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Abstract

This paper looks at the potential systematic variation in energy savings resulting from daylight saving time (DST) in a number of geographic areas varying in latitude ranging from Northern to Southern Europe. We are using the same econometric specification and estimation method for a consistent data set of electricity load covering 35 countries in Europe. Thus our results provide a comprehensive set of consistent and comparable estimates of the DST effect. The average treatment effect results obtained from difference-in-difference regression for 46 electricity load zones ranges from zero in northern most parts of Norway and Sweden to more than 2.5 % in a number of locations. We find some evidence that energy savings from DST decreases with latitude, and especially for homogeneous groups of country. The diversity in estimated effects cuts across geographical, cultural and economic factors.

Keywords: daylight savings time, electricity consumption, difference-in-difference

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1. Introduction

Daylight saving time (DST) is a policy tool widely implemented across the globe as a measure to conserve energy. Historically, humans have used sunlight as a means to organize their routine activities. However, due to innovations and technical advancement, daily routine activities are now following clock time, rather than the natural daylight cycle of the sun. The change in human lifestyle has resulted in deviation in routine activities from following the sun and an increase in usage of artificial lightening resulting in increased electricity consumption (Kellogg and Wolff, 2008).

As a mean to align the daily routine with naturally occurring daylight, governments around the globe intervene through daylight saving time policy to alter the standard time, known as daylight saving time or summer time, by regular advancement of standard time by one hour in spring and back to standard time in autumn. The objective of this clock time change is to better align the human routines with the natural light cycle. This change in the standard clock time provides an extra hour of daylight in the afternoon that can reduce, among other things, the artificial lighting loads (Mirza and Bergland, 2011). Therefore, the entire mechanism of DST relies on day length and it is directly connected to timing of people's sleeping and wake up times.

It is important to note that estimated, or calculated, impacts of DST depends on the amount of sunlight (day length) available at different geographical locations. This variation in day length is due to the geographical setting of the Earth and depends on latitude and longitude of the location. This cross country and over time variation in day length have lead to the formation of different time zones and adjustment of the clocks to utilize longer day length in the summer to conserve electricity and for other social and economic reasons.

Although the issues of high prices of primary energy resources, climate change, energy security, energy poverty and depletion of non-renewable energy sources have put the daylight saving time policy under the spotlight, the debate about its exact impacts on energy consumption is still open. The literature provides mixed evidence whether the DST policy reduces energy consumption, remains neutral or increases consumption.

The estimates on the impact assessment parameter of a DST policy vary to a great extent across countries (Aries and Newsham, 2008; Havranek et al., 2017). This ambiguity in results may be attributed to variation in geographical attributes and economic and cultural factors. These factors are seldom included in the analysis as most studies are limited to a single specific country. Traditionally, the focus has been to extensively employ various seasonal factors to explain electricity conservation due to DST in single country case studies (Table 1).

Weinhardt (2013) analyzed the effect of timing of daylight on electricity consumption in the US using aggregated annual data with a high geographical resolution. On average, the energy savings from a DST policy is lower in the northern parts of the US compared to the southern parts.

A recently conducted meta-analysis by Havranek et al. (2017) of 44 studies concluded that DST has reduced electricity consumption on average with 0.34 percent. Additionally, their analysis pointed out that the latitude of the country in question is one of the most important factors explaining the heterogeneity of the results in the literature. Their conclusion, based on studies

Table 1: Overview of the existing literature on energy savings from daylight saving time.

Study	Variables	Region	Method
Studies finding reduced electricity consumption			
Rivers (2017)	Hourly electricity loads, temperature, seasonal factors	Canada	regression discontinuity design
Verdejo et al. (2016)	Hourly electricity loads, temperature, day length	Chile	heuristic approach, difference-in-difference
Sangupta and Ahuja (2012)	Hourly electricity loads, luminance index, temperature, day length	India	simulation models
Momani et al. (2009)	Hourly electricity loads, seasonal variables, lightening data in residential and commercial sector	Jordan	graphical analysis
Mirza and Bergland (2011)	Hourly electricity loads, temperature, day length, electricity prices	Norway, Sweden	natural experiment, difference-in-difference
Aries and Newsham (2008)	Hourly electricity loads, seasonal factors	existing literature	literature review
Hill et al. (2010)	Electricity loads, seasonal factors, house design, lightening information, environmental factors	United Kingdom	engineering model
Karasu (2010)	Hourly electricity loads, season factors	Turkey	simulation model
Fong et al. (2007)	Hourly electricity loads, household lightening	Japan	simulation model
Bouillon (1983)	Electricity loads	Europe	simulation model
U.S. Department of Transportation (1975)	Electricity loads	USA	survey analysis
California Energy Commision (2001)	Electricity loads, seasonal factors	USA	simulation model
Her Majesty's Stationary Office (1970)	Electricity loads	United Kingdom	graphical analysis
Studies finding no or little change in electricity consumption			
Choi et al. (2017)	Half-hourly electricity loads, temperature, seasonal variables, day length, wind	Australia	natural experiment
Studies finding increased electricity consumption			
Kellogg and Wolff (2008)	Half-hourly electricity loads, seasonal variables, day length, sunshine	Australia	natural experiment
Rock (1997)	Electricity loads, seasonal factors, house design	USA	engineering model
Shimoda et al. (2007)	Electricity loads, temperature, cooling information, solar radiation, building information		natural experiment, difference-in-difference
Kotchen and Grant (2011)	Electricity loads, billing data, seasonal factors, heating and cooling information	Indiana, USA	natural experiment

from both the subtropical and the temperate climate zones, is that locations further away from equator experiences greater energy savings.

