highly cited studies published in the best journals. Furthermore, this approach considers latitudinal effects to account for geographical variation among the countries. To compare the results of this exercise with those of Bergland & Mirza (2017), we construct the synthetic estimates for Slovakia and the European average. The results can be found in Table 5: the Slovak estimate of -0.084% is the share of total electricity consumption on days when DST is applied. The yearly DST effect on electricity consumption amounts to $-0.084\% * 210/365$, which is hardly 0.05% of energy savings in terms of yearly electricity consumption. More importantly, the possible savings from DST are unlikely to exceed $-0.846\% * 210/365$, amounting to approximately 0.5% of yearly electricity consumption. This best-practice estimate is even smaller than what we (in Table 4) or Bergland & Mirza (2017) found. Nevertheless, some researchers (such as Hancevic & Margulis, 2016) argue that the efficiency of power supply meeting demand should be investigated on an hourly basis.

5.4 Hourly Effects

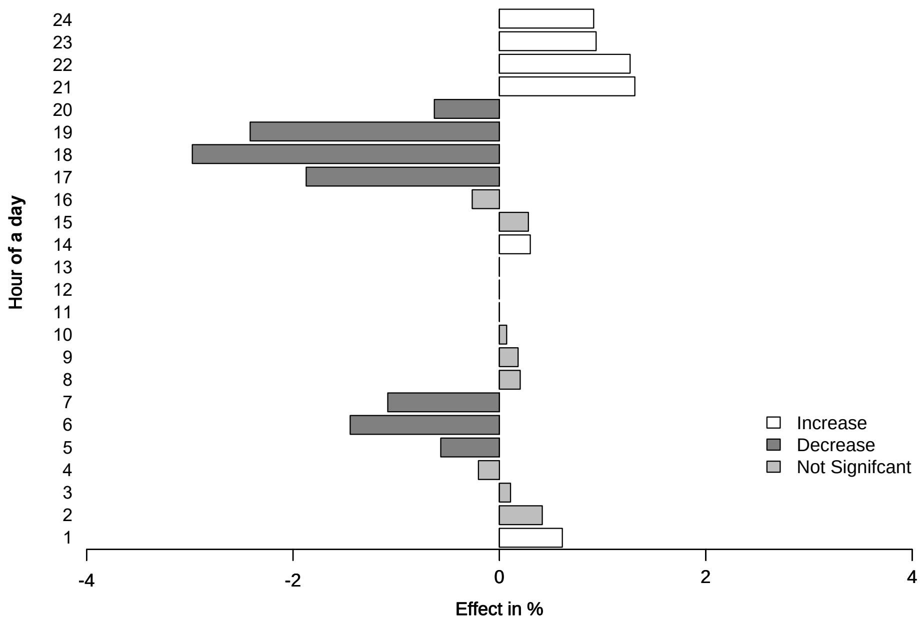
Several studies (Kellogg & Wolff, 2008; Kotchen & Grant, 2011; Bergland & Mirza, 2017) discuss the effects of DST policy on peak demand and the commonly occurring hourly trade-offs between the positive and negative consumption changes due to DST policy throughout the day. Choi *et al.* (2017) and Kellogg & Wolff (2008) find that the evening savings are offset by the morning increase in consumption, leading to an overall non-significant effect. Kotchen & Grant (2011)

Table 5: Based on Havranek *et al.* (2018a), the DST effect in Slovakia is small and close to the European average

	Mean	95% conf. int.	
Slovakia	-0.00084	-0.00846	0.00677
European Union	-0.00083	-0.00845	0.00679

Notes: The table presents the mean estimates of the DST effect implied by Bayesian model averaging and the best practice defined by Havranek *et al.* (2018a). Negative estimates represent savings because of the DST policy. The estimate for Europe is a consumption-weighted average of individual countries' savings. The confidence intervals are approximate and constructed using the standard errors estimated by OLS.

Figure 4: DST policy results in electricity savings during both the morning and evening peak demand



Notes: The figure shows the distribution of the DST effect on electricity consumption throughout the day.

show that the increase in morning consumption exceeds any savings and that the overall DST effect is an increase in consumption. The policy impact becomes especially important when no production capacity is available to meet the increased peak demand. Given that Slovakia has large generating capacity, the policy effects should not create additional installation expenses but could result in lower generation costs. Figure 3 indicates a reduction in peak electricity consumption during the morning and evening hours after the policy change but also an increase in electricity consumption during the rest of the day.

The estimation of (3) in Table 8 corresponds to such policy impacts: the largest energy savings occur during evening peak hours from 5PM to 8PM and range from 0.6% to almost 3% of hourly consumption. Another peak occurs in the morning from 5AM to 7AM and ranges between 0.5% and 1.5% savings. Similar patterns are observed in previous studies; see, for example, Mirza & Bergland (2011) and Verdejo *et al.* (2016). On the other hand, an increase in electricity demand occurs at night between 9PM and 12PM, and the cost reaches 1.3% of electricity consumption. The early morning hours bring small changes in the magnitude of the effect and are statistically insignificant. The summary of the DST impact of individual hours can be found in Figure 4.

Table 6: Financial savings from reduced household consumption

Year	Reduction [GWh]	Price [EUR/MWh]	Financial Benefits [million EUR]
2010	115 - 211	15.23	1.7 - 3.2
2011	132 - 243	16.43	2.2 - 4.0
2012	132 - 243	16.66	2.2 - 4.0
2013	128 - 237	16.63	2.1 - 3.9
2014	127 - 234	13.84	1.8 - 3.2
2015	130 - 240	13.97	1.8 - 3.4
2016	137 - 253	14.21	1.9 - 3.6

Notes: The table presents a valuation for the DST estimate of our benchmark model in Table 3, 1.56%, and the synthetic best-practice estimate implied by Havranek *et al.* (2018a), 0.85%. Volumes retrieved from ENTSO-E (2017), price data retrieved from Eurostat (2019).

Our preferred estimate from the difference-in-difference analysis indicates that the DST effect on electricity consumption in Slovakia reaches 1.6% (Table 3), while the synthetic estimate based on the study of Havranek *et al.* (2018a) indicates an effect of no more than 0.9% for the period when the DST policy is active (corresponding to the range between 0.5% and 1% of annual savings). In Table 6, we estimate the welfare effect stemming from decreased consumption due to DST based on these two estimates. We use ENTSO-E (2017) data to estimate the portion of electricity consumption saved and the yearly residential electricity prices (retrieved from Eurostat, 2019) for the period of 2010–2016. Although the assumption that the energy savings are created only for households is strong, we want to show the maximum possible savings. This price includes the production costs of electricity, network costs, taxes and levies. The valuation of Table 6 shows savings between 120 GWh and 250 GWh, which translates between EUR 2M and EUR 4M of financial benefit. Since a common Slovak household annually consumes approximately 20 MWh (SPP, 2017), the energy savings could be compared to the total energy consumption of 6,000 to 13,000 households per year.

6 Conclusion

The daylight saving time policy in Europe was originally introduced for the purpose of energy savings. Recent academic evidence, such as Hill *et al.* (2010), Bergland & Mirza (2017), and Havranek *et al.* (2018a), suggests the unified policy across the European Union has different impacts on the electricity consumption of its member states. This paper provides the first comprehensive analysis of the DST effects on electricity consumption in Slovakia. Using 2010–2017 hourly electricity load data and accounting for different weather conditions, macro variables, annual cycle and seasonality, we show that the policy does affect electricity consumption in Slovakia to some extent. The magnitude of this effect indicated by the difference-in-differences analysis using a proxy control group appears to be relatively high, around 1% of yearly electricity consumption. The magnitude decreases, however, to a level close to zero when we built a synthetic best-practice estimate from a meta-analysis (applying Havranek *et al.*, 2018a, methodology); the best-practice also suggests that the estimate is unlikely to exceed 0.5% of yearly electricity consumption.

We also observe that the DST effect varies throughout the day. The decrease in demand for electricity due to the policy occurs mostly during the early morning hours and early evening hours, amounting to, during some hours, almost 3% of electricity consumption when the policy is applied. The forenoon hours tend to be impacted the least, while the largest costs due to the policy are observed before midnight, reaching 1.6% of consumption when the policy is applied. The DST policy decreases peak consumption during the early morning and early evening hours and does not present any additional constraint on generating capacity. An important positive effect of the policy is thus redistributing consumption more evenly during the day. The overall annual effect of 0.5%–1% of savings on electricity consumption corresponds to the total annual energy consumption of approximately 6,000 to 13,000 Slovak households. The direct benefits of the DST policy thus bring significant economic savings of about 2 to 4mEUR annually (based on the 2016 energy savings from DST of about 140GWh).

