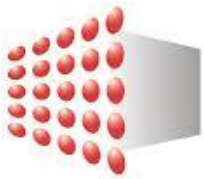
How Much Do Labels Actually Matter for Electricity Savings? Singapore's Case for Residential Air-Conditioner Purchases and Usage Behaviour.



ENERGY STUDIES INSTITUTE

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Hofburg Congress Center, Vienna, Austria
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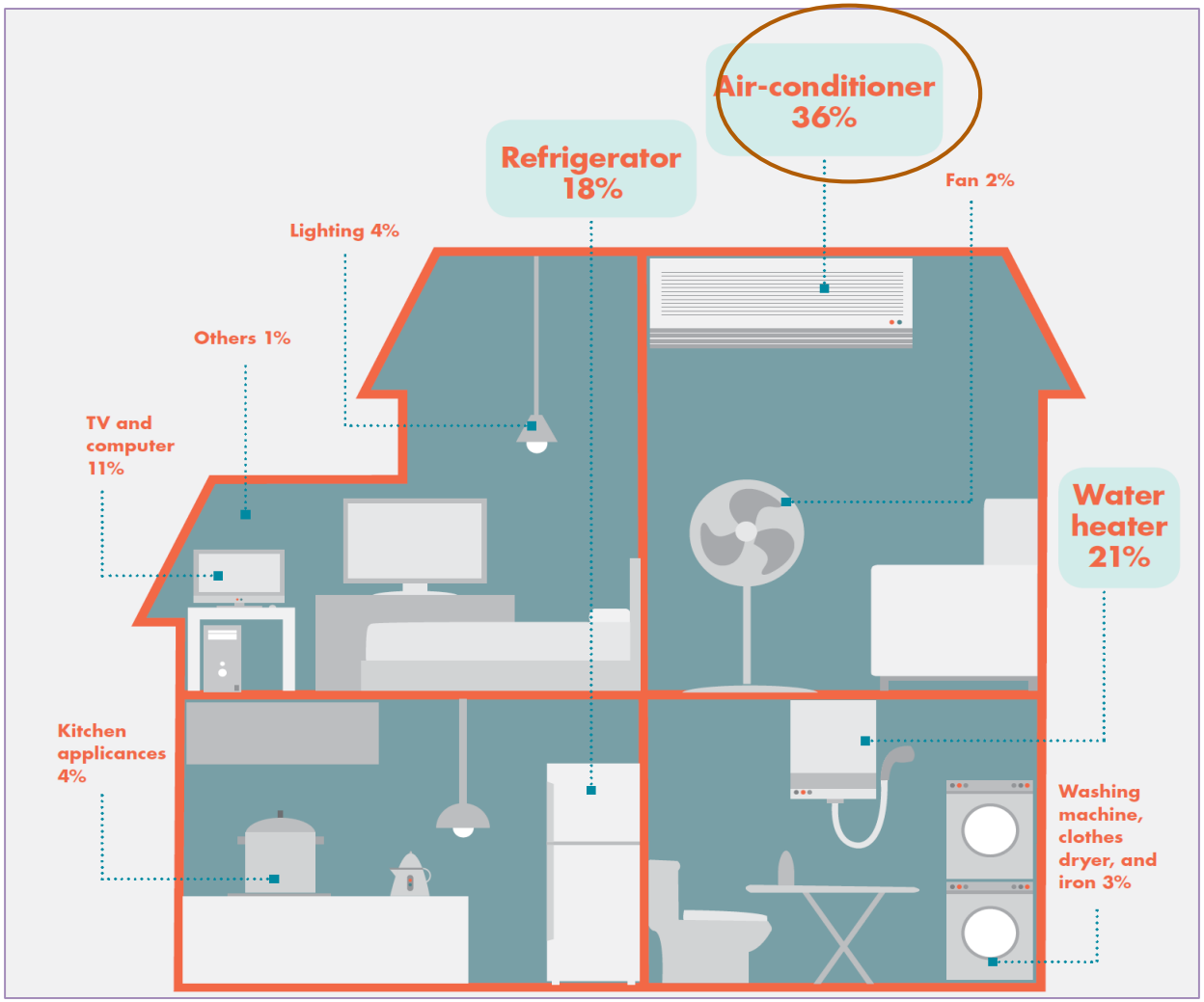
Residential Electricity Requirements – Tropical CIty

- Biggest energy guzzler: Air-Conditioning
- 3 top appliances take up 75% of total electricity demand
- Need to evaluate effectiveness of policy interventions on these appliances.