This paper looks at the potential systematic variation in electric energy savings resulting from DST in a number of geographic areas varying in latitude ranging from Northern to Southern Europe. Using a consistent set of data on 46 electricity load zones in 35 European countries, models and estimation technique, we investigate if latitude has a systematic impact on the potential energy savings from a DST policy.

Our study contributes to the existing literature in a number of ways. To the best of our knowledge, this is the only study based on primary data that has estimated and compared the energy conservation on account of DST across countries. Moreover, by exploiting our long time series data on temperature and electricity consumption, we are able to directly assess the impact of latitude on electricity consumption, which is an addition to the literature on daylight savings time and energy savings.

The rest of the paper is organized as follows. Section 2 of the paper presents methods and data to be used in the empirical analysis. Section 3 presents the estimation results whereas section 4 concludes the paper.

2. Material and Methods

2.1. Identification Strategy

The aforementioned literature has extensively employed natural experiments to estimate electricity conservation corresponding to DST implementation (California Energy Commision, 2001; Fong et al., 2007; Rock, 1997; Mirza and Bergland, 2011; Choi et al., 2017). These studies used difference-in-differences (DID) regression analysis for the impact assessment purposes. But the non-availability of control periods due to regular implementation of DST has compelled a few existing studies to use electricity demand in winter as a control group to compare it with a treatment period in which the DST is implemented (California Energy Commision, 2001). However, policy evaluation based on such type of analysis requires a symmetric seasonal condition for control and treatment periods to obtain robust estimates (Kellogg and Wolff, 2008). This ambiguity in the identification of control periods using such identification strategy invokes potential bias in point estimates of DID regression as electricity demand itself decreases as temperature decreases in the fall. Furthermore, as stated in previous section, the geographical attributes and cross-country analysis of DST estimates is entirely missing in the existing literature.

This study uses a two-pronged method to assess the impact of latitude on the electricity conservation on account of DST. In first stage, electricity conservation due to DST has been estimated by DID regression analysis for 35 European countries respectively. The identification of control period has been done by using the ”equivalent day normalization technique” proposed by Mirza and Bergland (2011). Equivalent day normalization technique exploits the fact that the electricity consumption during the mid-day and middle of the night hours remains unaffected to clock time adjustments. Hence, these hours can be used as a control period for estimating the impact of DST on electricity consumption without getting into any seasonal bias (Mirza and Bergland, 2011). This approach partitions the 24 hours of the day into DST and non-DST hours. DST hours include morning and evening hours, whereas non-DST hours consists of midday and midnight hours (Mirza and Bergland, 2011). The difference between these two groups can be attributed to DST policy under the assumption that other factors remain constant.

The second stage of the method explores the relationship between the DST impact assessment parameter for different countries with the latitudes of these countries in order to establish any insight about the geographical attributes of countries as a means to explain cross country differences in the point estimates of DST.

2.2. Difference-in-Difference Treatment Effect Model

To estimate the treatment effect of DST policy on energy conservation, we make use of the standard difference-in-differences average treatment effects regression model for carrying out the analysis (Wooldridge, 2010). The following three empirical specifications were utilized in the estimation of the models and serves a check for the robustness of the impact assessment parameter:

$$\begin{aligned}\ln C_t = \alpha_0 &+ \gamma_1 \mathrm{EQH}_t + \gamma_2 \mathrm{DST}_t + \gamma_3 (\mathrm{EQH}_t \mathrm{DST}_t) + \\ &\delta_1 \mathrm{DL}_t + \delta_2 \ln \mathrm{HD}_t + \delta_3 \ln \mathrm{CD}_t + \\ &\beta_1 \ln \mathrm{Oil}_t + \beta_2 \mathrm{D}_t^{xmas} + \beta_3 \mathrm{D}_t^{east} + \beta_4 \mathrm{D}_t^{fmay} + \beta_5 \mathrm{D}_t^{msum} + \\ &\sum_i \beta_i^Y \mathrm{Y}_t^i + \sum_i \beta_i^H \mathrm{H}_t^i + \eta_1 \mathrm{tsin}_t + \eta_2 \mathrm{tcos}_t + \varepsilon_t\end{aligned} \tag{1}$$

$$\begin{aligned}\ln C_t = \alpha_0 &+ \gamma_1 \mathrm{EQH}_t + \gamma_2 \mathrm{DST}_t + \gamma_3 (\mathrm{EQH}_t \mathrm{DST}_t) + \\ &\delta_1 \mathrm{DL}_t + \delta_2 \ln \mathrm{HD}_t + \delta_3 \ln \mathrm{CD}_t + \delta_4 \ln \mathrm{HD}_{t-1} + \delta_5 \ln \mathrm{CD}_{t-1} + \\ &\beta_1 \ln \mathrm{Oil}_t + \beta_2 \mathrm{D}_t^{xmas} + \beta_3 \mathrm{D}_t^{east} + \beta_4 \mathrm{D}_t^{fmay} + \beta_5 \mathrm{D}_t^{msum} + \\ &\sum_i \beta_i^Y \mathrm{Y}_t^i + \sum_i \beta_i^H \mathrm{H}_t^i + \eta_1 \mathrm{tsin}_t + \eta_2 \mathrm{tcos}_t + \varepsilon_t\end{aligned} \tag{2}$$

