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#IAEE19LJ

Analysis of consumer preference on a hypothetical green certificate program in Korea: application of a choice experiment

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Background

- Electricity producers are monopsonists in the REC(Renewable Energy Certificate) market in Korea as they are regulated by the RPS (Renewable Portfolio Standard).
- But, there is no room for households, commercials, or industrial sectors to participate in the REC market.
- So called ‘a green certificate program’ which is proposed in this study is designed for households, commercial, or industrial sectors who are interested in trading renewable energy (green) certificates.
- The idea on the green certificate program is also affected by the diffusion of the RE100 program where global enterprises such as google, Microsoft, BMW, Starbucks, etc. have engaged.

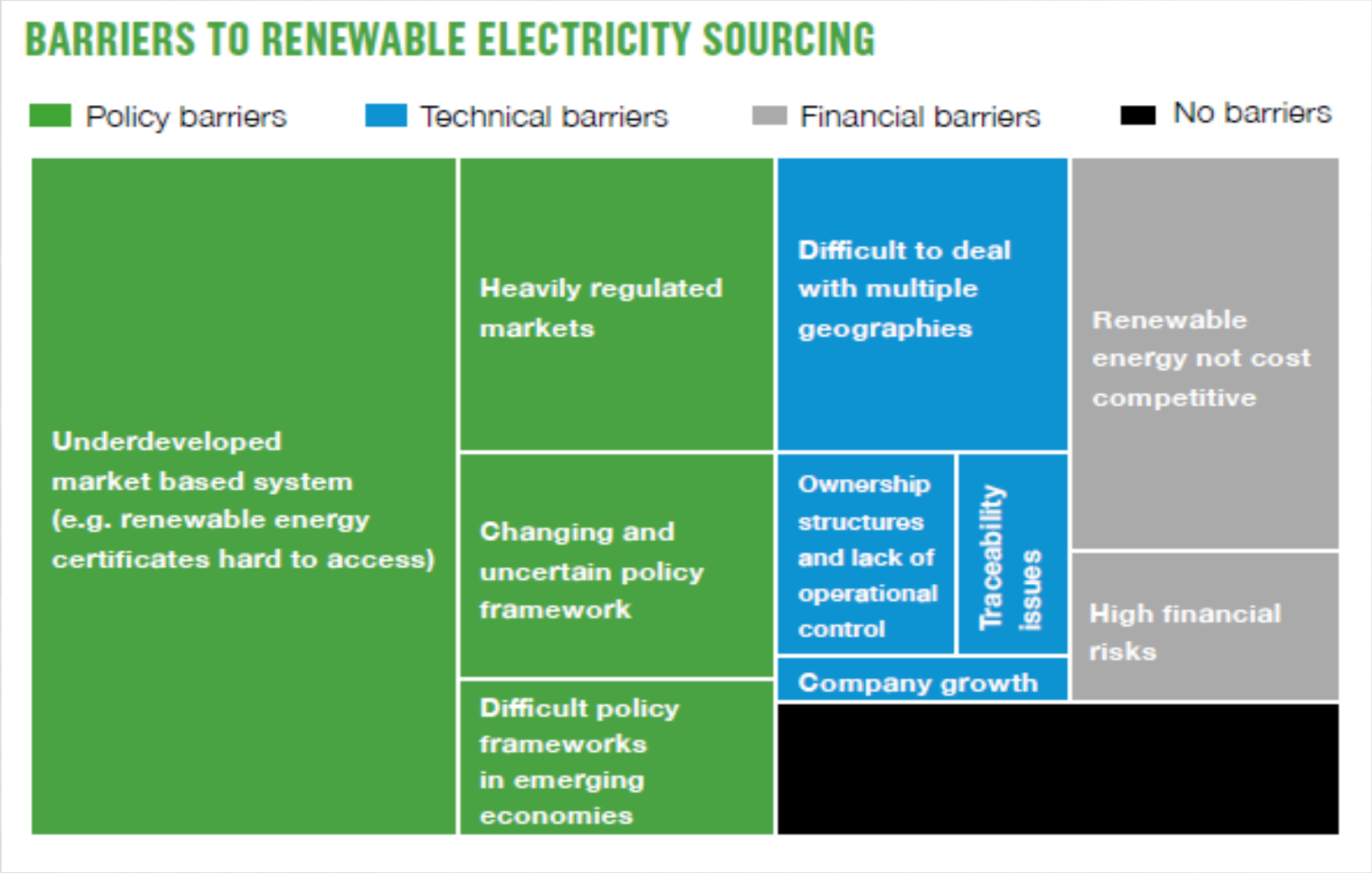
RPS policy and REC market

- A REC is a marketable instrument that embodies the property rights to the environmental, social and other non-power attributes of renewable electricity generation (EPA, 2017).
- RECs have been used to meet the general obligations of RPS regulations that require increased production of renewable electricity.
- RECs are issued when 1MWh of electricity is generated from a renewable energy source and delivered to the electricity grid.
- Electricity producers under the RPS policy receive RECs when they produce renewable energy, then can sell their RECs separately from commodity electricity.
- In Korea, The RPS regulation is applied to only power suppliers with over 500MW of power capacity to provide renewable electricity based on annual requirements.

RE100 program

- It’s a voluntary global campaign for providing renewable energy as sources of producing commodity.
- Apple, googol, Microsoft, etc. have participated in the RE100 program.
- The Climate Group and CDP(Carbon Disclosure Project) alliance, and Climate Week NYC launched in Sep. 2014.
- 122 of leading companies have implemented their goals of providing renewable electricity in 100%.
- The annual total energy demands of these companies in 2016 already exceeded 159TWh which is higher than total electricity supply of Malaysia, New York, or Poland.

Barriers to renewable electricity diffusion



Source: CDP, 2018, 'RE100 Progress and Insights Report'

How to obtain green power by customers in the U.S?