Often excluded from the analysis of DST are indirect benefits of the policy. Such an indirect benefit comes in the form of carbon abatement and can be calculated using the concept of the social cost of carbon. Social cost of carbon represents the dollar value of total damages from emitting one ton of carbon dioxide into the atmosphere (see, for example, Havranek *et al.*, 2015). In terms of emissions saved from electricity generation due to DST, 140GWh amounts to approximately 35kt of CO_2 (or 48kt of CO_2eq, based on the national emission factors for consumed energy published by IEA, 2018). Using the authoritative estimate of the social cost of carbon by Pindyck (2019), the social savings due to the use of DST are about 0.9—1.5 mEUR, which represents approximately a half of the direct savings from the lower electricity consumption.

This estimate of indirect benefits could still be viewed as a conservative one. The effects of the DST policy are limited to marginal changes in domestic consumption in certain hours of the day in a certain period of the year; it may be the case that the marginal change in emissions are different from the national average. Unfortunately, for Slovakia there are no data revealing the marginal technology in the different hours and seasons. In Slovakia, as is the case elsewhere, changes in the intra-day load curve due to the DST policy probably affect the fuel mix used for the electricity generation. The electricity saved from smoothing the peak demand comes from the sources where electricity is available on short notice (i.e., the emission-heavy coal or gas power plants). If the electricity savings came from the coal power plants only, for example, the amount of saved emissions could be as much as 113kt of CO_2, which translates to social benefits of at least 2.8 mEUR.

Although our results apply for the specific case of Slovakia, the study can also be utilized in a cross-country context. The recent meta-analysis by Havranek *et al.* (2018a) uses 44 such studies and identifies the implied effect that can be drawn from the stock of the available country-specific cases. The authors employ the information from single studies to identify several systematic factors that drive the estimated results. Moreover, meta-analysis can not only increase the statistical power of the estimates but also account for drawbacks of individual studies, such as the unavailability of data that forces the researchers to apply less preferred statistical methods when estimating the researched effects. According to Havranek *et al.* (2018a), one of the important drivers is the latitudinal effect observed also in several recent studies (Shaffer, 2017; Bergland & Mirza, 2017). The largest electricity savings from DST are enjoyed by countries with the longest daylight summer hours; smaller savings are observed in countries closer to the equator.

There are, however, other aspects of the DST policy, besides those related to energy, that should be considered in a policy evaluation. Most of the DST literature researches the effects of changes in lighting, the effects of sleep deprivation, or both. Especially in recent years, various impacts have been thoroughly investigated (see Table 10): a large number of studies have been dedicated to health issues, such as the risk of acute myocardial infarction (Manfredini *et al.*, 2019), ischemic stroke (Sipila *et al.*, 2016), psychiatric illness (Shapiro *et al.*, 1990), suicide (Berk *et al.*, 2008), and spontaneous delivery (Laszlo *et al.*, 2016), in addition to general life satisfaction (Kuehnle & Wunder, 2016), recreational evening activities (Wolff & Makino, 2012;

Goodman *et al.*, 2014), and self-reported health and human capital (Jin & Ziebarth, 2016).

Researchers have also found an effect of DST on behavior and performance (of both humans and animals), such as criminal incidence (Doleac & Sanders, 2015), aggressive assaults (Umbach *et al.*, 2017), milk production (Niu *et al.*, 2014), stock market returns and volatility (Kamstra *et al.*, 2000), cyberloafing (Wagner *et al.*, 2012), cognitive performance and risk-taking behavior (Schaffner *et al.*, 2018), student performance (Herber *et al.*, 2017), laboratory mix-ups (Ehlers *et al.*, 2018) and police harassment (Wagner *et al.*, 2016). The remaining pool of studies considers road and work safety, including road lighting conditions (Bunnings & Schiele, 2018), fatal vehicle crashes (Smith, 2016), work and traffic accidents (Robb & Barnes, 2018), construction injuries (Holland & Hinze, 2000), and even animal road kill (Ellis *et al.*, 2016). The disruption of the circadian rhythm persists up to a few days (Kantermann *et al.*, 2007), so short-term effects are likely more significant than long-term effects. The magnitude and direction of these effects is, however, often inconclusive and, to the best of our knowledge, not yet evaluated for the specific case of the Slovak Republic.

References

ADEME (1995): "Internal ADEME (French Environment and Energy Management Agency - Agence de l'environnement et de la maitrise de l'energie) estimate on energy savings from DST." In K.-J. Reincke & F. van den Broek (editors), "Summer Time: Thorough examination of the implications of summer-time arrangements in the Member States of the European Union," Executive summary. Commission Europeenne 1999: Leiden.

ADEME (2010): "Impact of the clock change (in French: Impact du changement d'heure)." *Impact study prepared by energies demain for ademe*, Agence de l'environnement et de la maitrise de l'energie.

Babecky, J. & T. Havranek (2014): "Structural reforms and growth in transition." *Economics of Transition* **22(1)**: pp. 13–42.

Barnes, C. M. & D. T. Wagner (2009): "Changing to daylight saving time cuts into sleep and increases workplace injuries." *Journal of Applied Psychology* **94(5)**: pp. 1305 –1317.

Bellere, S. (1996): "Report on the proposal for an eighth European Parliament and Council Directive on summer-time arrangements (COM(96)0106 - C4-0252/96 - 96/0082(COD))." *Opinion (to the letter of 26 april 1996 the commission submitted to parliament)*, Committee on Transport and Tourism of the European Parliament, PE 218.712/fin.

Belzer, D. B., S. W. Hadley, & S.-M. Chin (2008): "Impact of Extended Daylight Saving Time on National Energy Consumption: Technical Documentation for Report to Congress." *Energy policy act of 2005, section 110*, U. S. Department of Energy.

Bergland, O. & F. Mirza (2017): "Latitudinal Effect on Energy Savings from Daylight Savings Time." *Working Paper Series 08/2017*, Norwegian University of Life Sciences, School of Economics and Business.

Berk, M., S. Dodd, K. Hallam, L. Berk, J. Gleeson, & M. Henry (2008): "Small shifts in diurnal rhythms are associated with an increase in suicide: The effect of daylight saving." *Sleep and Biological Rythms* **6(1)**: pp. 22–25.

Berument, M. H., N. Dogan, & B. Onar (2010): "Effects of daylight saving time changes on stock market volatility." *Psychological Reports* **106(2)**: pp. 632–640.

Bessec, M. & J. Fouquau (2008): "The non-linear link between electricity consumption and temperature in Europe: A threshold panel approach." *Energy Economics* **30(5)**: pp. 2705–2721.

Bildirici, M. E. & F. Kayikci (2016): "Electricity consumption and growth in Eastern Europe: An ARDL analysis." *Energy Sources, Part B: Economics, Planning, and Policy* **11(3)**: pp. 258–266.

Bossmann, T. & I. Staffell (2015): "The shape of future electricity demand: Exploring load curves in 2050s Germany and Britain." *Energy* **90(2)**: pp. 1317–1333.

Bouillon, H. (1983): "Mikro- und Makroanalyse der Auswirkungen der Sommerzeit auf den Energie- und Leistungsbedarf in den verschiedenen Energieverbrauchssektoren der Bundesrepublik Deutschland." *Unpublished dissertation*, Technischen Universität München.

Bunnings, C. & V. Schiele (2018): "Spring forward, don't fall back: The effect of daylight saving time on road safety." *Ruhr Economic Papers 768*, RWI - Leibniz-Institut fur Wirtschaftsforschung, Germany: Essen.

Bushnell, J. B. & E. T. Mansur (2005): "Consumption Under Noisy Price Signals: A Study Of Electricity Retail Rate Deregulation In San Diego." *Journal of Industrial Economics* **53(4)**: pp. 493–513.

Castoralova, L. (2019): "Does Daylight Saving Time Save Energy? Evidence from the Czech Republic." *Master thesis*, Institute of Economic Studies, Charles University.

Cho, K., C. M. Barnes, & C. L. Guanara (2017): "Sleepy Punishers Are Harsh Punishers: Daylight Saving Time and Legal Sentences." *Psychological Science* **28(2)**: pp. 242–247.