Ministry of National Development, 2016
Climate Action Plan – Take Action Today

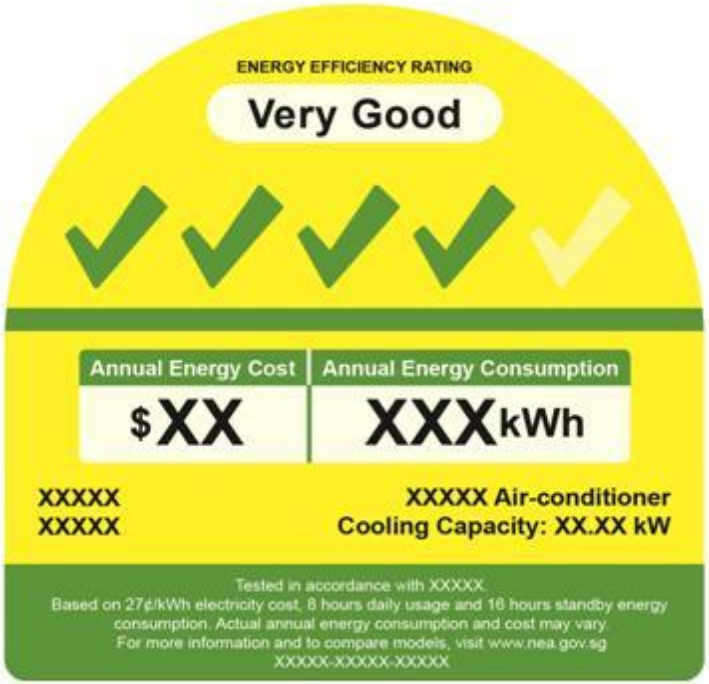
Energy Labelling Standards in Singapore (Air-Conditioners)

2008

Efficient Model – COP >2.64

2014

Efficient Model – COP >3,78



COP Improvement of 43.2%

Power Input Requirements Decrease by 30%

National Environment Agency, 2017. http://www.nea.gov.sg/corporate-functions/newsroom/news-releases/revised-energy-labels-and-rating-system-for-air-conditioners-refrigerators-and-clothes-dryers

The Rebound Effect

- Existing Literature

Policy Evaluation/ Micro-econometric studies	1)Direct Rebound 2)Panel household/Building specific experimental data 3)Targets specific Policies 4)Econometric	**Davis, Fuchs and Gertler (2014)** Mexico Appliance Replacement program. **Zivin and Novan (2016)** Free EE retrofits for households – U.S. Energy Weatherization program. **Haas and Biermayr (2000)** Rebound effect for space heating in Austria.
Macro- Modelling	1') Indirect Rebound 2) Sectoral-specific and government data 3) Computable general equilibrium models (CGE)/Econometric	**Chitnis and Sorrell (2015)** Rebound Effect for UK households with live tables. **Vikstrom (2004)** CGE modelling of Rebound in Sweden. **Adetutu et al (2016)** Economy-wide Rebound for 55 countries.
Productivity and Economic Growth (Hybrid models)	1) Indirect/economy-wide Rebound 2) Growth Theories, ecology, input-output and Khazoom-Brookes Postulate.	**Jaume Freire-Gonzalez (2017)** Econometric, IO and re-spending model for EU-27 countries. **Brinda & Inez (2013)** IO model of direct + indirect rebound for US.