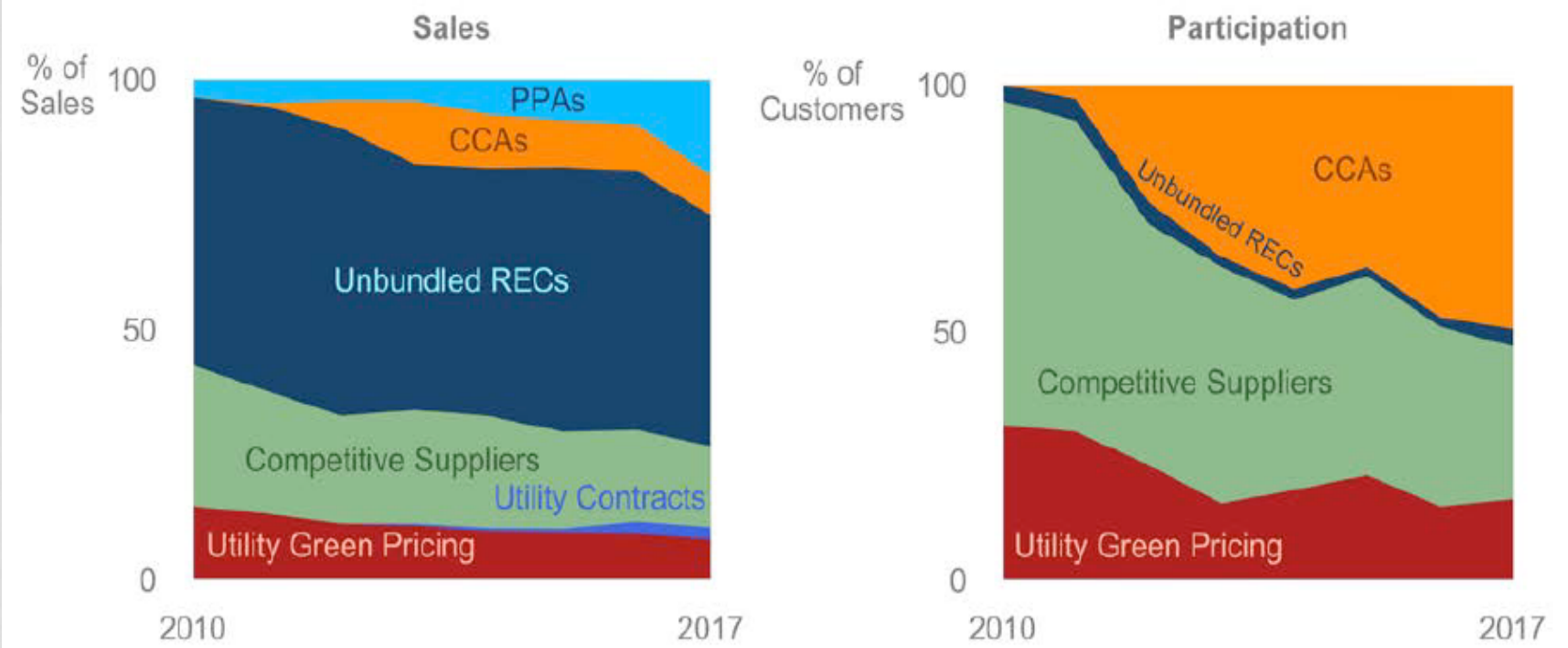


Figure ES-2. Voluntary green power market shares of different products in terms of sales (left) and customers (right), 2010–2017

PPA = power purchase agreement; CCA = community choice aggregation; REC = renewable energy certificates

Source: O'Shaughnessy, E., et al., 2018, 'Status and trends in the U.S. Voluntary green power market', NREL/TP-6A20-72204

Objectives

- As a separate renewable energy market, we examine social acceptability of the green certificate program to households as electricity consumers.
- Electricity consumers are asked to choose one between an existing electricity provider (KEPCO) and a new local electricity provider.
- Once a consumer decided to use the local electricity provider, he/she can purchase a green certificate by paying more electricity tariff.
- A choice experimental (CE) approach is employed to derive consumers' preferences on the green certificate program.
- Conditional logit, mixed logit, individual coefficient estimation, latent class logit, and hybrid models are used to estimate parameters of the attributes that comprise the green certificate program.

Previous studies on valuation of renewable electricity in the other countries

Authors and year of study	Renewable energy source	WTPs	Unit	Conditions/estimation methods	Geographic location
Borchers et al. (2007)	Solar PV	14.68~21.54	US Dollar/month	voluntary vs. mandatory program for 10% vs. 25% of green electricity	New Castle, Delarware, USA
	Wind	6.14~15.47			
	Farm methane	1.08~12.38			
	Biomass	-2.22~10.59			
Yoo and Ready (2014)	Solar PV	3.58~16.63(5.18)	US Dollar/month	Conditional logit, mixed logit, latent class models (Brackets are estimates from hybrid model)	Pennsylvania, USA
	Wind	4.91~17.67(7.27)			
	Biomass	-0.323~2.09(2.09)			
	Others	4.751~15.28(3.908)			
O'keeffe(2014)	Geothermal	4.927	US Dollar/month	Conditional logit and mixed logit models	USA
	Wind	7.58~10.82			
	Tidal	3.38~5.48			
	Solar PV	9.307~10.17			
Cicia et al. (2012)	Wind	52.76/7.86/48.31	Euro/bi-month	Latent class model (3classes)	Italy
	Solar PV	49.09/13.45/1.99			
	Agricultural Biomass	66.25/33.63/40.06			
Kotchen and Moore (2007)	Solar PV	6.59	US Dollar/month	Tobit, negative binomial, probit, Cragg	USA
	Wind	1.58	US Cent/kWh		

Basic CE model(RUM)

