How Does Daylight Saving Time Affect Electricity Demand?

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Motivation

- Daylight saving time (DST) affects more than 1.6 billion people worldwide (Kotchen and Grant (2011))
- The level of peak demand determines the necessary capacity within an electricity network
- It has long been a popular belief that DST reduces electricity demand
- Excessive electricity consumption has been linked to climate change
- Existing studies on the overall relationship between DST and electricity demand come to conflicting conclusions
  - Increase: Kotchen and Grant (2011), Rock (1997), Momani et al. (2009)
  - Decrease: Department of Transportation (1974), Belzer et al. (2008),Hill et al. (2010), Mirza and Bergland (2011)
  - No effect: Kandel and Sheridan (2007), Kellogg and Wolff (2008)
- Studies of the distributional effect (how DST affects demand at different times of the day) are also inconclusive

My Paper

- It is notable that other studies do not utilise quasi-natural experiments with the implementation of DST, but instead focus on periods without an experiment, DST extensions, micro-level data and simulations, all of which have limitations
- This paper identifies the distributional and overall effect of DST on electricity demand through the use of a unique dataset
- The time period covered by the dataset includes the most recent three-year trial of DST in Western Australia as well as three summers without DST
- The data are also half-hourly, allowing distributional analysis
- A difference-in-differences (DID) framework is used to ascertain the difference between electricity demand in the treatment period during DST and demand in the same period without DST

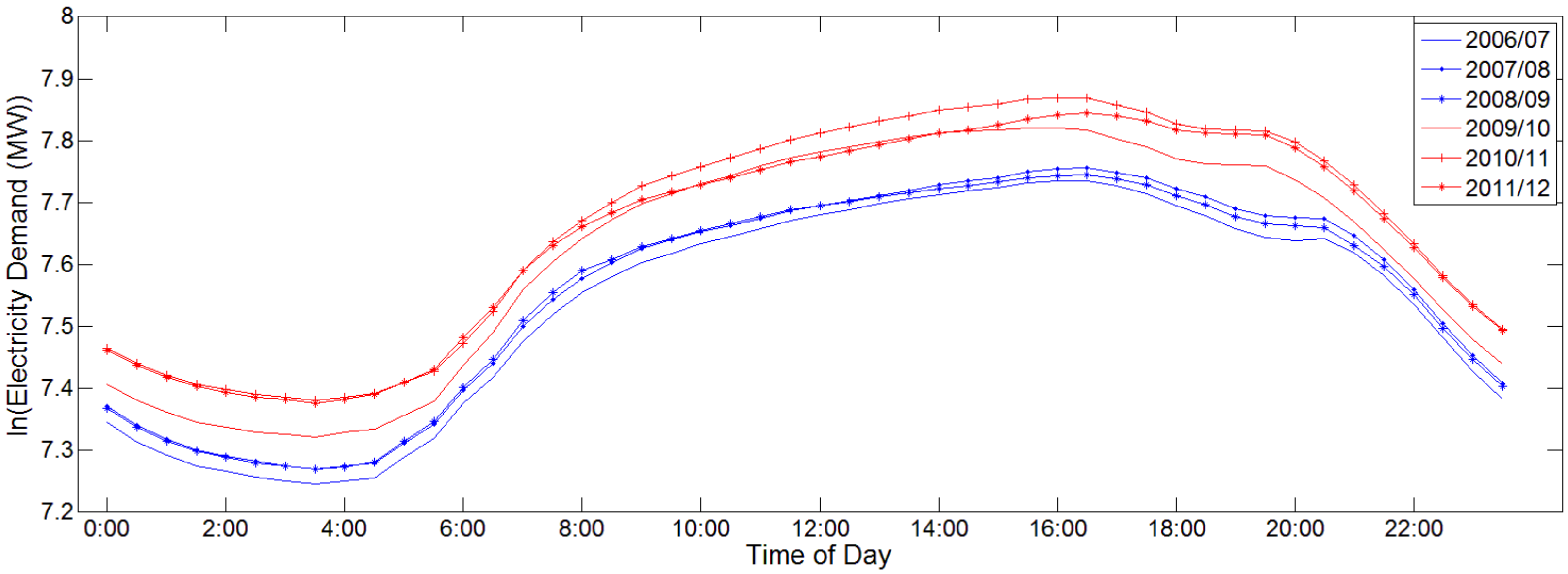
Conceptual Framework

- Should one expect DST to affect electricity consumers' behaviour?
- Yes
  - Consumers' schedules (both residential and commercial) are invariably based on clock time as opposed to solar time
  - DST effectively delays the daily cycle, so that mornings become darker and evenings are prolonged
  - Because consumers are exposed to darker, colder conditions when they wake up, morning electricity demand should increase
  - More sunlight during the evening should influence people to engage in more recreation or use less light while indoors at a given clock time (although it will also be hotter)
  - Expect the lighting effect to outweigh the cooling effect until dark
- Is overall consumption affected?
  - Not necessarily - the two effects may well cancel each other out