Methodology and Sample Data

Natural Ex-Post Evaluation – To evaluate the actual effectiveness of the EE policies: After air-conditioner replacement. No subsidies for purchase.

- For this study, we utilize a subsample of ~232 households for analysis

a) Energy Bills from January 2014 to October 2016
b) Survey Data on cross-sectional socio-economic characteristics
c) Monthly Weather Data.

Methodology and Sample Data

- Natural Experiment – To evaluate the actual effectiveness of the Mandatory Labelling Scheme (MELS) and Mandatory Energy Efficiency Standards (MEPS): After air-conditioner replacement. No subsidies for purchase.

- Recruited Households on the following basis:

Control Group: Households who purchased air-conditioners before MELS in 2008.

Treatment Group: Household who purchased a replacement air-conditioner between January 2015 to June 2016

Methodology and Sample Data

- Actual Electricity Savings should be positive
- However, as in many previous studies, we believe actual savings < theoretical savings.
- Keeping capacity constant, the rebound effect should be relatively small (i.e. < 50%).

Methodology and Sample Data

Treatment Households			
	2008 Base Value	**2 ticks**	**> 3 ticks**
COP Value	3.176667	4.035	4.575
% of Treatment households		13%	87%
Reference Cooling Capacity	7.5kW	7.5kW	7.5kW
(Based on >50% sales between 7-7.9kW)			
Power Input Required	2.36	1.86	1.64
Theoretical Savings		21%	31%
Weighted Average Theoretical Savings			29%

COP improvements from the EE air-conditioner purchases after 2014: **29%**

Methodology and Sample Data

- Descriptive Statistics for 232 households

1) Socio-economic Characteristics

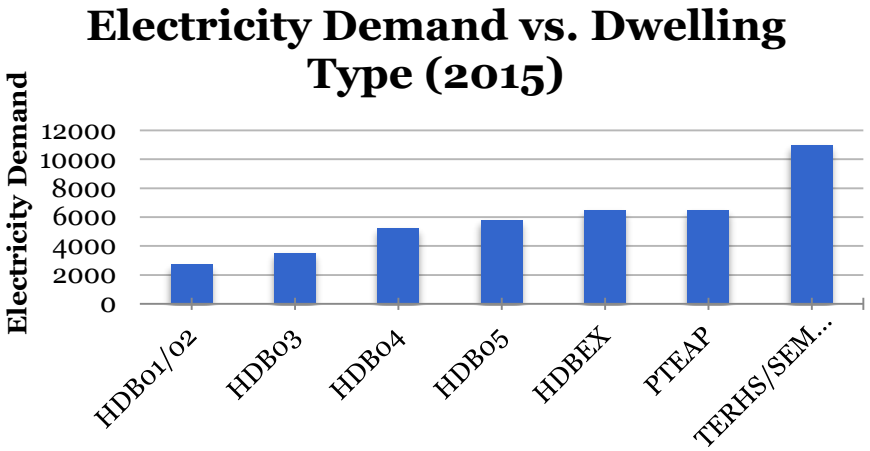
	Control	Treatment
Frequency	158	74
Average Electricity demand 2014	5227.98	5909.97
Average Electricity demand 2015	5495.29	5840.30
Proportion Living in Private Apartments	19%	10.80%
Median Household Income	6000-6999	6000-6999
Household Size	3.785	3.716
Auto Bill Payment	70%	60%
No of children below 12	0.56	0.40
No of children below 18	1.00	0.69
Children Indicator 12	0.342	0.257
Children indicator 18	0.544	0.432
% with Elderly	35%	34%
Average Hours spent at home - weekdays	45	42
Average Hours spent at home - weekends	53	47
No of hours air-con turned on at home	10.3	16.2
Average age of airconditioners	10.614	1.108
No with Clothes Dryers	20	5
Dwelling Age - Based on Leasing Date	1991	1989
Education level no of Years	12.1	11.9