- Utility that a respondent n obtains by choosing alternative j for sth choice set is affected by observable attributes x and unobservable attributes u

$$U_{nis} = \beta' x_{nis} + u_{nis}$$

- Conditional logit probability based on the random utility model(RUM) : probability of respondent n choosing alternative j for sth choice set

$$P_{nis} = \frac{\exp(x'_{nis}\beta)}{\sum_{j=1}^{J} \exp\left(x'_{njs}\beta\right)}$$

  - Formula for willingness to pay (WTP) for an attribute a w.r.t. monetary attribute c

$$WTP_a = \frac{\partial U / \partial \beta_a}{\partial U / \partial \beta_c}$$

Mixed logit Model

- Mixed (or random parameter) logit (RPL) model relaxes the IIA condition, and assumes random parameters on the attributes
- It allows for correlations among random parameters
- Relative to the CLM, RPL model detects unobservable heterogeneity of respondents

$$U_{nis} = \beta'_n x_{nis} + u_{nis}$$

$$P_{nis}^{MLM} = \int \prod_{s=1}^{S} \prod_{j=1}^{J} \frac{\exp(\beta'_n x'_{nis})}{\sum_{j=1}^{J} \exp\left(\beta'_n x'_{njs}\right)} g(\beta/\theta) d\beta$$

Latent class logit model (LCM)

- Optimal number of classes are determined by AIC or BIC analysis
- Parameters of attributes differ across classes, but are fixed within a class
- Unobservable heterogeneity of respondents are grouped according to specific features

$$\mathrm{U_{nis/c}} = \beta'_{\mathrm{c}}\mathrm{x_{nis/c}} + \mathrm{u_{nis/c}}$$

$$P_n = \sum_{c=1}^{C} P_{nc}P_{nis/c} = \frac{\exp(\delta_c Z_n)}{\sum_{c=1}^{C}\exp(\delta_c Z_n)} \prod_{s=1}^{S} \frac{\exp(X_{nis}\beta_c)}{\sum_{j=1}^{J}\exp(X_{njs}\beta_c)}$$

Individual level parameter estimation model

- The conditional mean of the coefficient distribution for the sub-group of individuals who face the same alternatives and make the same choices
- Parameter vectors are randomly drawn from multivariate normal distribution functions estimated by the mixed logit model
- From repeating this process by 500 times, we get individual estimators, and show graphical outputs for Kernal density functions of attribute parameters

$$\hat{\beta}_n = \frac{1}{Q}\left\{\frac{\sum_{q=1}^{Q}\beta_n^{[q]}\prod_{s=1}^{S}\prod_{j=1}^{J}\left[\frac{\exp\left(\beta_n^{[q]}x_{nis}\right)}{\sum_{j=1}^{J}\exp\left(\beta_n^{[q]}x_{njs}\right)}\right]^{y_{njs}}}{\sum_{q=1}^{Q}\prod_{s=1}^{S}\prod_{j=1}^{J}\left[\frac{\exp\left(\beta_n^{[q]}x_{nis}\right)}{\sum_{j=1}^{J}\exp\left(\beta_n^{[q]}x_{njs}\right)}\right]^{y_{njs}}}\right\}$$

Hybrid model

- Most recent estimation method is a hybrid of mixed logit and latent class logit models
- At first, we estimate attribute parameters by using the LCM, and then mixed logit models are applied to each estimated class

$$\sum_{n=1}^{N} lnP_n = \sum_{c=1}^{C} ln \sum_{c=1}^{C} \frac{\exp(\delta_c Z_n)}{\sum_{c=1}^{C} \exp(\delta_c Z_n)} \prod_{s=1}^{S} \sum_{j=1}^{J} \varphi_{njc}$$

Where $\varphi_{njc} = \int \frac{\exp(X_{nis}\beta_c)}{\sum_{j=1}^{J} \exp(X_{njs}\beta_c)}$ is the conditional choice probability with an open form

Survey outline

- Korea NOG's Energy Network launched this project on this early June.
- Korea Research company developed online platform for the CE based survey
- In June. 26th, 2018, initial survey questionnaire was designed based on advices from the focus group
- Preliminary survey: 2018. 8. 8 ~ 8. 15 (82 respondents)
- Final survey: 2018. 8. 28 ~ 9.12. (424 respondents)