Data

- This study uses half-hourly electricity generation, weather and lighting data in Western Australia from 21 September 2006 to 1 March 2013
- The dataset is unique in the context of the literature, as it contains a *rich quasi-natural experiment*
  - Western Australia (WA) observed DST in 2006/07, 2007/08 and 2008/09, but discontinued the trial after an unfavourable referendum
  - Hence, WA did not observe DST in 2009/10, 2010/11 or 2011/12
- The quasi-natural experiment lies in DST being observed and subsequently not being observed during the same time of the year (the last week of October until the last week of March)
- No other study has such data, and hence they use different techniques to identify the DST effect, but these techniques are subject to limitations
- Furthermore, the half-hourly nature of the data allows a detailed analysis of the distributional effect of DST on demand as well as the overall effect

Intraday Seasonality and Annual Trend during DST Months



Empirical Analysis

- The *preliminary* model estimates the effect of DST in a given half hour through a simple dummy variable equal to one if the observation took place during DST and zero otherwise:

$$\ln(electricity\_demand_{dh}) = \beta_0 + \beta_1 DST_{dh} + \gamma seasonality_{dh} + \varphi environment_{dh} + \omega interactions_{dh} + \varepsilon_{dh}$$

- The *final* model is the same except that it employs a more sophisticated DID framework to estimate the DST effect in a given half hour:

$$\ln(electricity\_demand_{dh}) = \beta_0 + \beta_1 DST\_year_{dh} + \delta_0 DST\_period_{dh} + \delta_1 (DST\_year_{dh} \times DST\_period_{dh}) + \gamma seasonality_{dh} + \varphi environment_{dh} + \omega interactions_{dh} + \varepsilon_{dh}$$

Empirical Analysis (Other Variables)

- $seasonality_{dh}$
  - A matrix containing variables that control for various types of seasonality in the series, such as day, month, year and holiday dummies
- $environment_{dh}$
  - A matrix containing weather and lighting variables
- $interactions_{dh}$
  - A matrix containing interactions between variables in different matrices, e.g. temperature-month interactions

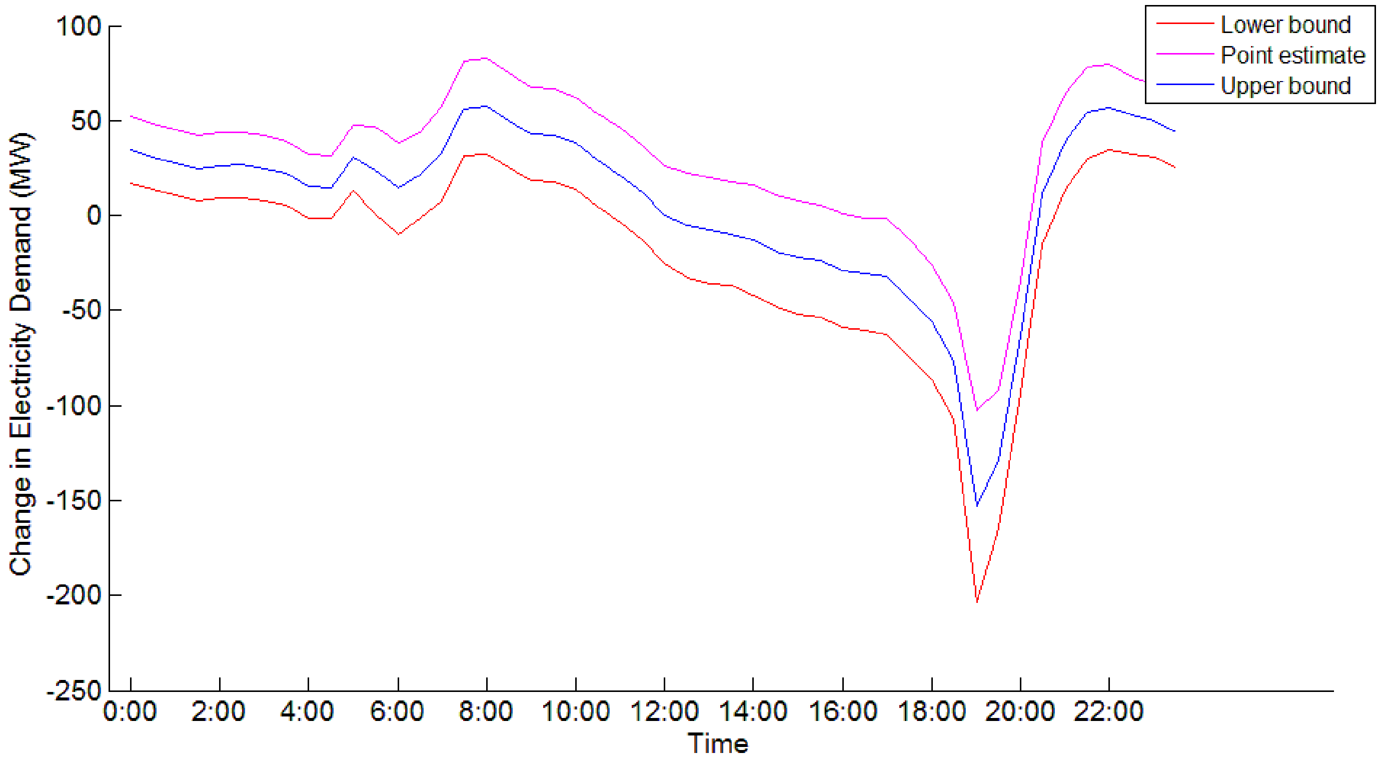
Results (Simple): Effect of DST on Electricity Demand