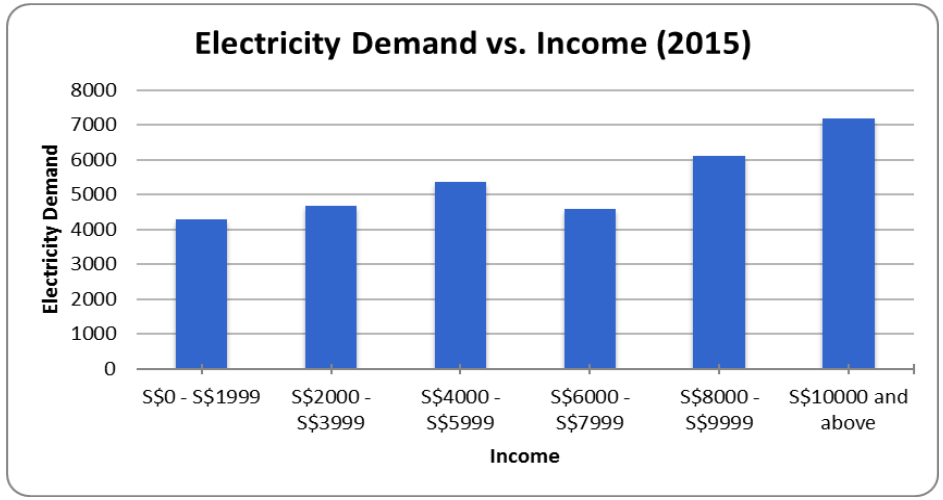
As Compared to National Statistics

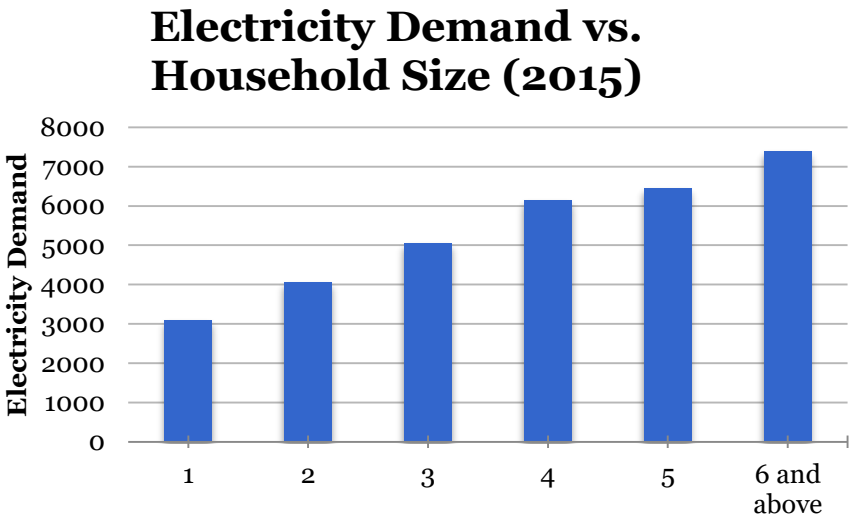
- Slightly lower median income
- Slightly higher household size.
- Larger proportion living in the East