Choi, S., A. Pellen, & V. Masson (2017): "How does daylight saving time affect electricity demand? An answer using aggregate data from a natural experiment in Western Australia." *Energy Economics* **66**: pp. 247–260.

Coren, S. (1996): "Daylight savings time and traffic accidents." *New England Journal of Medicine* **334(14)**: pp. 924–925.

Danish Government Report (1974): "Betaenkning over forslag til lov om anvendelse af sommertid." *Government report (betaenkning afgivet af erhvervsudvalget d. 27.3.1974)*, Danmarks regeringer (med dansk statsminister Poul Hartling).

Doleac, J. L. & N. J. Sanders (2015): "Under the Cover of Darkness: How Ambient Light Influences Criminal Activity." *Review of Economics and Statistics* **97(5)**: pp. 1093–1103.

Ebersbach, K. & H. Schaefer (1980): "Sommerzeit und Energieeinsparung. Überraschendes Ergebnis einer detaillierteren Untersuchung: Es wird mehr Öl verbraucht." *Energiewirschaftliche Tasesfragen* **30(7)**: pp. 496–498.

Ebersole, N., D. Rubin, E. Darling, I. Englander, L. Frenkel, N. Meyerhoff, D. Prerau, K. Schaeffer, & J. Morrison (1975): "The Daylight Saving Time Study: Volume I - Final Report on the Operation and Effects of Daylight Saving Time." *A report to Congress from the Secretary of Transporta-*

tion, Washington: US Department of Transportation.

EC (2019): "European Commission welcomes the Parliament's endorsement to put an end to seasonal clock changes." *Technical report*, European Commission, Brussels, Daily News as of March 26, 2019. Online at http://europa.eu/rapid/press-release_MEX-19-1851_en.htm.

Ehlers, A., R. L. Dyson, C. K. Hodgson, S. R. Davis, & M. D. Krasowski (2018): "Impact of Daylight Saving Time on the Clinical Laboratory." *Academic Pathology* **5**: pp. 1–7.

Ellis, W. A., S. I. FitzGibbon, B. J. Barth, A. C. Niehaus, G. K. David, B. D. Taylor, H. Matsushige, A. Melzer, F. B. Bercovitch, F. Carrick, D. N. Jones, C. Dexter, A. Gillett, M. Predavec, D. Lunney, & R. S. Wilson (2016): "Daylight saving time can decrease the frequency of wildlife–vehicle collisions." *Biology Letters* **12(20160632)**: pp. 1–5.

ELTRA (1984): "Internal ELTRA (Denmark Power Grid Operator) estimate on energy savings from DST via Mr. Henning Parbo." In K.-J. Reincke & F. van den Broek (editors), "Summer Time: Thorough examination of the implications of summer-time arrangements in the Member States of the European Union," Executive summary. Commission Europeenne 1999: Leiden.

ENEL (1999): "Internal ENEL (Italian national energy company - Ente nazionale per l'energia elettrica) estimate on energy savings from DST via ing. Mario Moro." In K.-J. Reincke & F. van den Broek (editors), "Summer Time: Thorough examination of the implications of summer-time arrangements in the Member States of the European Union," Executive summary. Commission Europeenne 1999: Leiden.

EnergieNed (1995): "Internal estimate of the Federation of Energy Companies in the Netherlands (Energie-Nederland) on energy savings from DST." In K.-J. Reincke & F. van den Broek (editors), "Summer Time: Thorough examination of the implications of summer-time arrangements in the Member States of the European Union," Executive summary. Commission Europeenne 1999: Leiden.

ENTSO-E (2017): "Hourly load values of a specific country for a specific month." *Technical report*, European Network of Transmission System Operators for Electricity. Available online at https://www.entsoe.eu/data/power-stats/hourly_load/ [Accessed Feb-13, 2017].

Eurostat (2019): "Electricity prices for household consumers - bi-annual data from 2007 onwards [Datafile] ." *Technical report*, Eurostat database, the Statistical Office of the European Union. Retrieved from http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do [Accessed Mar 1, 2019].

EVA (1978): "Internal EVA (Austrian Energy Agency - Energieverwertungsagentur) forecast on energy savings from DST via Mag. Fickel." In K.-J. Reincke & F. van den Broek (editors), "Summer Time: Thorough examination of the implications of summer-time arrangements in the Member States of the European Union," Executive summary. Commission Europeenne 1999: Leiden.

Fischer, U. (2000): "Does the summer time help to save energy? (in German: Hilft die Sommerzeit beim Sparen von Energie?" *Licht* **52(5)**: pp. 574–577.

Fong, W. K., H. Matsumoto, Y. F. Lun, & R. Kimura (2007): "Energy Savings Potential of the Summer Time Concept in Different Regions of Japan From the Perspective of Household Lighting." *Journal of Asian Architecture and Building Engineering* **6(2)**: pp. 371–378.

FRED (2017): "FRED Economic Data." *Technical report*, Federal Reserve Bank of St. Louis, Missouri: St. Louis. Available at https://fred.stlouisfed.org [Accessed Nov 11, 2017].

Goodman, A., A. S. Page, & A. R. Cooper (2014): "Daylight saving time as a potential public health intervention: an observational study of evening daylight and objectively-measured physical activity among 23,000 children from 9 countries." *International Journal of Behavioral Nutrition and Physical Activity* **11(84)**: pp. 1–9.

Gregory-Allen, R., B. Jacobsen, & W. Marquering (2010): "The Daylight Saving Time Anomaly In Stock Returns: Fact Or Fiction?" *Journal of Financial Research* **33(4)**: pp. 403–427.

Hancevic, P. & D. Margulis (2016): "Daylight saving time and energy consumption: The case of Argentina." *MPRA Working Paper 80481*, University Library of Munich, Germany.

Havranek, T., D. Herman, & Z. Irsova (2018a): "Does Daylight Saving Save Electricity? A Meta-Analysis." *The Energy Journal* **39(2)**: pp. 35–61.

Havranek, T. & Z. Irsova (2010): "Meta-Analysis of Intra-Industry FDI Spillovers: Updated Evidence." *Czech Journal of Economics and Finance* **60(2)**: pp. 151–174.

Havranek, T. & Z. Irsova (2017): "Do Borders Really Slash Trade? A Meta-Analysis." *IMF Economic Review* **65(2)**: pp. 365–396.

Havranek, T., Z. Irsova, & K. Janda (2012): "Demand for gasoline is more price-inelastic than commonly thought." *Energy Economics* **34(1)**: pp. 201–207.

Havranek, T., Z. Irsova, K. Janda, & D. Zilberman (2015): "Selective reporting and the social cost of carbon." *Energy Economics* **51(C)**: pp. 394–406.

Havranek, T., Z. Irsova, & T. Vlach (2018b): "Measuring the Income Elasticity of Water Demand: The Importance of Publication and Endogeneity Biases."

Land Economics **94(2)**: pp. 259–283.

Havranek, T., Z. Irsova, & O. Zeynalova (2018c): "Tuition Fees and University Enrolment: A Meta?Regression Analysis." *Oxford Bulletin of Economics and Statistics* **80(6)**: pp. 1145–1184.

Herber, S. P., J. S. Quis, & G. Heineck (2017): "Does the transition into daylight saving time affect students' performance?" *Economics of Education Review* **61**: pp. 130 – 139.

Hill, S. I., F. Desobry, E. W. Garnsey, & Y. F. Chong (2010): "The impact on energy consumption of daylight saving clock changes." *Energy Policy* **38(9)**: pp. 4955–4965.

Hillman, M. (1993): *Time for Change: Setting Clocks Forward by One Hour throughout the Year. A new review of the evidence.* Policy Studies Institute, London.

HMSO (1970): *Review of British Standard Time.* Command 4512 Series. Her Majesty's Stationary Office: Great Britain - Home Office and Great Britain - Scottish Home and Health Dept.

Holland, N. & J. Hinze (2000): "Daylight savings time changes and construction accidents." *Journal of Construction Engineering and Management* **126(5)**: pp. 404–406.

IEA (2018): "Emissions factors." *IEA Statistics 2018 edition*, International Energy Agency.

IEA (2018): "Energy policies of IEA countries: Slovak Republic 2018 review." *Technical report*, International Energy Agency.

Janda, K. (2018): "Slovak electricity market and the price merit order effect of photovoltaics." *Energy Policy* **122**: p. 551–562.