Survey Design

- Socio-economic and demographic questions, awareness on green electricity and energy sources for electricity, consciousness on environment, questions on electricity tariff, and political propensity were included in the survey
- 16 choice sets were created from D-efficiency orthogonal design, and they are allocated to 4 blocks of respondents.
- Hence, each respondent was asked to answer 4 choice set questions
- Each choice set has 3 alternatives that vary depending on different levels for 4 attributes, so total observations are 424*3*4=5,088

Attributes and levels used in the choice experiment survey

Type of attribute	Attribute	Level
Green energy sources	Solar	0 / 1
	Wind	0 / 1
	Bio-energy	0 / 1
Other factors	Share of green electricity (%)	25/ 50/ 75 / 100
	Premium monthly electricity bill (1,000KRW)	2.5 /5.0 /7 .5 /10
Method of using the certifi cate	Sales of the certificate	0 / 1
	Donation to low income family	0 / 1

An example of choice sets

Attribute	Green certificate type A	Green certificate type B	No willingness to participate green certificate
Renewable energy type	Bio	Wind	
Green electricity share	100%	75%	
Use of green certificate	Sales	Donation	
Premium electricity tariff(KRW/month)	10000	2500	
Your choice	□	□	□

Estimation results: CLM

Variable	Coefficient
Wind power	0.407***(0.134)
Solar PV	0.861***(0.134)
Bio energy	0.341**(0.134)
Green share	0.003**(0.001)
Price premium	-0.0002***(0.0000)
Sales of certificate	0.310***(0.063)
Log likelihood	-1745.6883
Pseudo R^2	0.0631
N. of obs.	5,088

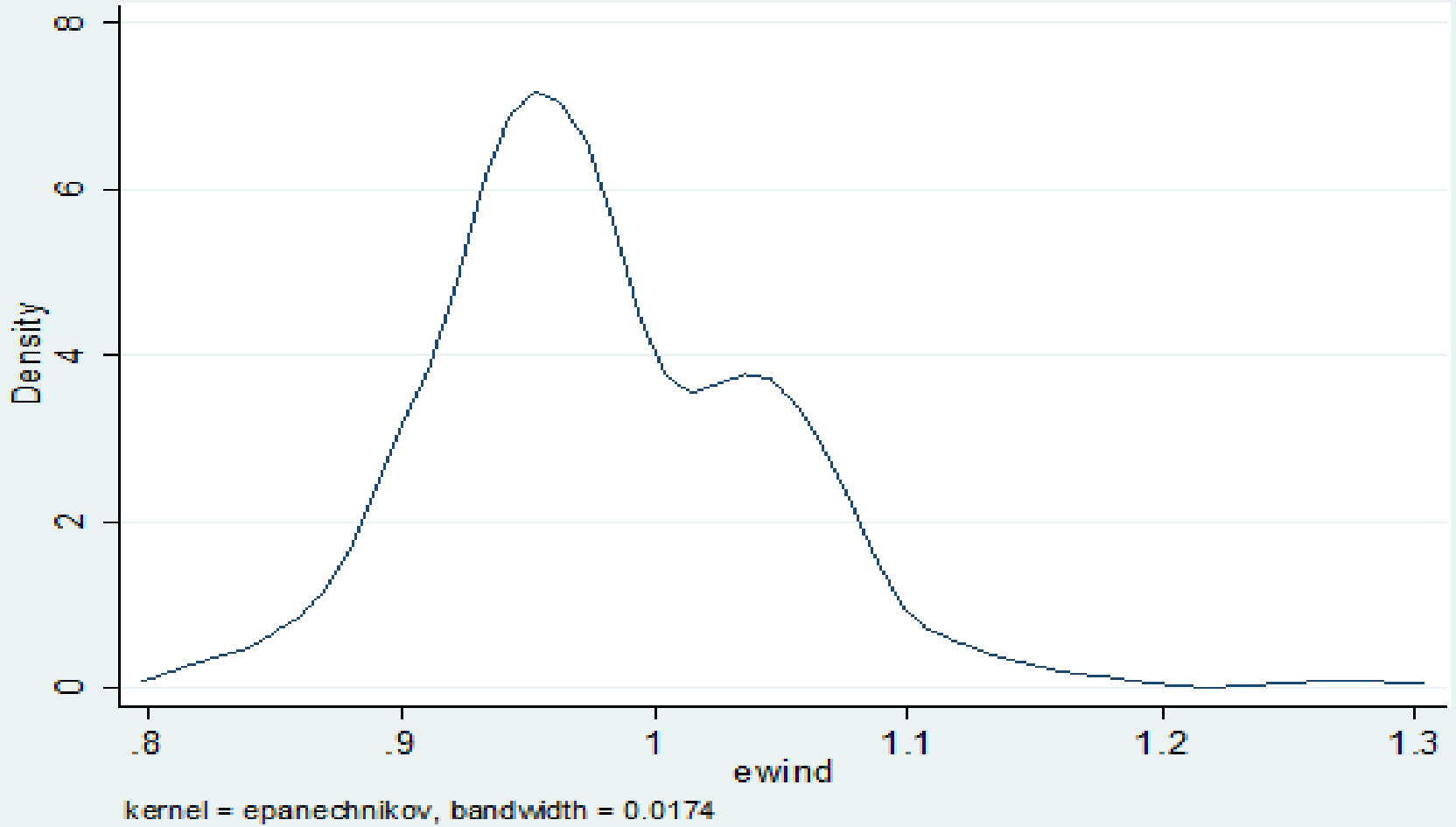
Estimation results : CLM_INT (income)