Methodology and Sample Data

- Descriptive Statistics for 232 households – Socio-characteristics







Methodology and Sample Data

- Descriptive Statistics for 232 households

2) Environmental Attributes/Energy Saving Habits

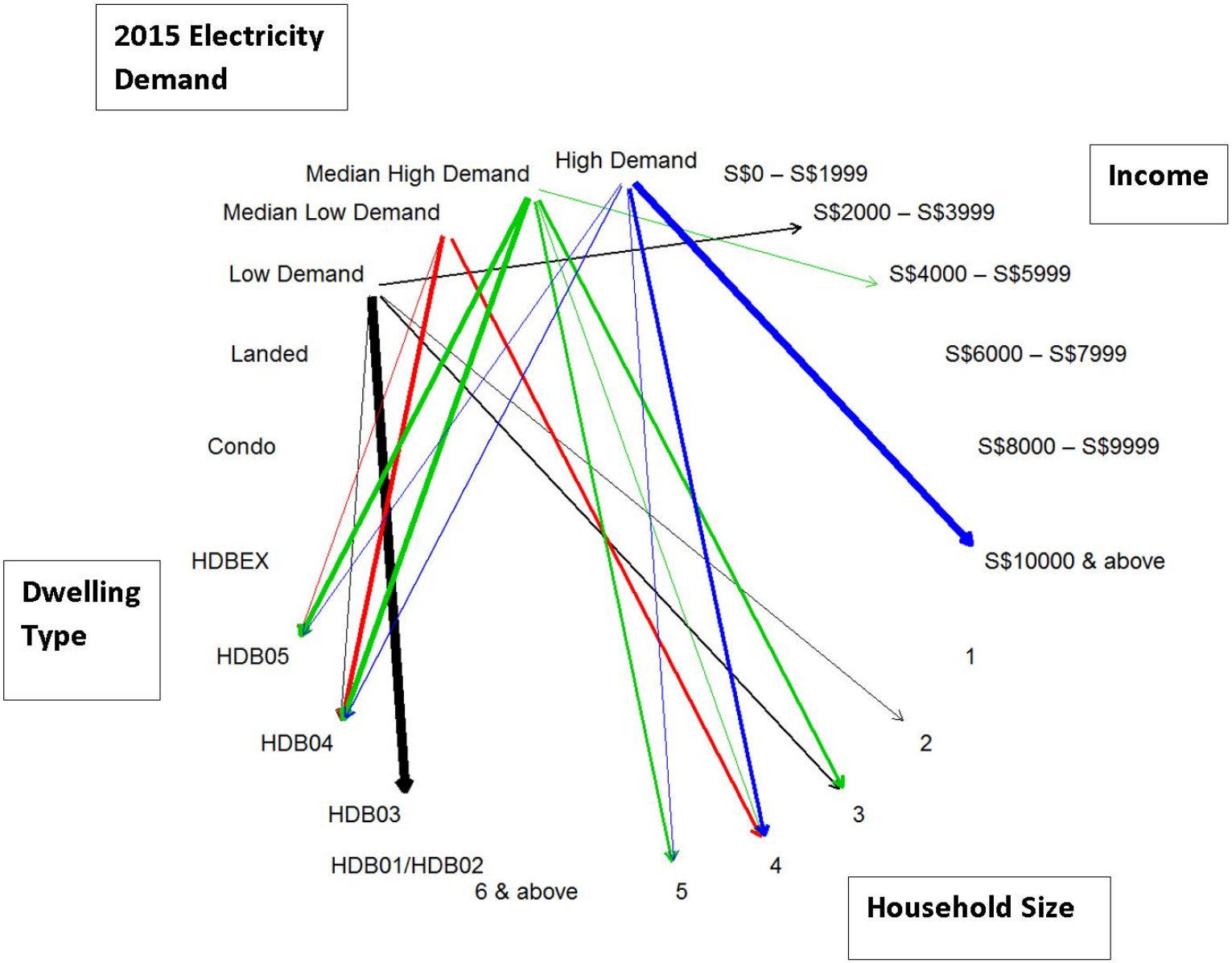
Attributes	Control	Treatment
Aware of Labelling scheme	56.33%	62.16%
Do not on air-con and fan at the same time	53.16%	54.05%
Set temperature 25 degrees and above	68.99%	68.92%