Janszky, I., S. Ahnve, R. Ljung, K. J. Mukamal, S. Gautam, L. Wallentin, & U. Stenestrand (2012): "Daylight saving time shifts and incidence of acute myocardial infarction–Swedish Register of Information and Knowledge About Swedish Heart Intensive Care Admissions (RIKS-HIA)." *Sleep Medicine* **13(3)**: pp. 237–242.

Jilek, K. (2000): "Zimni cas: Zmena casu usteri pul procenta spotreby energie (in English: Winter time: Time change will save half percent of the energy consumption)." *Technical report*, https://archiv.neviditelnypes.zpravy.cz/clanky/7242_0_0_0.html [Accessed on March 8, 2019].

Jin, L. & N. Ziebarth (2016): "Sleep and Human Capital: Evidence from Daylight Saving Time." *Working Papers 160001*, Canadian Centre for Health Economics.

Kamstra, M. J., L. A. Kramer, & M. D. Levi (2000): "Losing sleep at the market: the daylight saving anomaly." *American Economic Review* **90(4)**: pp. 1005–1011.

Kandel, A. (2007): "Electricity Savings of Early Daylight Saving Time." *Staff paper*, California Energy Commission.

Kantermann, T., M. Juda, M. Merrow, & T. Roenneberg (2007): "The human circadian clocks seasonal adjustment is disrupted by daylight saving time." *Current Biology* **17(22)**: pp. 1996–2000.

Karasu, S. (2010): "The effect of daylight saving time options on electricity consumption of Turkey." *Energy* **35(9)**: pp. 3773–3782.

Kellogg, R. & H. Wolff (2007): "Does extending daylight saving time save energy? Evidence from an Australian experiment." *IZA Discussion Paper 2704*, Institute for the Study of Labor.

Kellogg, R. & H. Wolff (2008): "Daylight time and energy: Evidence from an Australian experiment." *Journal of Environmental Economics and Management* **56(3)**: pp. 207–220.

Kotchen, M. J. & L. E. Grant (2011): "Does Daylight Saving Time Save Energy? Evidence from a Natural Experiment in Indiana." *The Review of Economics and Statistics* **93(4)**: pp. 1172–1185.

Kozuskova, K. (2011): "Jake jsou naklady a vynosy letniho casu." *Bachelor thesis*, The University of Economics, Prague, Faculty of Economics.

Kuehnle, D. & C. Wunder (2016): "Using the life satisfaction approach to value daylight savings time transitions. Evidence from Britain and Germany." *Journal of Happiness Studies* **17(6)**: p. 2293–2323.

Lahti, T., E. Nysten, J. Haukka, P. Sulander, & T. Partonen (2010): "Daylight saving time transitions and road traffic accidents." *Journal of Environmental and Public Health* **2010(657167)**: pp. 1–3.

Lamb, R., R. Zuber, & J. Gandar (2004): "Don't lose sleep on it: a re-examination of the daylight savings time anomaly." *Applied Financial Economics* **14(6)**: pp. 443–446.

Laszlo, K., S. Cnattingius, & I. Janszky (2016): "Transition into and out of daylight saving time and spontaneous delivery: A population-based study." *BMJ Open* **6(e010925)**: pp. 1–7.

Lieskovsky, M., M. Trenciansky, A. Majlingova, & J. Jankovsky (2019): "Energy Resources, Load Coverage of the Electricity System and Environmental Consequences of the Energy Sources Operation in the Slovak Republic—An Overview." *Energies* **12(9)**: p. 1701.

Madlener, R. & B. Alcott (2009): "Energy rebound and economic growth: A review of the main issues and research needs." *Energy* **34(3)**: pp. 370–376.

Manfredini, R., F. Fabbian, R. Cappadona, A. D. G. F. Bravi, T. Carradori, M. E. Flacco, & L. Manzoli (2019): "Daylight Saving Time and Acute Myocardial Infarction: A Meta-Analysis." *Journal of Clinical Medicine* **8(3(404))**: pp. 1–10.

Medina, D., M. Ebben, S. Milrad, B. Atkinson, & A. C. Krieger (2015): "Adverse Effects of Daylight Saving Time on Adolescents' Sleep and Vigilance." *Journal of Clinical Sleep Medicine* **11(8)**: pp. 879–884.

Mirza, F. M. & O. Bergland (2011): "The impact of daylight saving time on electricity consumption: Evidence from southern Norway and Sweden." *Energy Policy* **39(6)**: pp. 3558–3571.

Momani, M. A., B. Yatim, & M. A. M. Ali (2009): "The impact of the daylight saving time on electricity consumption—A case study from Jordan." *Energy Policy* **37(5)**: pp. 2042–2051.

Muller, L., D. Schiereck, M. W. Simpson, & C. Voigt (2009): "Daylight saving effect." *Journal of Multinational Financial Management* **19(2)**: pp. 127–138.

Niu, M., Y. Ying, P. Bartell, & K. Harvatine (2014): "The effects of feeding time on milk production, total-tract digestibility, and daily rhythms of feeding behavior and plasma metabolites and hormones in dairy cows." *Journal of Dairy Science* **97(12)**: pp. 7764–7776.

OKTE (2017): "Statistics on Trend of STM Indexes." *Technical report*, Short-term electricity Market Operator /Organizator kratkodobeho trhu s elektrinou/, Slovakia: Bratislava (Available at https://www.okte.sk/en/short-term-market/statistics/trend-of-stm-indexes/ [Accessed Nov 12, 2017].

Olders, H. (2003): "Average sunrise time predicts depression prevalence." *Journal of Psychosomatic Research* **55(2)**: pp. 99–105.

Pindyck, R. S. (2019): "The social cost of carbon revisited." *Journal of Environmental Economics and Management* **94**: pp. 140–160.

Pout, C. (2006): "The effect of clock changes on energy consumption in UK buildings." *Technical Report Client report number 222-601*, Building Research Establishment.

Robb, D. & T. Barnes (2018): "Accident rates and the impact of daylight saving time transitions." *Accident Analysis & Prevention* **111**: pp. 193–201.

Rock, B. A. (1997): "Impact of daylight saving time on residential energy consumption and cost." *Energy and Buildings* **25(1)**: pp. 63–68.

Schaffner, M., J. Sarkar, B. Torgler, & U. Dulleck (2018): "The implications of daylight saving time: A quasi-natural experiment on cognitive performance and risk taking behaviour." *Economic Modelling* **70(C)**: pp. 390–400.

SEP (1995): "Internal estimate of the Samenwerkende Energie Producenten (SEP) on energy savings from DST." In K.-J. Reincke & F. van den Broek (editors), "Summer Time: Thorough examination of the implications of summer-time arrangements in the Member States of the European Union," Executive summary. Commission Europeenne 1999: Leiden.

SEPS (2017): "Rocne udaje o prevadzke 2017 - Slovensky elektroenergeticky dispecing SEPS (in English "Annual report 2017 - National Control Centre of Slovakia SEPS")." *Technical report*, Slovenska elektrizacna prenosova sustava - SEPS (Slovak transmission system operator). Available at https://www.sepsas.sk/Dokumenty/RocenkySed/ROCENKA_SED_2017.pdf [Accessed Feb 20, 2019].

SEPS (2018): "Desatrocny plan rozvoja prenosovej sustavy na roky 2018-2027 (in English "Ten-year development plan of electrical transmission system for 2018-2027")." *Technical report*, Slovenska elektrizacna prenosova sustava - SEPS (Slovak transmission system operator). Available at https://www.sepsas.sk/Dokumenty/ProgRozvoj/2018/07/DPR_PS_2018_2027.pdf.

SEPS (2019): "Vyroba a spotreba SR 2009-2018 (in English "Production and Consumption of the Slovak Republic 2009-2018")." *Technical report*, Slovenska elektrizacna prenosova sustava - SEPS (Slovak transmission system operator). Available at https://www.sepsas.sk/Vyroba_spotreba.asp?kod=568 [Accessed Feb 26, 2019].

Shaffer, B. (2017): "Location matters: daylight saving time and electricity use." *MPRA Paper 84053*, University Library of Munich, Germany.

Shapiro, C. M., F. Blake, E. Fossy, & B. Adams (1990): "Daylight saving time in psychiatric illness." *Journal of Affective Disorders* **19(3)**: pp. 177–181.

Shimoda, Y., T. Asahi, A. Taniguchi, & M. Mizuno (2007): "Evaluation of city-scale impact of residential energy conservation measures using the detailed end-use simulation model." *Energy* **32(9)**: pp. 1617–1633.