$$\begin{aligned}\ln C_t = \alpha_0 &+ \gamma_1 \mathrm{EQH}_t + \gamma_2 \mathrm{DST}_t + \gamma_3 (\mathrm{EQH}_t \mathrm{DST}_t) + \\ &\delta_1 \mathrm{DL}_t + \delta_2 \ln \mathrm{HD}_t + \delta_3 \ln \mathrm{CD}_t + \delta_4 \ln \mathrm{HD}_{t-1} + \delta_5 \ln \mathrm{CD}_{t-1} + \\ &\beta_1 \ln \mathrm{Oil}_t + \beta_2 \mathrm{D}_t^{xmas} + \beta_3 \mathrm{D}_t^{east} + \beta_4 \mathrm{D}_t^{fmay} + \beta_5 \mathrm{D}_t^{msum} + \\ &\sum_i \beta_i^Y \mathrm{Y}_t^i + \sum_i \beta_i^H \mathrm{H}_t^i + \sum_i \beta_i^W \mathrm{W}_t^i + \varepsilon_t\end{aligned} \tag{3}$$

where t is an index for the sequential hours across the sample for each location. The variables are defined in Table 2, and all parameters to be estimated are denoted with Greek letters.

The dependent variable is the logarithm of electricity load in an hour t. The parameter γ_3 is an estimate of the effect of DST time change on electricity load, and can be interpreted in percentage terms. The effect of temperature is captured by using heating degrees, i.e. the number of degrees below 18 C, and cooling degrees, i.e. the number of degrees above 18 C.

The sample period include the financial crisis as well as periods with population and demographic changes and increased emphasize on energy efficiency and savings. Any resulting long-term trends in electricity consumption are included through the use of year specific dummy variables ($\mathtt{Y}_t^i$). The seasonal cycle in electricity consumption is captured with trigonometric functions ($\mathtt{tsin}_t$ and $\mathtt{tcos}_t$) in two of the specifications, and with a series of dummy variables ($\mathtt{W}_t^i$) for each week of the year in the third model (Al-Zayer and Al-Ibrahim, 1996; Mirza and Bergland, 2011). Use of trigonometric functions is a parsimonious specification for capturing a single peaked annual cycle in consumption. The non-parametric specification in model 3 allows for

Table 2: Definition and symbol for the variables used in the models.

Name	Description
C_t	electricity load in hour *t*
DST_t	dummy variable for DST in effect for hour *t*
EQH_t	dummy variable for control period for hour *t*
DL_t	fraction of an hour with sunlight
HD_t	heating degrees
CD_t	cooling degrees
Oil_t	Brent oil spot price (EUR)
D_t^{xmas}	dummy variable for Christmas/New Year
D_t^{east}	dummy variable for Easter
D_t^{fmay}	dummy variable for May First
D_t^{msum}	dummy variable for midsummer
H_t^i	dummy variable for hour *i* of the week
W_t^i	dummy variable for week *i* of the year
Y_t^i	dummy variable for year *i*
tsin_t	annual sine function
tsin_t	annual cosine function

multiple peaks and/or asymmetric cycles. The cyclic weekly and daily patterns are modeled with dummy variables ($\mathtt{H}_t^i$) for each hour of the week. Daylight is measured as the fraction of a given hour the sun is above the horizon (Johnsen, 2001; Ericson, 2009). Important holidays that may influence the electricity consumption are included as well, see Table 2.

All three models are estimated with ordinary least squares (OLS) using version 14.2 of STATA. The standard errors for the parameters are calculated as heteroskedasticity and autocorrelation consistent standard errors with a lag of 24 observations (hours) (Verbeek, 2012).

2.3. Instrumental Variables Specification

Electricity load in a country/load zone depends on local weather conditions such as temperature. At an aggregate level the model specifications include heating and cooling degrees based upon a single temperature variable. It possible to use temperature data from a single location, data from multiple locations or a weighted average based on multiple locations. An alternative is to regard temperature series from a specific location as an indicator of the underlying unobserved aggregate temperature variable. Additional temperature series can then be included in the model as instrumental variables (Wooldridge, 2010) for the temperature variable already in the model and parameters estimated using a two-stage least squares or instrumental variable (IV) estimator.

2.4. Data Sources

Our primary source for electricity consumption in individual countries is the ENTSO-E Data Transparency Platform[1] that provide access to key electricity market data for all members of

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[1] See `https://www.entsoe.eu/`.