Interaction variable	Income	Education	Age	Sex	Distance
Wind power	0.024(0.009)***	0.036(0.011)***	0.026(0.013)*	0.057(0.062)	0.055(0.021)***
Solar PV	0.065(0.009)***	0.076(0.011)***	0.052(0.013)***	0.112(0.060)*	0.071(0.020)***
Bio energy	0.026(0.009)***	0.038(0.011)***	0.005(0.013)	0.0520.059)	0.035(0.020)*
Green share	0.001(0.000)***	0.001(0.000)***	-0.000(0.000)	0.000(0.001)	0.000(0.000)
Sales of certificate	0.024(0.005)***	0.030(0.006)***	0.020(0.007)***	0.108(0.041)***	0.037(0.010)***
Interaction variable	Gov. Effort	Pollution	Progressive	Neutral	Conservative
Wind power	0.070(0.026)***	0.081(0.032)**	0.203(0.067)***	0.025(0.062)	-0.041(0.083)
Solar PV	0.108(0.025)***	0.136(0.031)***	0.325(0.067)***	0.194(0.059)***	-0.216(0.083)***
Bio energy	0.001(0.026)	0.011(0.031)	0.105(0.065)	0.025(0.061)	0.046(0.081)
Green share	0.001(0.001	0.001(0.001)	0.006(0.001)***	0.001(0.001)	-0.004(0.002)***
Sales of certificate	0.054(0.015)***	0.059(0.017)***	-	-	-
Donation of certificate			0.185(0.048)***	0.133(0.041)***	-0.002(0.062)