SHMU (2019): "Review of historical extremes of selected meteorological elements at the territory of Slovak republic." *Technical report*, Slohak Hydro-Meteorological Institute, Slovakia: Bratislava. Online at http://www.shmu.sk/en/?page=1384 [Accessed on Feb-12, 2019].

Sipila, J. O., J. O. Ruuskanen, P. Rautava, & V. Kyto (2016): "Changes in ischemic stroke occurrence following daylight saving time transitions." *Sleep Medicine* **27-28**: pp. 20–24.

Smith, A. V. (2016): "Spring Forward at Your Own Risk: Daylight Saving Time and Fatal Vehicle Crashes." *American Economic Journal: Applied Economics* **8(2)**: p. 65–91.

SOSR (2019): "Public database STATdat." *Database*, Statistical Office of the Slovak Republic, Slovakia: Bratislava. Online at http://statdat.statistics.sk [Accessed Mar-1, 2019].

SPP (2017): "Rocne naklady na palivo a energiu pre rodinny dom vratane investicii v EUR (in English: Annual fuel and energy costs for a household including investments in EUR." *Technical report*, Slovensky plynarensky priemysel (Slovak Gas Industry), Slovakia: Bratislava. Online at http://www.spp.sk/sk/Cds/AdminDownload/? filename=2350_Rocne_naklady_DOM_januar_2017 [Accessed Feb-3, 2018].

TAB (2016): "Assessment of Daylight Saving Time." *Tab-fokus no. 8 regarding report no. 165*, Buro fur Technikfolgen-Abschatzung beim Deutschen Bundestag.

Terna (2016): "Daylight saving time: In seven months Italy saved..." *Press releases from October 2006-2016*, Terna Group: grid operator for electricity transmission in Italy.

Umbach, R., A. Raine, & G. Ridgeway (2017): "Aggression and sleep: a daylight saving time natural experiment on the effect of mild sleep loss and gain on assaults." *Journal of Experimental Criminology* **13(4)**: pp. 439–453.

Varughese, J. & R. P. Allen (2001): "Fatal accidents following changes in daylight savings time: the American experience." *Sleep Medicine* **2(1)**: pp. 31–36.

Verbeek, M. (2008): *A Guide to Modern Econometrics*. John Wiley & Sons.

Verdejo, H., C. Becker, D. Echiburu, W. Escudero, & E. Fucks (2016): "Impact of daylight saving time on the Chilean residential consumption." *Energy Policy* **88(C)**: pp. 456–464.

Wagner, D. T., C. M. Barnes, L. V. K. G., & F. D. Lance (2012): "Lost Sleep and Cyberloafing: Evidence From the Laboratory and a Daylight Saving Time Quasi-Experiment." *Journal of Applied Psychology* **97(5)**: p. 1068–1076.

Wagner, D. T., C. M. Barnes, & C. Guarana (2016): "Law and Error: Daylight Saving Time and Police Harassment." *Working paper*, Lundquist College of Business, University of Oregon and Foster School of Business, University of Washington.

Wanko & Ingeborg (1983): "Die Einführung der Sommerzeit in Österreich: Eine energiewirtschaftliche Betraucht der Ausgangsvoraussetzungen und Auswirkungen." *Technical report*, Economic University in Vienna.

Whittaker, J. D. (1996): "An investigation into the effects of British summer time on road traffic accident casualties in Cheshire." *Journal of Accident and Emergency Medicine* **13(3)**: pp. 189–192.

Wolff, H. & M. Makino (2012): "Extending Becker's Time Allocation Theory to Model Continuous Time Blocks: Evidence from Daylight Saving Time." *IZA Discussion Papers 6787*, The Institute for the Study of Labor, Bonn.

A Appendix

Table 7: Validity of control hours

DST Dummy	Coefficient	HAC SE
Hour 24	-0.049***	0.015
Hour 1	-0.046***	0.014
Hour 2	-0.054***	0.011
Hour 11	-0.019	0.014
Hour 12	-0.019	0.015
Hour 13	-0.017	0.014
Hour 14	-0.027**	0.012

Notes: The table presents a validation test for the correct group of control hours (insignificance indicates that the hour is not affected by the DST policy). Test follows (1) with the pair of variables *Temperature* and *Temperature squared*. The specification with the pair of variables *Cooling degrees* and *Heating degrees* does not change the conclusions of the test. To account for potential heteroskedasticity and serial correlation, we follow Verbeek (2008) and use heteroskedasticity and autocorrelation consistent (HAC) standard errors (SE) with 24 lags. *p<0.1; **p<0.05; ***p<0.01.

Table 8: Hourly DST effects using different groups of control hours

Variable	Benchmark control hours 11, 12, 13	Control hours 24, 1, 2, 12, 13, 14	Control hours 12, 13, 14	Control hours 24, 1, 2
Constant	8.229***	8.158***	8.229***	8.107***
	(0.051)	(0.053)	(0.051)	(0.051)
DST	−0.027***	−0.028***	−0.026***	−0.021***
	(0.005)	(0.005)	(0.005)	(0.005)
Treatment	−0.123***	−0.018***	−0.123***	0.122***
	(0.002)	(0.001)	(0.002)	(0.002)
DST * Treatment * Hour 1	0.0061**		0.005*	
	(0.003)		(0.003)	
DST * Treatment * Hour 2	0.0042		0.003	
	(0.003)		(0.003)	
DST * Treatment * Hour 3	0.0011	0.003	−0.0003	−0.005***
	(0.003)	(0.002)	(0.003)	(0.002)
DST * Treatment * Hour 4	−0.002	−0.0002	−0.003	−0.008***
	(0.003)	(0.002)	(0.003)	(0.002)
DST * Treatment * Hour 5	−0.0056**	−0.004**	−0.007***	−0.012***
	(0.003)	(0.002)	(0.003)	(0.002)
DST * Treatment * Hour 6	−0.0145***	−0.013***	−0.016***	−0.021***
	(0.003)	(0.002)	(0.003)	(0.002)
DST * Treatment * Hour 7	−0.0108***	−0.009***	−0.012***	−0.017***
	(0.003)	(0.003)	(0.003)	(0.003)
DST * Treatment * Hour 8	0.002	0.003	0.001	−0.004
	(0.003)	(0.003)	(0.003)	(0.003)
DST * Treatment * Hour 9	0.0018	0.002	0.0005	−0.005*
	(0.002)	(0.002)	(0.002)	(0.003)
DST * Treatment * Hour 10	0.0007	0.001	−0.001	−0.006**
	(0.001)	(0.002)	(0.002)	(0.002)
DST * Treatment * Hour 11		−0.0001	−0.002*	−0.007***
		(0.002)	(0.001)	(0.002)
DST * Treatment * Hour 12				−0.008***
				(0.002)
DST * Treatment * Hour 13				−0.003
				(0.002)
DST * Treatment * Hour 14	0.00299*			−0.003
	(0.002)			(0.003)
DST * Treatment * Hour 15	0.0028	0.005***	0.001	−0.004
	(0.002)	(0.002)	(0.002)	(0.003)
DST * Treatment * Hour 16	−0.0026	−0.001	−0.004**	−0.009***
	(0.002)	(0.002)	(0.002)	(0.003)
DST * Treatment * Hour 17	−0.0187***	−0.017***	−0.020***	−0.025***
	(0.002)	(0.002)	(0.002)	(0.003)
DST * Treatment * Hour 18	−0.0298***	−0.028***	−0.031***	−0.036***
	(0.003)	(0.002)	(0.002)	(0.003)
DST * Treatment * Hour 19	−0.0242***	−0.022***	−0.025***	−0.031***
	(0.003)	(0.002)	(0.002)	(0.003)
DST * Treatment * Hour 20	−0.0063***	−0.005**	−0.008***	−0.013***
	(0.002)	(0.002)	(0.002)	(0.002)
DST * Treatment * Hour 21	0.0131***	0.014***	0.012***	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
DST * Treatment * Hour 22	0.0127***	0.014***	0.011***	0.006***
	(0.002)	(0.001)	(0.002)	(0.001)
DST * Treatment * Hour 23	0.0094***	0.011***	0.008***	0.003**
	(0.002)	(0.001)	(0.002)	(0.001)
DST * Treatment * Hour 24	0.0091***		0.008***	
	(0.002)		(0.002)	
Weather variables				
Humidity	−0.0002***	−0.0002***	−0.0002***	−0.0002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Air pressure	−0.00004	−0.0001	−0.00004	−0.00004
	(0.00004)	(0.00005)	(0.00004)	(0.00004)
Sunlight	−0.0004***	−0.0003***	−0.0004***	−0.0004***
	(0.00004)	(0.00004)	(0.00004)	(0.00004)
Precipitation	0.003***	0.004***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Radiation	−0.00002	0.00000	−0.00002	−0.00002
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Price variable				
Electricity price	0.002***	0.002***	0.002***	0.002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Cyclicity	−0.00001**	−0.00001	−0.00001**	−0.00001**
	(0.00001)	(0.00001)	(0.00001)	(0.00001)
Weekend	−0.076***	−0.074***	−0.076***	−0.076***