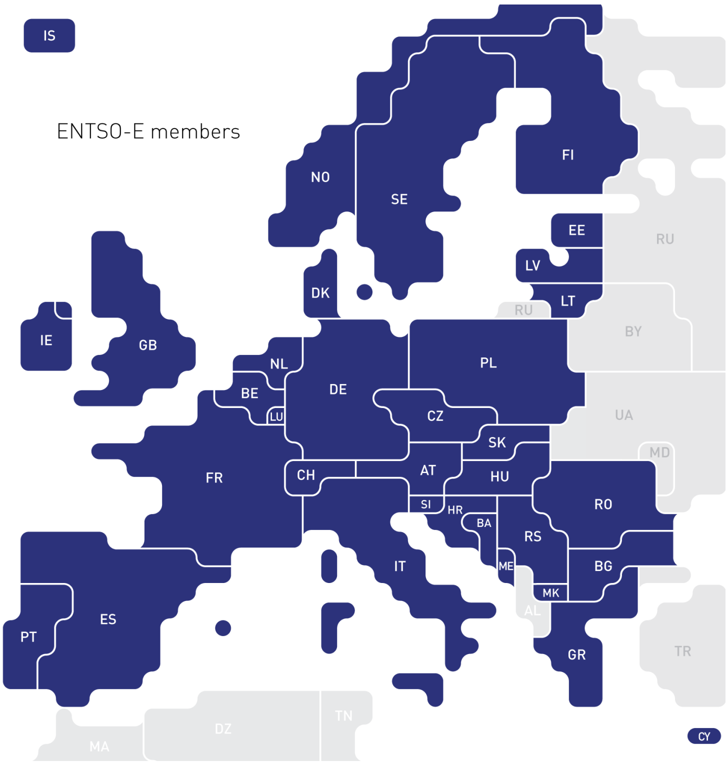

Figure 1: Map of the ENTSO-E countries and their country codes. Source: ENTSO-E.

ENTSO-E (European Network of Transmission System Operators for Electricity). Figure 1 shows the ENTSO-E countries. In addition to these members the ENTSO-E platform also provide data for the western parts of Ukraine.[2]

Several countries have divided their electricity markets into multiple bidding zones as a means to manage internal bottlenecks in their transmission grids, i.e. Italy, Norway and Sweden. Electricity load data for Italy were obtained from the Italian network operator Terna.[3] Load data for the Nordic and Baltic countries were obtained from Nord Pool.[4] The bidding zones in Norway are dynamic zones that are changed by the transmission system operator as part of the management of transmission bottlenecks. We have constructed three load zones for Norway based on exact geographical expanse such that the load data obtained from Nord-Pool is comparable for the entire time period used in the analysis.

Altogether there are 46 different price bidding zones with load data in our database. The time period covered by load data goes from 2004 up to early 2017. However, the exact start date for the data series differs between the different countries. The ENTSO-E data ends in 2016 for most

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[2] Iceland is excluded from our analysis as they do not practice DST. Data for Albania and Turkey have recently been added to the database, however the period covered is too short for a meaningful analysis at this time.

[3] See `http://www.terna.it/`.

[4] See `http://npspot.com/`.

Table 3: Countries and price/load zones. Each zone is associated with an airport weather station identified by its ICAO code. Latitude refers to the airport. The time period covered by the data for each zone and the total number of observations. Load refers to the average annual load (TWh) in a zone.

Country	Zone	ICAO	Latitude	Start Date	End Date	Observations	Load
Austria	AT	LOWW	48.10	01.01.2011	30.12.2016	52 584	69.2
Belgium	BE	EBBR	50.90	01.01.2007	31.12.2016	87 672	86.4
Bosnia-Hercegovina	BA	LQSA	43.82	01.01.2007	31.12.2016	87 672	12.1
Bulgaria	BG	LBSF	42.68	01.01.2007	31.12.2016	87 672	37.3
Croatia	HR	LDZA	45.73	01.01.2007	30.12.2016	87 648	17.4
Cyprus	CY	LCLK	34.87	01.01.2013	30.12.2016	35 040	4.4
Czech Republic	CZ	LKPR	50.10	01.01.2007	31.12.2016	87 672	63.3
Denmark	DK1	EKBI	55.73	05.01.2005	08.01.2017	105 288	20.5
Denmark	DK2	EKCH	55.62	05.01.2005	08.01.2017	105 288	13.9
Estonia	EE	EETN	59.40	01.02.2012	31.01.2017	43 848	8.0
Finland	FI	EFHK	60.32	05.01.2006	08.01.2017	96 528	83.9
France	FR	LFPO	48.72	01.01.2007	30.12.2016	87 648	484.2
Germany	DE	EDDF	50.03	01.01.2007	31.12.2016	87 672	487.6
Great Britain	GB	EGLL	51.47	01.02.2010	31.12.2015	51 840	301.2
Greece	GR	LGAV	37.93	01.01.2007	31.12.2014	70 128	51.2
Hungary	HU	LHBP	47.43	01.01.2007	31.12.2016	87 672	40.7
Ireland	IE	EIDW	53.42	01.01.2008	30.12.2016	78 888	26.4
Italy	NORD	LIMC	45.62	01.01.2012	31.12.2016	43 848	160.3
Italy	CNOR	LIRQ	43.80	01.01.2012	31.12.2016	43 848	31.2
Italy	CSUD	LIRF	41.80	01.01.2012	31.12.2016	43 848	46.2
Italy	SUD	LIRN	40.88	01.01.2012	31.12.2016	43 848	24.6
Italy	SARD	LIEA	40.62	01.01.2013	31.12.2016	35 064	8.5
Italy	SICI	LICJ	38.17	01.01.2012	31.12.2016	43 848	18.1
Latvia	LV	EVRA	56.92	01.01.2014	31.12.2016	26 304	7.1
Lithuania	LT	EYVI	54.63	01.01.2013	31.12.2016	35 064	9.8
Luxembourg	LU	ELLX	49.62	01.01.2007	30.12.2016	87 648	6.4
Macedonia	MK	LWSK	41.95	01.01.2007	30.12.2016	87 648	8.2
Montenegro	ME	LYPG	42.35	01.01.2010	30.12.2016	61 344	3.6
The Netherlands	NL	EHAM	52.30	01.01.2007	30.12.2016	87 648	111.1
Northern Ireland	NI	EGAA	54.65	01.01.2008	31.12.2015	70 128	9.0
Norway	NOM	ENVA	63.45	08.03.2010	06.03.2016	52 584	21.4
Norway	NON	ENBO	67.27	08.02.2010	05.02.2017	61 320	18.4
Norway	NOS	ENGM	60.20	07.03.2005	06.03.2016	96 432	87.8
Poland	PL	EPWA	52.15	01.01.2007	31.12.2015	78 888	144.2
Portugal	PT	LPPT	38.77	01.01.2007	31.12.2016	87 672	49.8
Romania	RO	LROP	44.57	01.01.2007	31.12.2016	87 672	52.7
Serbia	RS	LYBE	44.82	01.01.2008	31.12.2016	78 912	39.5
Slovakia	SK	LZIB	48.17	01.01.2007	31.12.2016	87 672	28.1
Slovenia	SI	LJLJ	46.22	01.01.2007	30.12.2016	87 648	12.8
Spain	ES	LEMD	40.47	01.01.2007	31.12.2016	87 672	253.0
Sweden	SE1	ESPA	65.53	01.02.2013	31.01.2017	35 064	9.5
Sweden	SE2	ESNU	63.78	01.01.2012	31.12.2016	43 848	16.1
Sweden	SE3	ESSA	59.65	01.01.2012	31.12.2016	43 848	86.5
Sweden	SE4	ESMS	55.52	01.01.2012	31.12.2016	43 848	24.3
Switzerland	CH	LSZH	47.45	01.01.2011	31.12.2014	35 064	47.6
Ukraine	UA	UKBB	50.33	01.01.2011	31.12.2015	43 824	5.7
Sweden	SE	ESSA	59.65	02.02.2004	05.02.2017	114 072	140.9