- Descriptive Statistics for 232 households

3) Geographical Distribution

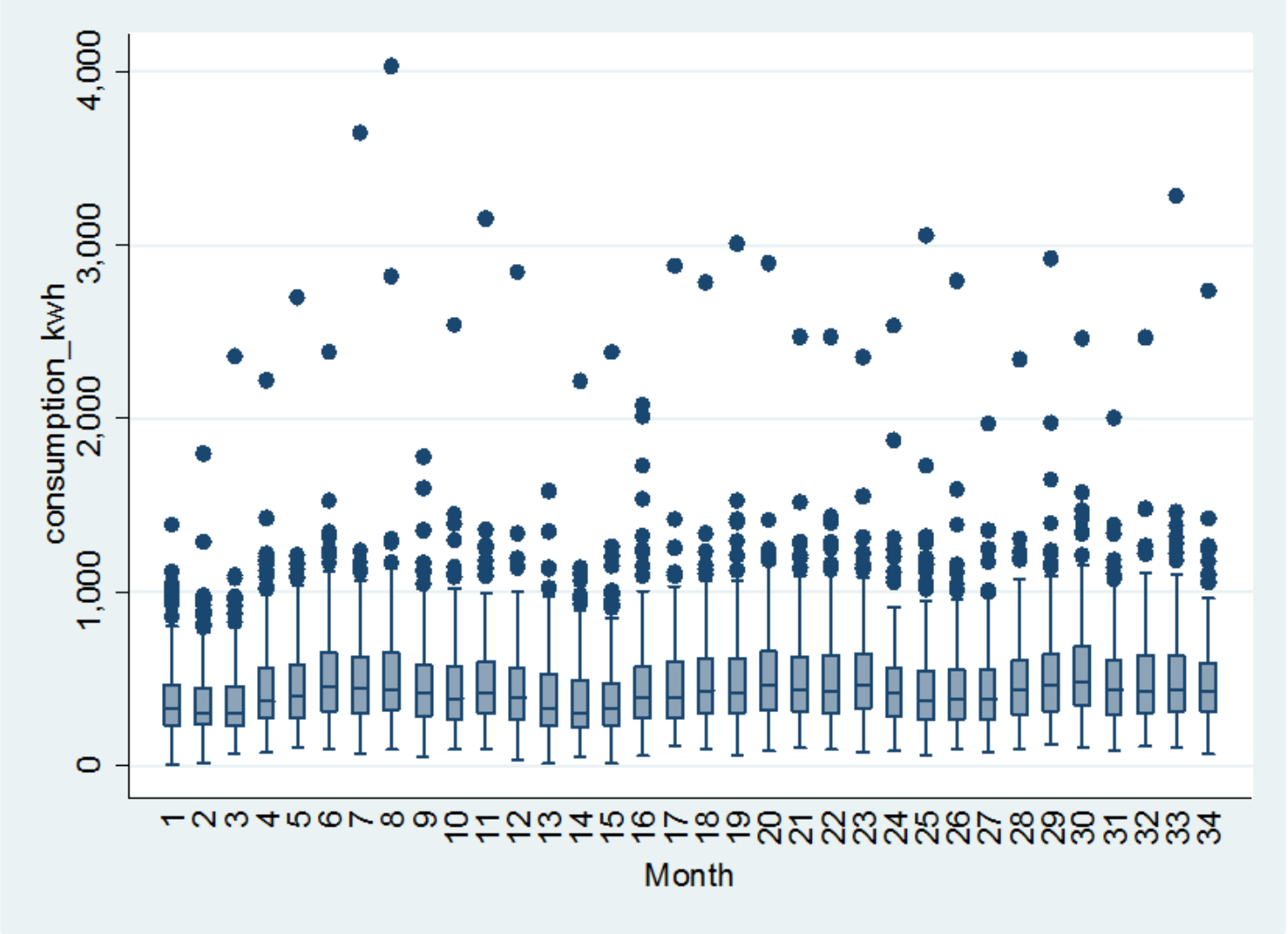
Region	Frequency	% Distribution
North	31	13%
South	24	10%
East	77	33%
West	57	24%
Central	43	18%