Half Hour	β_1	Half Hour	β_1	Half Hour	β_1	Half Hour	β_1	Half Hour	β_1	Half Hour	β_1
0:00	**2.37%* (4.77)**	4:00	**1.04%* (2.1)**	8:00	**2.75%* (5.17)**	12:00	0.11% (0.21)	16:00	-0.86% (-1.43)	20:00	**-2.37%* (-4.17)**
0:30	**2.03%* (4.03)**	4:30	**1.03%* (2.08)**	8:30	**2.22%* (4.28)**	12:30	-0.04% (-0.08)	16:30	-0.93% (-1.57)	20:30	0.9% (1.7)
1:00	**1.88%* (3.63)**	5:00	**1.9%* (3.78)**	9:00	**2.22%* (4.28)**	13:00	-0.22% (-0.37)	17:00	-0.97% (-1.61)	21:00	**2.22%* (4.23)**
1:30	**1.73%* (3.32)**	5:30	**1.5%* (2.43)**	9:30	**1.93%* (3.47)**	13:30	-0.25% (-0.46)	17:30	**-1.42%* (-2.35)**	21:30	**3.03%* (5.79)**
2:00	**1.73%* (3.32)**	6:00	0.72% (1.12)	10:00	**1.77%* (3.56)**	14:00	-0.31% (-0.54)	18:00	**-1.99%* (-3.38)**	22:00	**3.29%* (6.05)**
2:30	**1.82%* (3.47)**	6:30	1.14% (1.9)	10:30	**1.46%* (2.94)**	14:30	-0.51% (-0.88)	18:30	**-2.85%* (-4.52)**	22:30	**3.16%* (6.28)**
3:00	**1.76%* (3.42)**	7:00	**1.63%* (2.8)**	11:00	**1.13%* (2.26)**	15:00	-0.56% (-0.94)	19:00	**-6.43%* (-7.11)**	23:00	**3.06%* (6.23)**
3:30	**1.58%* (3.15)**	7:30	**2.78%* (5.05)**	11:30	0.77% (1.56)	15:30	-0.65% (-1.09)	19:30	**-5.06%* (-7.22)**	23:30	**2.8%* (5.65)**

Main Results: Effect of DST on Electricity Demand (DID)