countries.[5] Table 3 gives details about the sample period for each location. Sweden was divided into four different bidding zones in November of 2011. In our analysis we have included these four bidding zones. Furthermore, we estimated our models using the total electricity load for Sweden with data starting in 2005.

Temperature data has been obtained from Weather Underground.[6] This website contains primary data recorded automatically at airports around the world. Table 3 shows the ICAO code[7] and latitude for the airport assigned to each country and bidding zone. Temperature may have been recorded multiple times for each hour, and for some of the (smaller) airports there may not have been a single recording in a given hour. There may also have been occasional equipment failures for a few hours. We have averaged and interpolated temperature data to make a complete series of hourly temperature measures for each country and location. The quality of the data is rather poor and spotty before 2005 and even as late as 2010 for some weather stations. Some of the load data series have been shortened due to lack of reliable weather data.

The daily Brent oil spot prices are collected from the U.S. Energy Information Agency[8] and linearly interpolated between trading days to create a complete series of daily prices. Sunset and sunrise times were calculated based on the latitude and longitude of the ICAO locations using the routines provided in the PHP language (Lerdorf and Tatroe, 2002).

3. Results

A summary of the ordinary least squares estimates of the DST effect for all three model specifications are presented in Table 4.[9] The estimated parameter for Sweden show a reduction of about 1.4 percent for specifications 1 and 2 and of about 1.3 percent for specification 3. The estimated impact here is the same as the estimate of 1.3 percent reported in Mirza and Bergland (2011) who were using a shorter time period and a slightly different model specification.

The estimated parameters from all three specifications confirm that DST reduces electricity consumption and are statistically significant at the conventional 5 percent confidence level for most locations. Two notable exceptions are the northern most locations in Norway (NON) and Sweden (SE1). The estimated parameters are right above (NON) and right below (SE1) zero, however, only with model specification 2 is the increase in energy load in NON statistically significant. These two areas spans the artic circle and experience periods with midnight sun.

The three model specifications differ with respect to inclusion of lagged temperature variables and in the specification of the seasonal patterns. Model specifications 1 and 2 use a smooth trigonometric function to model any seasonal patterns not captured by temperature and day length. Specification 3 uses a non-parametric approach where weekly dummy variables may better capture multiple peaks and shorter seasonal patterns such as summer holidays and tourism. For the majority of the locations the estimated daylight savings effect is quit similar across all

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[5] Load data through the year 2015 are available from the old ENTSO-E Data Transparency Platform. See `https://transparency.entsoe.eu/`. Load data starting from January 2016 are available in a new version of the ENTSO-E Data Transparency Platform. See `https://www.entsoe.eu/data/statistics/Pages/monthly_hourly_load.aspx`.

[6] See `https://www.wunderground.com/`.

[7] The International Civil Aviation Organization assigns unique codes to civilian airports. See `https://www.icao.int/Pages/default.aspx` and `https://en.wikipedia.org/wiki/International_Civil_Aviation_Organization_airport_code`.

[8] See `https://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.html`.

[9] Detailed results can be provided upon request.

Table 4: Estimated overall DST effect (γ_3) for all three model specifications with heteroskedasticity auto-correlation consistent standard errors.