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Table 8 – *Continued from previous page*

Variable	Benchmark control hours 11, 12, 13	Control hours 24, 1, 2, 12, 13, 14	Control hours 12, 13, 14	Control hours 24, 1, 2
	(0.002)	(0.002)	(0.002)	(0.002)
Holidays	−0.066***	−0.065***	−0.066***	−0.066***
	(0.005)	(0.005)	(0.005)	(0.005)
Seasonality				
Summer	−0.004	−0.004*	−0.004	−0.004
	(0.003)	(0.003)	(0.003)	(0.003)
January	0.085***	0.088***	0.085***	0.085***
	(0.007)	(0.007)	(0.007)	(0.007)
February	0.092***	0.095***	0.092***	0.092***
	(0.007)	(0.007)	(0.007)	(0.007)
March	0.067***	0.069***	0.067***	0.067***
	(0.006)	(0.006)	(0.006)	(0.006)
April	0.027***	0.028***	0.027***	0.027***
	(0.004)	(0.004)	(0.004)	(0.004)
May	0.008**	0.009**	0.008**	0.008**
	(0.004)	(0.004)	(0.004)	(0.004)
June	0.015***	0.015***	0.015***	0.015***
	(0.003)	(0.003)	(0.003)	(0.003)
July	0.005	0.004	0.005	0.005
	(0.003)	(0.003)	(0.003)	(0.003)
September	0.018***	0.019***	0.018***	0.018***
	(0.003)	(0.003)	(0.003)	(0.003)
October	0.048***	0.050***	0.048***	0.048***
	(0.004)	(0.004)	(0.004)	(0.004)
November	0.056***	0.059***	0.056***	0.056***
	(0.007)	(0.007)	(0.007)	(0.007)
December	0.071***	0.075***	0.071***	0.071***
	(0.008)	(0.008)	(0.008)	(0.008)
Year 2010	−0.069***	−0.069***	−0.069***	−0.069***
	(0.003)	(0.003)	(0.003)	(0.003)
Year 2011	−0.074***	−0.074***	−0.074***	−0.074***
	(0.003)	(0.003)	(0.003)	(0.003)
Year 2012	−0.058***	−0.058***	−0.058***	−0.058***
	(0.003)	(0.003)	(0.003)	(0.003)
Year 2013	−0.049***	−0.048***	−0.049***	−0.049***
	(0.003)	(0.003)	(0.003)	(0.003)
Year 2014	−0.062***	−0.061***	−0.062***	−0.062***
	(0.003)	(0.003)	(0.003)	(0.003)
Year 2015	−0.033***	−0.031***	−0.033***	−0.033***
	(0.003)	(0.003)	(0.003)	(0.003)
Year 2016	−0.014***	−0.012***	−0.014***	−0.014***
	(0.003)	(0.003)	(0.003)	(0.003)
Hour 1	−0.029***	−0.077***	−0.029***	−0.029***
	(0.001)	(0.001)	(0.001)	(0.001)
Hour 2	−0.063***	−0.111***	−0.063***	−0.064***
	(0.001)	(0.001)	(0.001)	(0.001)
Hour 3	−0.081***	−0.112***	−0.081***	−0.203***
	(0.001)	(0.001)	(0.001)	(0.002)
Hour 4	−0.078***	−0.109***	−0.078***	−0.201***
	(0.001)	(0.001)	(0.001)	(0.002)
Hour 5	−0.061***	−0.092***	−0.061***	−0.183***
	(0.001)	(0.001)	(0.001)	(0.002)
Hour 6	−0.028***	−0.059***	−0.028***	−0.150***
	(0.001)	(0.001)	(0.001)	(0.002)
Hour 7	0.042***	0.009***	0.042***	−0.080***
	(0.002)	(0.002)	(0.002)	(0.002)
Hour 8	0.068***	0.034***	0.068***	−0.055***
	(0.002)	(0.002)	(0.002)	(0.002)
Hour 9	0.099***	0.064***	0.099***	−0.024***
	(0.002)	(0.002)	(0.002)	(0.001)
Hour 10	0.125***	0.089***	0.125***	0.002**
	(0.002)	(0.002)	(0.002)	(0.001)
Hour 11	0.007***	0.093***	0.130***	0.007***
	(0.001)	(0.002)	(0.002)	(0.001)
Hour 12	0.010***	0.078***	0.010***	0.010***
	(0.001)	(0.001)	(0.001)	(0.001)
Hour 14	0.119***	0.065***	−0.003***	−0.003***
	(0.002)	(0.001)	(0.001)	(0.001)
Hour 15	0.109***	0.073***	0.109***	−0.014***
	(0.002)	(0.002)	(0.002)	(0.001)
Hour 16	0.105***	0.070***	0.105***	−0.017***
	(0.002)	(0.002)	(0.002)	(0.001)
Hour 17	0.119***	0.084***	0.119***	−0.003***
	(0.002)	(0.002)	(0.002)	(0.001)
Hour 18	0.125***	0.089***	0.125***	0.002
	(0.002)	(0.002)	(0.002)	(0.001)

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Table 8 – *Continued from previous page*

Variable	Benchmark control hours 11, 12, 13	Control hours 24, 1, 2, 12, 13, 14	Control hours 12, 13, 14	Control hours 24, 1, 2
Hour 19	0.119***	0.084***	0.119***	−0.003**
	(0.002)	(0.002)	(0.002)	(0.002)
Hour 20	0.119***	0.084***	0.119***	−0.003**
	(0.002)	(0.002)	(0.002)	(0.001)
Hour 21	0.109***	0.075***	0.109***	−0.013***
	(0.002)	(0.001)	(0.002)	(0.001)
Hour 22	0.073***	0.040***	0.073***	−0.049***
	(0.001)	(0.001)	(0.001)	(0.001)
Hour 23	0.033***		0.033***	−0.090***
	(0.001)		(0.001)	(0.002)
Weather variables				
Temperature * Hour 1	−0.004***	−0.003***	−0.004***	−0.004***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 2	−0.004***	−0.003***	−0.004***	−0.004***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 3	−0.004***	−0.004***	−0.004***	−0.004***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 4	−0.004***	−0.004***	−0.004***	−0.004***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 5	−0.004***	−0.004***	−0.004***	−0.004***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 6	−0.005***	−0.005***	−0.005***	−0.005***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 7	−0.004***	−0.004***	−0.004***	−0.004***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Temperature * Hour 8	−0.003***	−0.003***	−0.003***	−0.003***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Temperature * Hour 9	−0.002***	−0.002***	−0.002***	−0.002***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 10	−0.002***	−0.002***	−0.002***	−0.002***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 11	−0.002***	−0.002***	−0.002***	−0.002***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 12	−0.002***	−0.002***	−0.002***	−0.002***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 13	−0.001***	0.002***	−0.001***	−0.001***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 14	−0.001***	−0.001***	−0.001***	−0.001***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 15	−0.001***	−0.001***	−0.001***	−0.001***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 16	−0.002***	−0.002***	−0.002***	−0.002***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 17	−0.002***	−0.002***	−0.002***	−0.002***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 18	−0.002***	−0.002***	−0.002***	−0.002***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 19	−0.003***	−0.003***	−0.003***	−0.003***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 20	−0.003***	−0.003***	−0.003***	−0.003***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 21	−0.003***	−0.003***	−0.003***	−0.003***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 22	−0.003***	−0.003***	−0.003***	−0.003***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 23	−0.003***	−0.003***	−0.003***	−0.003***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Temperature * Hour 24	−0.003***	−0.006***	−0.003***	−0.003***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Observations	63,427	63,427	63,427	63,427

Notes: The table presents the results of difference-in-differences regression of the hourly demand model in (3). HAC-robust standard errors in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table 9: Robustness checks to Table 3 using different model specifications