Half Hour	δ_1	Half Hour	δ_1	Half Hour	δ_1	Half Hour	δ_1	Half Hour	δ_1	Half Hour	δ_1
0:00	**2.21%* (3.87)**	4:00	1.04% (1.8)	8:00	**2.78%* (4.5)**	12:00	0.02% (0.08)	16:00	-1.3% (-1.89)	20:00	**-2.85%* (-4.26)**
0:30	**2.02%* (3.51)**	4:30	1% (1.75)	8:30	**2.38%* (3.93)**	12:30	-0.25% (-0.38)	16:30	**-1.37%* (-2.04)**	20:30	0.54% (0.85)
1:00	**1.86%* (3.15)**	5:00	**1.99%* (3.49)**	9:00	**2.04%* (3.45)**	13:00	-0.36% (-0.55)	17:00	**-1.42%* (-2.06)**	21:00	**1.85%* (3.01)**
1:30	**1.68%* (2.83)**	5:30	**1.49%* (2.03)**	9:30	**2%* (3.41)**	13:30	-0.44% (-0.69)	17:30	**-1.9%* (-2.77)**	21:30	**2.71%* (4.04)**
2:00	**1.78%* (2.99)**	6:00	0.84% (1.16)	10:00	**1.79%* (3.04)**	14:00	-0.6% (-0.89)	18:00	**-2.38%* (-3.63)**	22:00	**2.99%* (4.9)**
2:30	**1.83%* (3.02)**	6:30	1.18% (1.86)	10:30	**1.36%* (2.32)**	14:30	-0.86% (-1.24)	18:30	**-3.25%* (-4.88)**	22:30	**2.92%* (4.99)**
3:00	**1.71%* (2.86)**	7:00	**1.69%* (3.46)**	11:00	0.97% (1.64)	15:00	-1% (-1.44)	19:00	**-6.61%* (-5.96)**	23:00	**2.91%* (5.14)**
3:30	**1.53%* (2.63)**	7:30	**2.79%* (4.47)**	11:30	0.56% (0.95)	15:30	-1.09% (-1.58)	19:30	**-5.62%* (-6.93)**	23:30	**2.68%* (4.69)**

Results (Distributional Change in Demand)



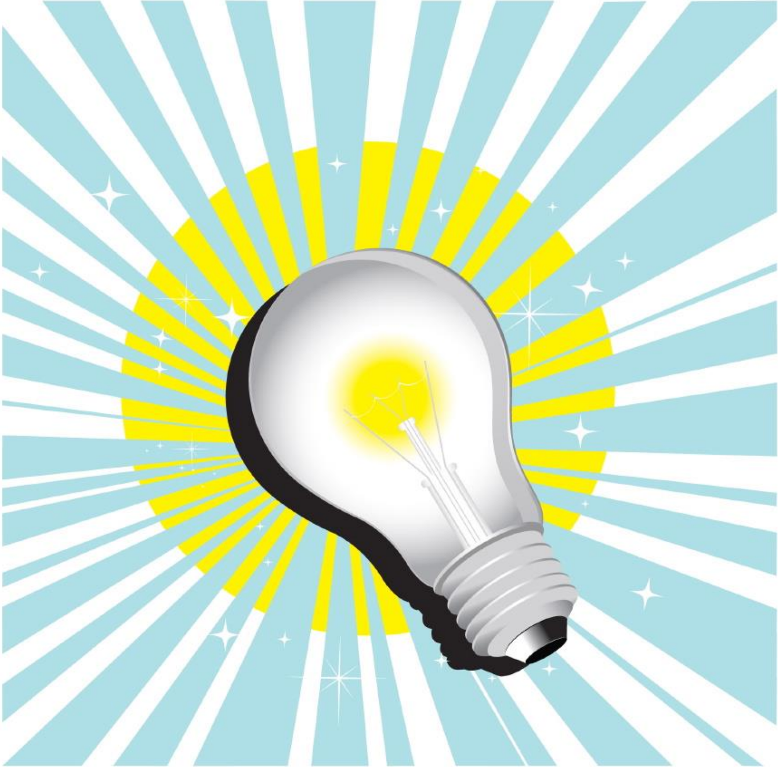
Discussion

- DST has a significant distributional effect on electricity demand
  - Increase: 5-6am and 7-11am
  - Decrease: 4:30-8:30pm
  - Increase: 9pm-4am
- Although demand increases in the majority of half hours, there are substantial savings during the late afternoon and early evening
  - Demand reaches its peak during this period
- There is a reduction in peak demand
- Overall, DST has no effect on electricity demand
- The robustness of the results to numerous weather specifications and declining growth in the number of air conditioners being sold both strengthen the validity and applicability of the results

Conclusion

- This study aims to determine the distributional and overall effect of DST on electricity demand using a unique dataset in a DID framework
- Variables that may confound the DST-demand relationship, such as weather, lighting and seasonality, are included in the model as controls
- The main finding of the study is that DST affects the distribution of electricity demand by decreasing it sharply in the late afternoon and early evening, and increasing it in the morning and at night
- The finding that DST does not save electricity overall is contrary to historical belief
- The reduction in peak demand has implications
- Some further issues to consider
  - Cost savings
  - Splitting up of data into residential, commercial and industrial components
  - Focus on peak demand (including capacity requirements)

Thank you for your attention!



Data (Summary Statistics)

Variable	Mean	Standard Deviation	Minimum	Maximum
Electricity Demand	1951.551	412.7197	1172.132	3855.374
Temperature	18.69424	6.584951	-0.6	43.2
Precipitation	0.0369475	0.3400472	0	36.4
Relative Humidity	63.48255	21.26113	6	100
Wind Speed	10.44276	6.399823	0	42