Methodology and Sample Data

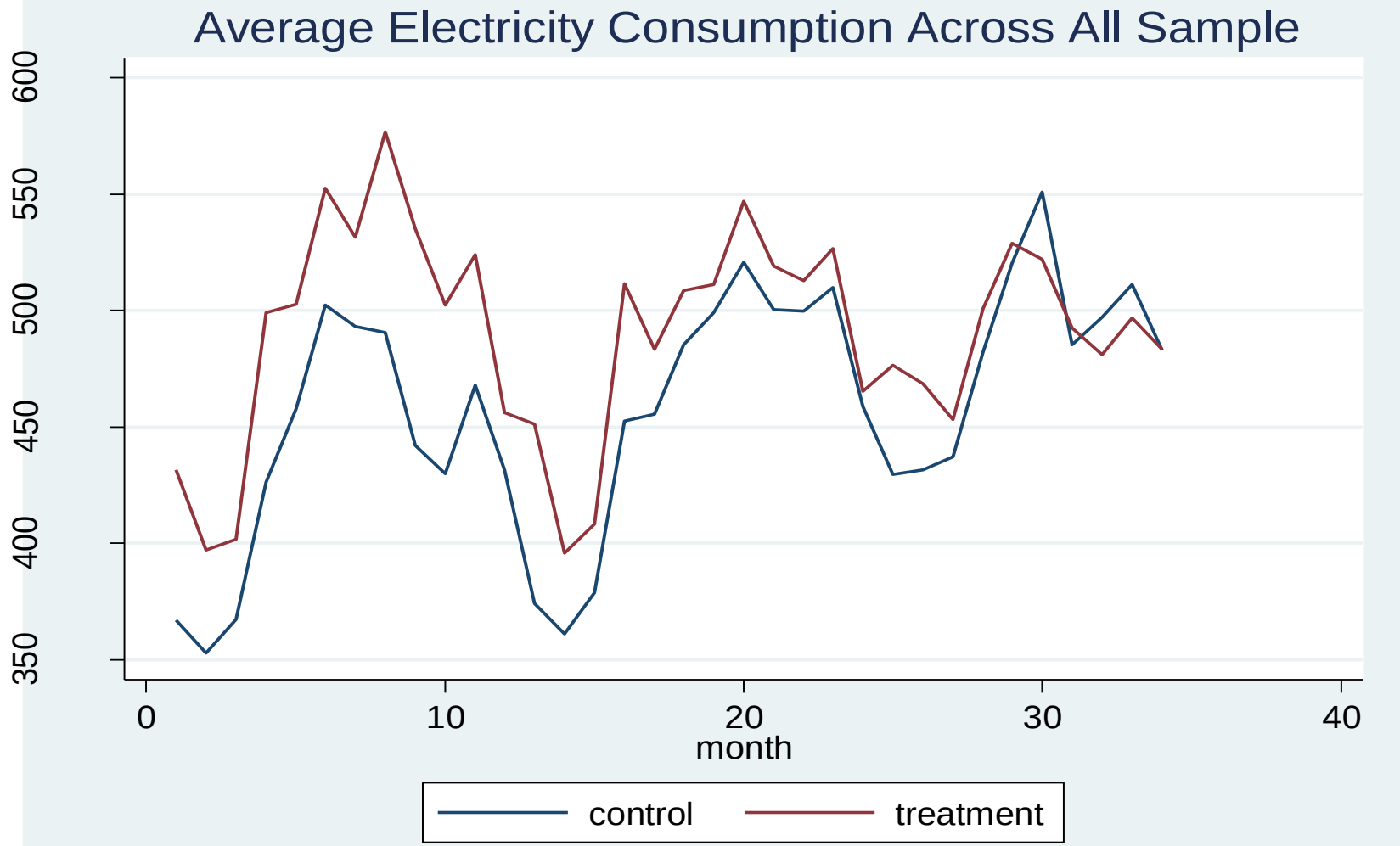


Methodology and Sample Data

- Seasonality



Methodology and Sample Data



Methodology and Sample Data

2) Econometric Specification and Results

- Main Idea is to estimate the replacement effect of air-conditioners as a representation of actual electricity savings over time.
- Control for various effects captured in our survey data, as well as weather elements and dwelling characteristics.
- Compare actual savings with predicted savings as forecasted by the engineering estimates.
- We use Ordlnary Least Squares (OLS), Fixed Effects (FE) for regression specification