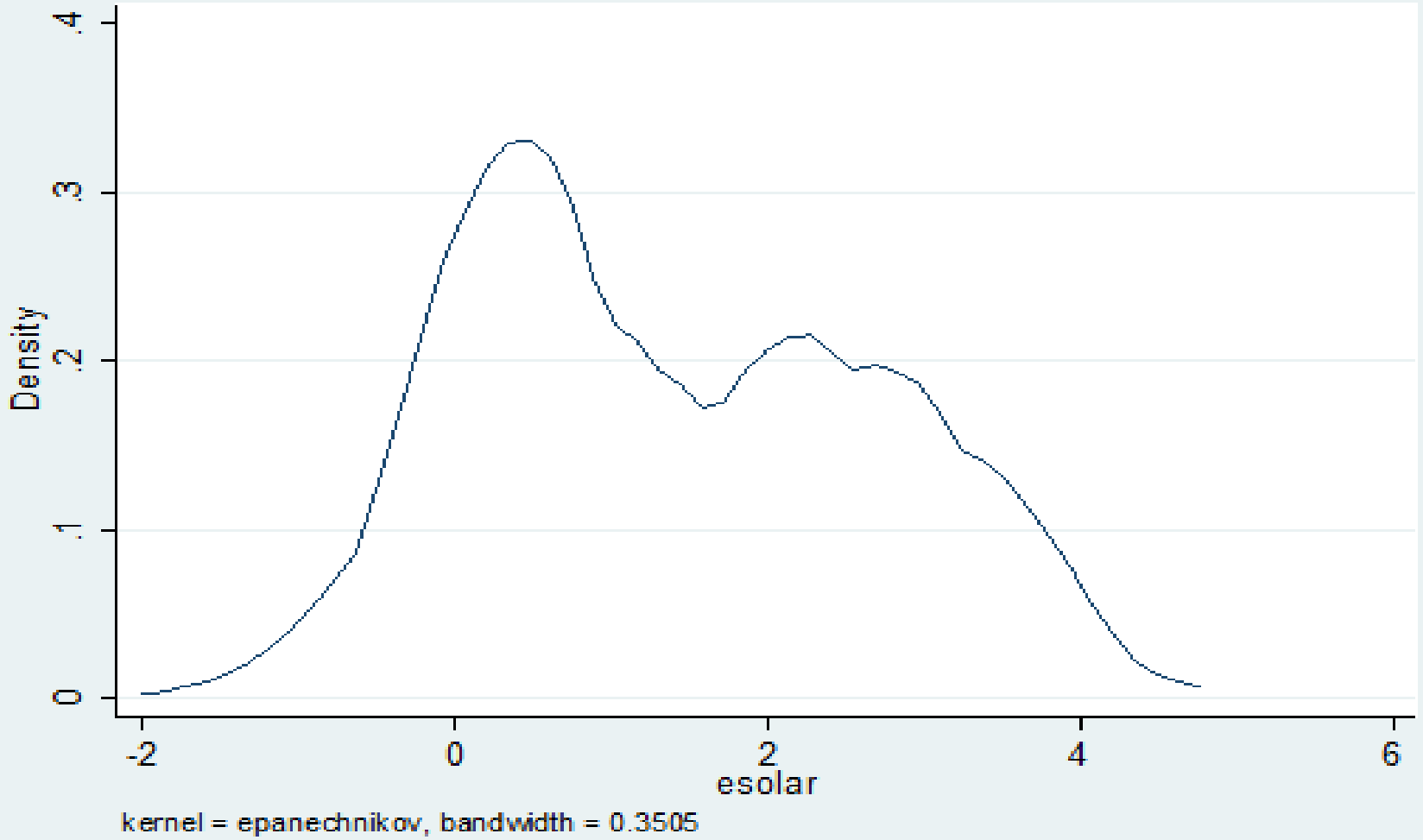
Estimation results: RPL model

Attribute	Coefficient
Mean	
Tariff premium	-0.3596(0.0336)***
Wind power	0.9793(0.1326)***
Solar PV	1.4062(0.1761)***
Bio energy	0.7846(0.1535)***
Green share	0.0001(0.0039)
Sales of certificate	0.2679(0.0976)***
S.D.	
Wind power	0.3081(0.2106)
Solar PV	1.8860(0.2267)***
Bio energy	1.1815(0.1529)***
Green share	0.0587(0.0045)***
Sales of certificate	1.2839(0.1451)***
Log likelihood	-1358.49
LR-χ	774.41***
N. of obs.	5,088