		Model 1		Model 2		Model 3	
Country	Zone	Effect	Std Err	Effect	Std Err	Effect	Std Err
Austria	AT	-1.03	0.08	-1.07	0.08	-1.20	0.07
Belgium	BE	-0.17	0.05	-0.13	0.06	-0.14	0.05
Bosnia-Herzegovina	BA	-0.92	0.06	-1.13	0.06	-1.21	0.06
Bulgaria	BG	-1.26	0.08	-1.64	0.09	-1.74	0.08
Croatia	HR	-2.00	0.07	-2.24	0.07	-2.52	0.06
Cyprus	CY	-1.06	0.25	-0.91	0.24	-3.13	0.19
Czech Republic	CZ	-1.00	0.06	-1.00	0.06	-0.86	0.05
Denmark	DK1	-1.69	0.06	-1.72	0.06	-1.54	0.05
Denmark	DK2	-1.49	0.06	-1.45	0.06	-1.54	0.06
Estonia	EE	-2.53	0.09	-2.52	0.09	-2.51	0.08
Finland	FI	-1.52	0.05	-1.49	0.05	-1.54	0.04
France	FR	-2.28	0.06	-2.35	0.06	-2.55	0.06
Germany	DE	-0.88	0.06	-0.75	0.06	-0.67	0.06
Great Britain	GB	-1.04	0.08	-0.98	0.09	-0.91	0.08
Greece	GR	-1.15	0.16	-1.13	0.15	-2.64	0.14
Hungary	HU	-1.06	0.06	-1.15	0.06	-1.19	0.05
Ireland	IE	-0.54	0.09	-0.44	0.09	-0.43	0.09
Italy	NORD	-1.49	0.13	-1.58	0.13	-1.15	0.11
Italy	CNOR	-1.33	0.17	-1.35	0.17	-1.50	0.16
Italy	CSUD	-1.14	0.14	-1.34	0.14	-1.96	0.13
Italy	SUD	-1.21	0.20	-1.05	0.19	-2.13	0.19
Italy	SARD	-1.09	0.16	-1.15	0.16	-2.12	0.15
Italy	SICI	-2.09	0.18	-2.09	0.18	-2.86	0.17
Latvia	LV	-2.41	0.10	-2.46	0.10	-2.45	0.10
Lithuania	LT	-0.97	0.09	-1.06	0.09	-1.14	0.09
Luxembourg	LU	-0.33	0.12	-0.32	0.12	-0.15	0.11
Macedonia	MK	-0.17	0.09	-0.31	0.09	-0.58	0.09
Montenegro	ME	0.38	0.12	0.11	0.11	-1.00	0.09
The Netherlands	NL	-0.91	0.06	-0.95	0.06	-0.91	0.06
Northern Ireland	NI	-2.90	0.08	-2.74	0.08	-2.66	0.07
Norway	NON	0.12	0.07	0.15	0.07	0.12	0.07
Norway	NOM	-1.22	0.08	-1.20	0.08	-1.21	0.07
Norway	NOS	-1.13	0.05	-1.08	0.05	-1.05	0.05
Poland	PL	-0.61	0.05	-0.63	0.05	-0.65	0.05
Portugal	PT	-0.58	0.07	-0.57	0.07	-0.62	0.07
Romania	RO	-1.55	0.06	-1.65	0.06	-1.71	0.06
Serbia	RS	-0.20	0.07	-0.35	0.07	-0.49	0.06
Slovakia	SK	-0.92	0.05	-0.99	0.05	-1.08	0.04
Slovenia	SI	-0.59	0.08	-0.77	0.08	-1.03	0.08
Spain	ES	-0.84	0.08	-1.05	0.08	-1.25	0.08
Sweden	SE1	-0.16	0.20	-0.12	0.20	-0.20	0.20
Sweden	SE2	-0.37	0.16	-0.36	0.16	-0.37	0.16
Sweden	SE3	-1.43	0.09	-1.41	0.09	-1.31	0.09
Sweden	SE4	-1.33	0.11	-1.30	0.11	-1.36	0.11
Switzerland	CH	-2.46	0.12	-2.51	0.12	-2.37	0.11
Ukraine	UA	-2.22	0.12	-2.30	0.12	-2.43	0.11
Sweden	SE	-1.43	0.05	-1.42	0.05	-1.34	0.05

Table 5: Estimated overall DST effect (γ_3) in model specification 3 using ordinary least squares (OLS) and instrumental variables (IV) methods with heteroskedasticity auto-correlation consistent standard errors.