Methodology and Sample Data

2) Econometric Specification

- $\text{Ln } E_{i,t} = \alpha_0 + \alpha_1(\text{Month of Replacement}) + \alpha_{2i}\sum Weather\ Effects + \alpha_3 \text{Ln (Price)} + \sum Seasonal\ Month\ Dummies\ + \sum Household\ Specific\ Effects + \varepsilon_{i,t}$

spikedummy	0.544***	0.555***
	(0.0474)	(0.0477)
holidaydummy	-0.846***	-0.849***
	(0.0728)	(0.0704)
treatmentstatus	-0.0548***	-0.0485***
	(0.0177)	(0.0171)
lntemp_degrees	1.666***	1.755***
	(0.320)	(0.312)
lnelectricityprice	-0.255***	-0.244***
	(0.0488)	(0.0478)
lnpollution_pm25	0.0375**	0.0421***
	(0.0150)	(0.0148)
lnrainfall	0.0134*	0.0149*
	(0.00809)	(0.00800)
income	0.0221***	0.0176***
	(0.00190)	(0.00186)
dwellingtype	-0.361***	-0.317***
	(0.0181)	(0.0169)
educationdummy	-0.0887***	-0.0792***
	(0.0123)	(0.0119)
clothesdryer		0.343***
		(0.0169)
West	-0.0451***	-0.0361***
	(0.0137)	(0.0133)
tenants	0.0430*	0.0438**
	(0.0221)	(0.0205)
Robust standard errors		
*** p<0.01, ** p<0.05, * p<0.1		

Crude OLS Estimates

buy energy efficient products	-0.0898***	-0.0942***
	(0.0112)	(0.0110)
switch off ac after a while	-0.178***	-0.187***
	(0.0115)	(0.0111)
set 25 and above	-0.0906***	-0.0701***
	(0.0120)	(0.0113)

- Regional differences
- Environmental Attributes matter for energy use
- Evidence of rebound effect

Empirical Results

	Fixed Effects		
	(1)	(2)	(3)
treatmentstatus	-0.0442*	-0.0442*	-0.0880**
	(0.0260)	(0.0196)	(0.0427)
spikedummy	0.606***	0.606***	0.592***
	(0.0372)	(0.0238)	(0.0367)
holidaydummy	-0.843***	-0.843***	-0.839***
	(0.0706)	(0.0649)	(0.0708)
lnrainfall	0.0180***	0.0180**	
	(0.00424)	(0.00549)	
lntemp_degrees	1.426***	1.426***	0.921**
	(0.213)	(0.288)	(0.449)
lnpollution_pm25	0.0386**	0.0386*	0.0865
	(0.0172)	(0.0158)	(0.0559)
lnelectricityprice	-0.249***	-0.249**	
	(0.0506)	(0.0582)	
Standard Errors	Robust	Region	Household

- Regional differences
- Environmental Attributes matter for energy use
- Evidence of rebound effect

Policy Implications

- There is evidence of the Rebound Effect with EE air-conditioner purchases. – Preliminary Estimates suggest 82%.
- This is likely due to purchase of larger air-conditioners, as well as greater use of both air-cons and other energy-related expenditure relating to household productivity.
- Need for thermal comfort may grow as income increases, which reduces realized savings.
- May be a limit to the effectiveness of the Energy Labels. Additional educational interventions may be required to encourage the purchase of right-sized air-conditioners, and the payback period/long-term cost savings of such purchases.

Future Work

- Further refinement of our model is required with a larger sample size (670)
- We will attempt to disentangle direct and indirect rebound effects with meter readings from the household.
- We will also attempt other methods (i.e. Matching) to isolate subsamples that are closer to one another before calculating the electricity savings.
- An accurate measure of the rebound effect is necessary to contribute to more accurate predictions of carbon emissions for Singapore.

Thank you!

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