Variable	Model 1 using C/H squared	Model 2 using new C/H	Model 3 using sin/cos	Model 4 using sin/cos	Model 5 using new C/H sq, sin, cos, no price
Constant	7.723***	7.729***	7.750***	7.710***	8.131***
	(0.068)	(0.067)	(0.077)	(0.068)	(0.076)
DST	-0.015**	-0.013*	-0.039***	-0.034***	-0.028***
	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)
Treatment	-0.133***	-0.133***	-0.136***	-0.138***	-0.170***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
DST * Treatment	**-0.0138*** **	**-0.0141*** **	**-0.0178*** **	**-0.0188*** **	**-0.0201*** **
	(0.001)	**(0.001)**	**(0.001)**	**(0.001)**	**(0.001)**
Temperature variables					
Temperature			-0.005***		
			(0.0003)		
Temperature squared			0.00009***		
			(0.00001)		
Heating degrees	0.002***	0.004***		0.005***	0.007***
	(0.0003)	(0.0002)		(0.0002)	(0.0004)
Heating degrees squared	0.0001***				-0.00003
	(0.00001)				(0.00002)
Cooling degrees	-0.0001	0.003***		0.0006*	-0.004***
	(0.0005)	(0.0003)		(0.0003)	(0.001)
Cooling degrees squared	0.0002***				0.0007***
	(0.00004)				(0.0001)
Weather variables					
Humidity	0.00004	0.000004	-0.00006	-0.00004	0.0001
	(0.0001)	(0.0001)	(0.00007)	(0.00006)	(0.0001)
Air pressure	-0.00003	-0.00003	-0.00003	-0.00002	0.000001
	(0.00004)	(0.00004)	(0.00005)	(0.00004)	(0.0001)
Sunlight	-0.001***	-0.0006***	-0.0005***	-0.0005***	-0.001***
	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
Precipitation	0.003***	0.004***	0.003**	0.003**	0.001
	(0.001)	(0.0008)	(0.001)	(0.001)	(0.001)
Radiation	0.0001***	0.00005***	0.00001	-0.00002	-0.00004**
	(0.00001)	(0.00001)	(0.00001)	(0.00001)	(0.00001)
Price variable					
Electricity price	0.002***	0.002***	0.002***	0.002***	
	(0.00007)	(0.00007)	(0.00009)	(0.00008)	
Holidays	-0.068***	-0.068***	-0.071***	-0.072***	-0.092***
	(0.005)	(0.005)	(0.007)	(0.005)	(0.007)
Weekend	-0.077***	-0.076***	-0.076***	-0.076***	-0.100***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Cyclicity (sin)	0.0001***	0.0001***	0.0001***	0.0001***	0.00003*
	(0.00002)	(0.00002)	(0.00001)	(0.00001)	(0.00001)
Cyclicity (cos)			0.00004***	0.00003***	-0.000004
			(0.00001)	(0.00001)	(0.00001)
Seasonality					
Summer	-0.005*	-0.005*			
	(0.002)	(0.002)			
January	0.070***	0.067***			
	(0.007)	(0.007)			
February	0.078***	0.076***			
	(0.007)	(0.007)			
March	0.062***	0.059***			
	(0.007)	(0.006)			
April	0.025***	0.022***			
	(0.004)	(0.004)			
May	0.006	0.006			
	(0.004)	(0.004)			
June	0.010***	0.010***			
	(0.003)	(0.003)			
July	-0.0004	-0.001			
	(0.003)	(0.003)			
September	0.029***	0.028***			
	(0.003)	(0.003)			
October	0.057***	0.055***			
	(0.004)	(0.004)			
November	0.060***	0.057***			
	(0.006)	(0.006)			
December	0.063***	0.060***			
	(0.007)	(0.007)			
Year 2010	-0.064***	-0.064***	-0.063***	-0.064***	-0.058***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
Year 2011	-0.069***	-0.069***	-0.064***	-0.066***	-0.052***

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Table 9 – *Continued from previous page*

Variable	Model 1 using C/H sq	Model 2 using new C/H	Model 3 using sin/cos	Model 4 using sin/cos	Model 5 using new C/H sq, sin, cos, no price
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
Year 2012	-0.054***	-0.054***	-0.049***	-0.051***	-0.051***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Year 2013	-0.045***	-0.046***	-0.040***	-0.042***	-0.053***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Year 2014	-0.057***	-0.057***	-0.051***	-0.052***	-0.069***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
Year 2015	-0.030***	-0.030***	-0.023***	-0.026***	-0.044***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Year 2016	-0.011***	-0.012***	-0.005	-0.008***	-0.032***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Hour 1	-0.034***	-0.033***	-0.034***	-0.034***	-0.040***
	(0.0004)	(0.0004)	(0.0004)	(0.001)	(0.0003)
Hour 2	-0.072***	-0.072***	-0.072***	-0.072***	-0.084***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hour 3	-0.092***	-0.092***	-0.092***	-0.093***	-0.108***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hour 4	-0.092***	-0.091***	-0.092***	-0.093***	-0.111***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hour 5	-0.079***	-0.079***	-0.080***	-0.081***	-0.098***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hour 6	-0.055***	-0.055***	-0.056***	-0.057***	-0.069***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hour 7	0.022***	0.022***	0.020***	0.020***	0.024***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hour 8	0.065***	0.065***	0.063***	0.064***	0.085***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Hour 9	0.103***	0.103***	0.102***	0.103***	0.133***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Hour 10	0.131***	0.131***	0.131***	0.133***	0.167***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Hour 11	-0.003***	-0.003***	-0.006***	-0.006***	-0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hour 12	0.003***	0.003***	0.001*	0.001**	0.004***
	(0.0005)	(0.0005)	(0.0004)	(0.001)	(0.001)
Hour 14	0.136***	0.136***	0.142***	0.144***	0.174***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Hour 15	0.124***	0.124***	0.131***	0.132***	0.159***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Hour 16	0.115***	0.115***	0.121***	0.122***	0.148***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Hour 17	0.115***	0.114***	0.121***	0.121***	0.148***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Hour 18	0.108***	0.108***	0.113***	0.113***	0.147***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Hour 19	0.102***	0.101***	0.106***	0.105***	0.144***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Hour 20	0.108***	0.107***	0.110***	0.110***	0.149***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Hour 21	0.110***	0.109***	0.111***	0.111***	0.144***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Hour 22	0.080***	0.080***	0.081***	0.081***	0.101***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hour 23	0.037***	0.037***	0.037***	0.037***	0.050***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.0003)
Observations	63,427	63,427	63,427	63,427	63,427
R^2	0.904	0.904	0.893	0.895	0.867
Adjusted R^2	0.904	0.903	0.893	0.894	0.867
Residual Std. Error	0.042	0.042	0.044	0.044	0.049
F Statistic	10,430***	10,790***	11,970***	12,210***	9,185***

Notes: The table presents the results of difference-in-differences regression of (2) with five different adjustments. In Model 1, instead of *Temperature* and its square we use *Cooling degrees*, defined as $max\{Temperature - 18°C, 0\}$, and *Heating degrees*, defined as $max\{18°C - Temperature, 0\}$, and their squared values to account for possible non-linearity in heating and cooling habits. In Model 2, we assume there is an interval in which heating and cooling does not consume electricity and redefine *Cooling degrees* as $max\{Temperature - 21°C, 0\}$, and *Heating degrees* as $max\{15°C - Temperature, 0\}$. In Model 3, we eliminate the annual seasonality variables and redefine the annual cycle using sine and cosine annual functional, and estimate the model with *Temperature* and *Temperature squared* variables. We do the same in Model 4 but include the original *Heating degrees* and *Cooling degrees.* In Model 5, we eliminate *Electricity price* variable from (2), and incorporate the assumptions of Model 1, Model 2, and Model 4 together. HAC-robust standard errors in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table 10: Studies estimating various impacts of the daylight saving time policy