	Load	ICAO			OLS Estimates		IV Estimates	
Country	Zone	Main	Alt 1	Alt 2	Effect	StdErr	Effect	StdErr
Denmark	DK1	EKBI	EKAH	EKYT	-1.54	0.05	-1.66	0.06
Denmark	DK2	EKCH	EKRK	ESMS	-1.54	0.06	-1.48	0.06
Estonia	EE	EETN	EFHK	.	-2.51	0.08	-2.48	0.08
Finland	FI	EFHK	EFJY	EFVA	-1.54	0.04	-1.58	0.04
France	FR	LFPO	LFBO	LFLL	-2.55	0.06	-2.99	0.10
Germany	DE	EDDF	EDDT	EDDM	-0.67	0.06	-0.27	0.07
Great Britain	GB	EGLL	EGCC	.	-0.91	0.08	-0.70	0.10
Greece	GR	LGAV	LGTS	.	-2.64	0.14	-2.48	0.16
Italy	NORD	LIMC	LIMF	LIPE	-1.15	0.11	-1.19	0.12
Italy	CNOR	LIRQ	LIPY	LIPE	-1.50	0.16	-1.20	0.17
Italy	CSUD	LIRF	LIRA	LIBP	-1.96	0.13	-1.90	0.15
Italy	SUD	LIBD	LIRN	.	-2.13	0.19	-1.83	0.20
Italy	SARD	LIEE	LIEA	.	-2.12	0.15	-1.73	0.16
Italy	SICI	LICC	LICJ	.	-2.86	0.17	-2.79	0.17
Lithuania	LT	EYVI	EYSA	.	-1.14	0.09	-1.34	0.09
The Netherlands	NL	EHAM	EHEH	EHRD	-0.91	0.06	-0.97	0.06
Norway	NON	ENBO	ENTC	ENHF	0.12	0.07	0.08	0.09
Norway	NOM	ENVA	ENOL	ENKB	-1.21	0.07	-1.22	0.08
Norway	NOS	ENGM	ENZV	.	-1.05	0.05	-1.70	0.08
Poland	PL	EPWA	EPKK	EPGD	-0.65	0.05	-0.62	0.05
Portugal	PT	LPPT	LPPR	LPFR	-0.62	0.07	-0.58	0.41
Spain	ES	LEMD	LEBL	LEZL	-1.25	0.08	-0.60	0.09
Sweden	SE1	ESPA	ESNQ	ESNO	-0.20	0.20	-0.26	0.20
Sweden	SE2	ESNU	ESNN	ESNZ	-0.37	0.16	-0.40	0.16
Sweden	SE3	ESSA	ESGG	ESSD	-1.31	0.09	-1.43	0.09
Sweden	SE4	ESMS	ESMQ	ESMX	-1.36	0.11	-1.40	0.11
Switzerland	CH	LSZH	LSGG	.	-2.37	0.11	-2.32	0.11

three specifications and with smaller standard errors in the third specification. However, for the Mediterranean locations Cyprus, Greece, Sardinia, Sicily and the two southern Italian zones (CSUD and SUD) there are substantial differences between the three models. Estimates based on model specifications 1 and 2 show modest DST effects at a little more than one percent, except for Sicily with 2.1 %, while the DST effect increased two to three percent with model specification 3. This difference is most likely related a seasonal pattern in load at these locations that shows more of a double peaked pattern which is poorly captured by the trigonometric seasonality function used in the first two specifications.

The DST effect for Luxembourg is statistically significant in model specifications 1 and 2, but drops to -0.15% in specification 3 with a robust standard error of 0.11. The DST effect for Luxembourg is quit close to the estimated effect in the neighbouring country Belgium,.

The estimated DST for Montenegro is +0.38% (standard error 0.12) in specification 1, it is +0.11% in specification 2 and -1.0% in specification 3. The load pattern in Montenegro has both a winter and summer peak, making model specification 3 the preferred specification.

Instrumental variable estimation results for model specification 3 for a subset of the countries are shown in Table 5 along with the OLS estimates. The instrumental variable estimates are based upon temperature series from one or two additional airports identified by their ICAO codes. The choice of additional airport locations and temperature series were to a large extent determined by the availability of reliable temperature series in different parts of the country. A comparison of OLS and IV parameters shows a close agreement of parameters for many locations, but with several notable exceptions. The estimated DST parameter was reduced for Germany and Spain, two geographically extensive countries, while there was an increase for France. The DST parameter also increased in magnitude for Southern Norway (NOS) which is a climatic diverse area. Furthermore, estimated DST effects for the southern Italian locations are also smaller with instrumental variables.

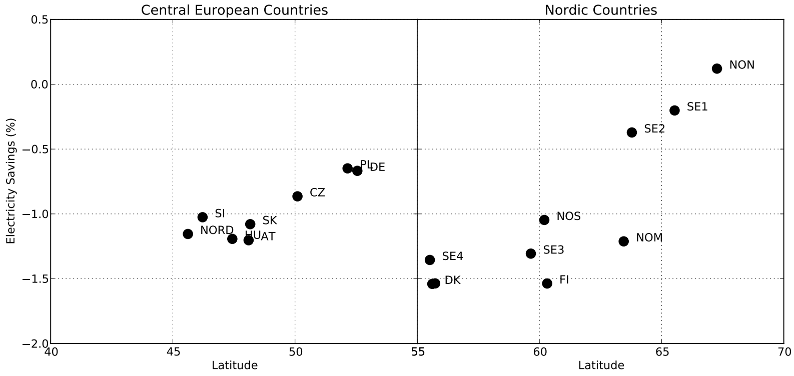

Figure 2: Estimated effects of DST policy and latitude for Nordic and Central European countries.

In order to assess any linkages between latitude and DST savings Figure 2 plots DST savings against latitude for two country groups. The left most panel coverin the Nordic countries show a clear latitudinal pattern from no effect of DST in the two most northern locations to an effect around -1.5 % at the southern most locations. The right most panel refers to Central European countries, i.e. Poland, Germany, Czech Republic, Slovakia, Austria, Hungary, Slovenia and Northern Italy). Increasing latitude is again associated with a decrease in electricity savings. However, the change in electricity savings with latitude is not as strong for this group of countries as for the Nordic countries. Furthermore, the “trend” lines for these two groups do not match.