Study	Effect	Notes
Incidence on economic activity		
Berument *et al.* (2010)	0% (no effect on returns or volatility)	DST does not affect stock market returns or volatility. Study examines weekend-effect market anomaly and is based on the equally weighted and value weighted daily indices of major United States stock markets (NYSE, S&P 500, AMEX, and NASDAQ) obtained from the Center for Research in Security Prices for the period of 1967 − 2007 on the first business day following DST changes.
Gregory-Allen *et al.* (2010)	0% (no effect on returns)	DST does not affect stock market returns. Study examines weekend-effect market anomaly and is based on the daily stock returns of value-weighted indices for 22 of the countries that made up the MSCI World Index acquired from the Global Financial Data on the days following a switch from or to DST.
Kamstra *et al.* (2000)	−200% to −500% (loss in returns)	DST-change weekends are followed by larger negative statistically significant returns in comparison to average negative Friday-to-Monday returns. Study examines weekend-effect market anomaly and is based on the equally weighted and value weighted daily indices of major United States (NYSE, S&P 500, AMEX, and NASDAQ), Canada (Toronto Stock Exchange), United Kingdom (total market return index), and Germany (DAX 100) stock markets observed individually for different periods between 1928 − 1998.
Lamb *et al.* (2004)	0% (no effect on returns)	DST does not affect stock market returns. Study examines weekend-effect market anomaly and is based on the equally weighted and value weighted daily indices of major United States stock markets (NYSE, S&P 500, AMEX, and NASDAQ) obtained from the Center for Research in Security Prices for the period of 1967 − 1997.
Muller *et al.* (2009)	0% (no effect on returns)	DST does not affect stock market returns. Study examines weekend-effect market anomaly and is based on ten daily indices from eight different European equity and bond markets acquired from the Thompson DataStream database for different periods between 1985 − 2007.
	−300% (loss in returns)	DST-change weekends are followed by large negative statistically significant returns for the period of 1980 − 1984.
Occurrence of traffic accidents		
Coren (1996)	+8% in the spring (increase in accidents); −8% in the fall (decrease in accidents)	Risk of traffic accidents increases after the spring shift and decreases after the autumn shift. Study is based on the traffic accidents rate using the total number (21,603) of all traffic accidents in Canada as reported to the Canadian Ministry of Transport for the years 1991 and 1992 by all provinces except Saskatchewan for the Monday around spring and fall time shifts.
Ellis *et al.* (2016)	−8% on weekdays (decrease in collisions) −11% at weekends (decrease in collisions)	DST decreases the frequency of wildlife-vehicle collisions. Study is based on the comparative index of collision risk taking into account the proportion of koala movement and hourly volume of vehicular traffic on three main arterial roads in southeast Queensland, Australia, during 2009 and 2010.
Lahti *et al.* (2010)	0% (no effect on accidents)	DST does not affect the traffic accidents rate. Study is based on the total number of all traffic accidents in Finland recorded by the Finnish Motor Insurers' Centre for one week before and one week after transitions into and out of DST during the 1981 − 2006 period.
Robb & Barnes (2018)	+16%Sun, +12%Mon in the spring (increase in accidents) 0% in the fall (no effect)	DST increases road accidents rate on Sunday and Monday after the spring time shift but has no effect in the fall. Study is based on the total number of all road accident claims in New Zealand reported to the Accident Compensation Corporation during 2005 − 2016.

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Table 10 – *Continued from previous page*

Study	Effect	Notes
Smith (2016)	+5% to +7% in the spring (increase in fatalities) 0% in the fall (no effect)	DST increases fatal traffic accidents rate after the spring time shift but has no effect in the fall. Study is based on the total number of fatal vehicle crashes in the United States (except for Arizona and Indiana which were not consistently observing DST) reported by the National Highway Traffic and Safety Administration for the years 2002 − 2011, excluding holidays with outlying risk.
Varughese & Allen (2001)	+7%Mon in the spring +10%Sun in the fall (increase in fatalities) 0% for the other days (no effect)	DST does affect fatal traffic accidents rate on Monday after the spring time change and Sunday after the autumn time change only. Study is based on the total number of fatal automobile accidents in the United States reported by the National Highway Traffic and Safety Administration for Saturday, Sunday, and Monday around the time shifts in 1975 − 1995.
Whittaker (1996)	spring: −6% in the morning −11% in the evening (decrease in accidents) fall: −6% in the morning +4% in the evening (decrease in accidents)	DST is associated with reductions in casualty numbers except for the effect of autumns' darker evenings associated with mainly vehicle and pedestrian accidents. Study is based on the total number (4,185) of all road traffic accident casualties in Cheshire, the United Kingdom as acquired from a database of the Cheshire Road Safety Unit for the period 1983 and 1993 in the morning (05.00−09.00) and in the evening (15.00−19.00), one week periods either side of the time change.
Occurrence of workplace injuries		
Barnes & Wagner (2009)	+6% injuries and +68% days off work in the spring (increase in injuries) 0% in the fall (no effect)	Workers sustain more workplace injuries and injuries of greater severity after the spring time change. Study is based on the total number of all mining injuries (576,292) and their severity (in terms of the total days work missed) in the United States reported to the National Institute for Occupational Safety and Health in the period 1983 − 2006.
Holland & Hinze (2000)	0% (no effect on injuries)	DST does not affect the frequency of construction injuries (on Mondays around the time shifts). Study is based on the total number of all injury claims of construction workers in the US state of Washington, acquired from the Department of Labor and Industries covering 1990 − 1996 period.
Robb & Barnes (2018)	0% (no effect on accidents)	Evidence of DST impact on work accidents, falls, and home accidents is limited. Study is based on the total number of accident claims related to work, falls, home accidents categories in New Zealand reported to the Accident Compensation Corporation during 2005 − 2016.
Effects on productivity		
Herber *et al.* (2017)	0% (no effect on cognition)	DST change has no effect on student performance. Study is based on the international student assessments data from the Trends in International Mathematics and Science Study and the Progress in International Reading Literacy Study on more than 22,000 students from six European countries during the 2011 spring transition.
Schaffner *et al.* (2018)	0% (no effect on cognition)	DST does not affect cognitive performance and risk aversion. Study is based on a quasi-experimental design (from 307 participants in wave 1 down to 138 participants in wave 3 completing Stroop Interference Tests and lottery tasks) and exploits the exogenous treatment of the New South Wales residents in comparison to the ones of Queensland, Australia, in 2013.
Wagner *et al.* (2012)	+3% (more cyberloafing)	DST affects cyberloafing behavior, workers search Internet more in comparison to the preceding Monday. Paper is based on a quasi-experiment which studies daily search volumes within the "entertainment" category. Authors use 3,492 measurement points acquired from the Google Insights for Search service and cover 203 United States metropolitan areas during the period of 2004 − 2009.
Effects related to crime fighting		

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Study	Effect	Notes
Cho *et al.* (2017)	+5% (longer imprisonments)	DST significantly prolongs the length of legal punishments. Study is based on the data on the length of imprisonment (4,037 observations) handed out in the United States federal courts acquired from the U.S. Sentencing Commission for the period 1992 – 2003, effect observed on Mondays around the spring time shift in comparison to other Mondays.
Doleac & Sanders (2015)	−7% in the spring (less robberies)	DST decreases the number of felony robberies following the spring time shift. Study is based on the crime incidence data in the United States from the National Incident-Based Reporting System and covers years of 2005 – 2008.
Umbach *et al.* (2017)	−3% in the spring (decrease in assaults) +3% in the fall (increase in assaults)	DST is associated with decrease in aggressive assault rates on Mondays around the spring time shift and increase on Mondays around the autumn shift. Study is based on the daily data (122,879 observations) gathered from the National Incidence Based Reporting System and city-reported data from Chicago, New York, Philadelphia, and Los Angeles for the period of 2001 – 2014.
Wagner *et al.* (2016)	LADP: 0% (no harassment effect) but +6% of Black suspects harassed and −11% of White suspects harassed FBI: 0% (no harassment effect) but +9% of Black suspects harassed and −3% of White suspects harassed	The harassment rate, i.e. the incidence of policemen arresting an individual that does not merit arrest, does not change due to DST. Nevertheless, police officers are more prone to exhibit racial bias in their harassment of suspects due to the DST change. Study is based on the data gathered from the Los Angeles Police Department (799,814 observations) and the Federal Bureau of Investigation (61.6 mil. observations) for the years 2003 – 2004 and 1991 – 2011, respectively. The effect is observed on Mondays around the spring time shifts.
Health issues due to time change		
Goodman *et al.* (2014)		child physical activity
Janszky *et al.* (2012)		heart infarction
Kantermann *et al.* (2007)		human biorhythm
Kuehnle & Wunder (2016)		life satisfaction
Medina *et al.* (2015)		sleepiness
Olders (2003)		depression
Shapiro *et al.* (1990)		psychiatric illness
Wolff & Makino (2012)		healthier lifestyle

Notes: The table presents different studies of impacts of the daylight saving time policy other than those enery-related.