Figure 3 shows the DST estimates for Italy and Greece for model specifications 2 and 3 (OLS) and instrumental variables model. As discussed above, the difference between the two specifications is most likely related to the restricted seasonal pattern imposed through the functional form. The OLS and IV estimates of model specification 3 are reasonably close for all locations, and show a clear decline in the DST effect with latitude.

Figure 4 shows the estimated DST effect for all locations against their latitude. There is a overall negative relationship between latitude and DST energy savings as indicated by the fitted line. However, the diversity in results is equally striking as the relationship with latitude. There is a group of countries, Croatia, Estonia, France, Latvia, Northern Ireland, Switzerland and Ukraine, with estimated DST effects around -2.5% that is robust across all model specifications and IV estimation. There is very little evidence of a DST effect in Belgium and Luxembourg. This may possibly be related to the structure of economy in these two countries. The small DST effect in Portugal may be related to the Atlantic climate, while the very large effect observed

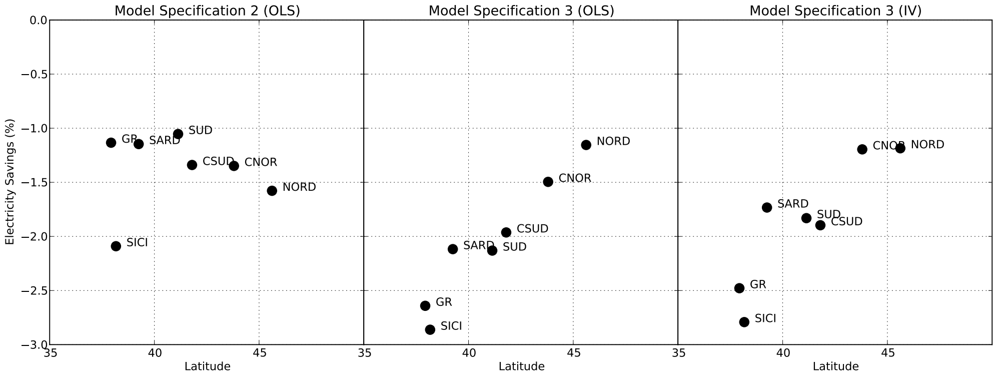

Figure 3: Estimated effects of DST policy and latitude for model specifications 2 and 3 and instrumental variables estimation for Mediterranean countries.

for some Mediterranean countries may be related to holiday effects. It is not obvious that this diversity in estimated DST effects can be explained by a few factors such as latitude, climate and cultural and economic conditions.

4. Conclusions

Our study contributes to the literature by being one of the first multi-country studies of electric energy savings effects of DST. We are using the same econometric specification and estimation method for a consistent data set of electricity load covering 35 countries in Europe. Thus our results provide a comprehensive set of consistent and comparable estimates of the DST effect.

Past studies of the potential electric energy savings effect of a DST policy have shown a range of different effects ranging from clear positive effects to smaller negative effects. We find that DST has an electricity saving effects across most of Europe with the only exceptions located in the extreme north. The magnitude varies from less than 0.5 percent to more than 2.5 percent.

We find some evidence that DST savings decreases with latitude, and that this effect is more pronounced for some homogeneous groups of countries. We do not find any evidence in support for the opposite view that DST savings increases with latitude, while noting that our geographical area is within the northern temperate climate zone.

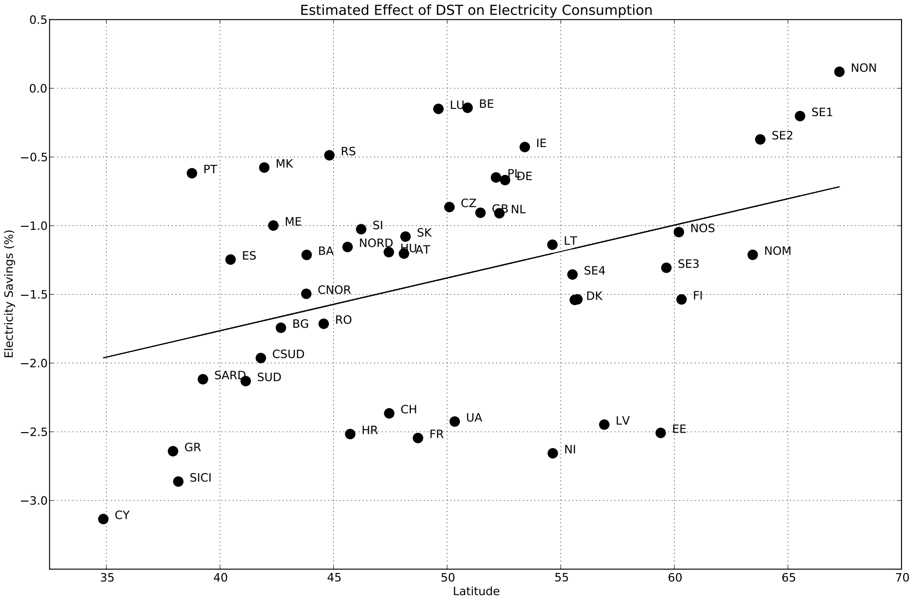

Figure 4: Estimated effects of DST policy and latitude for all locations.

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