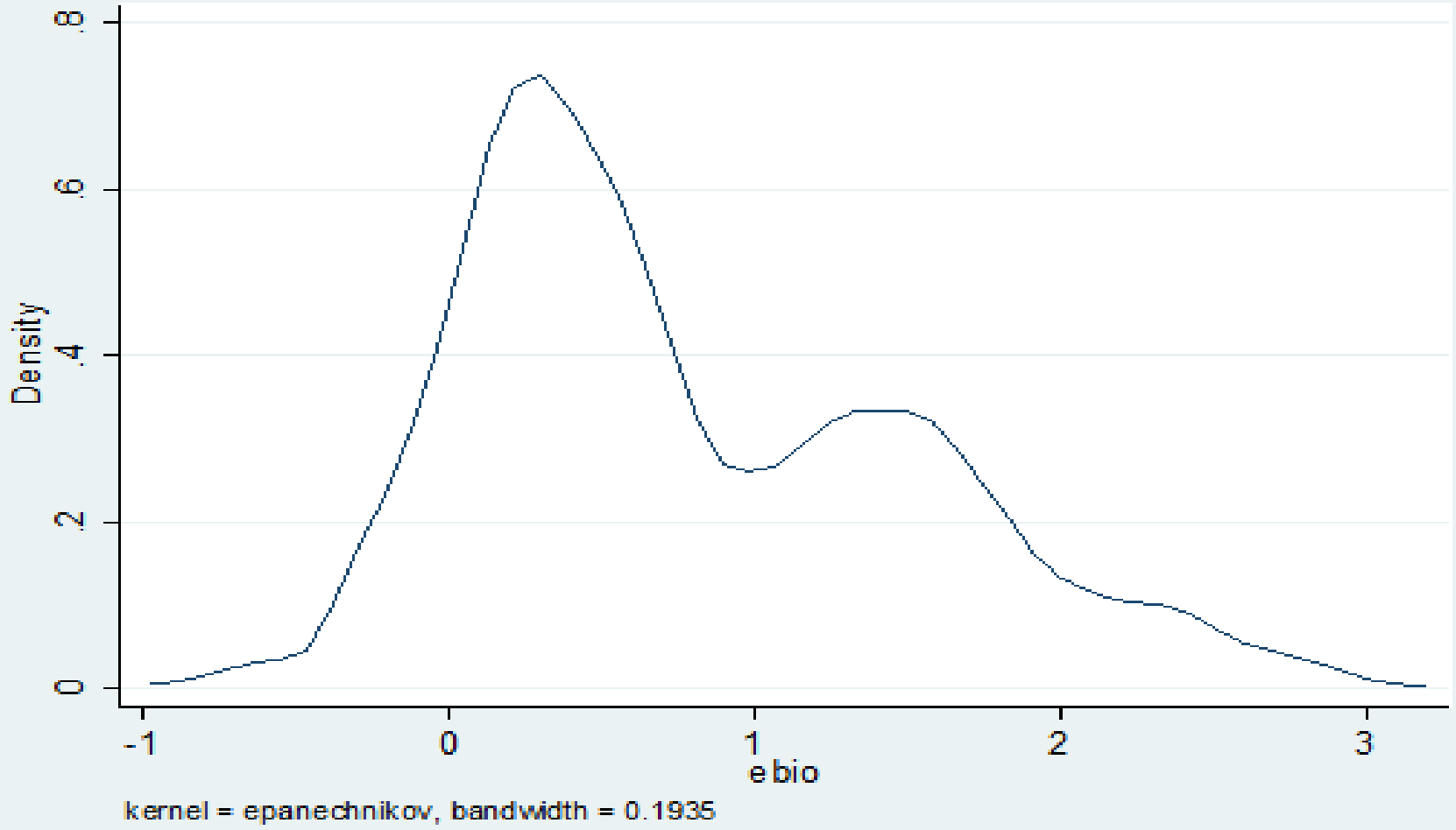
Individual parameter estimation for wind



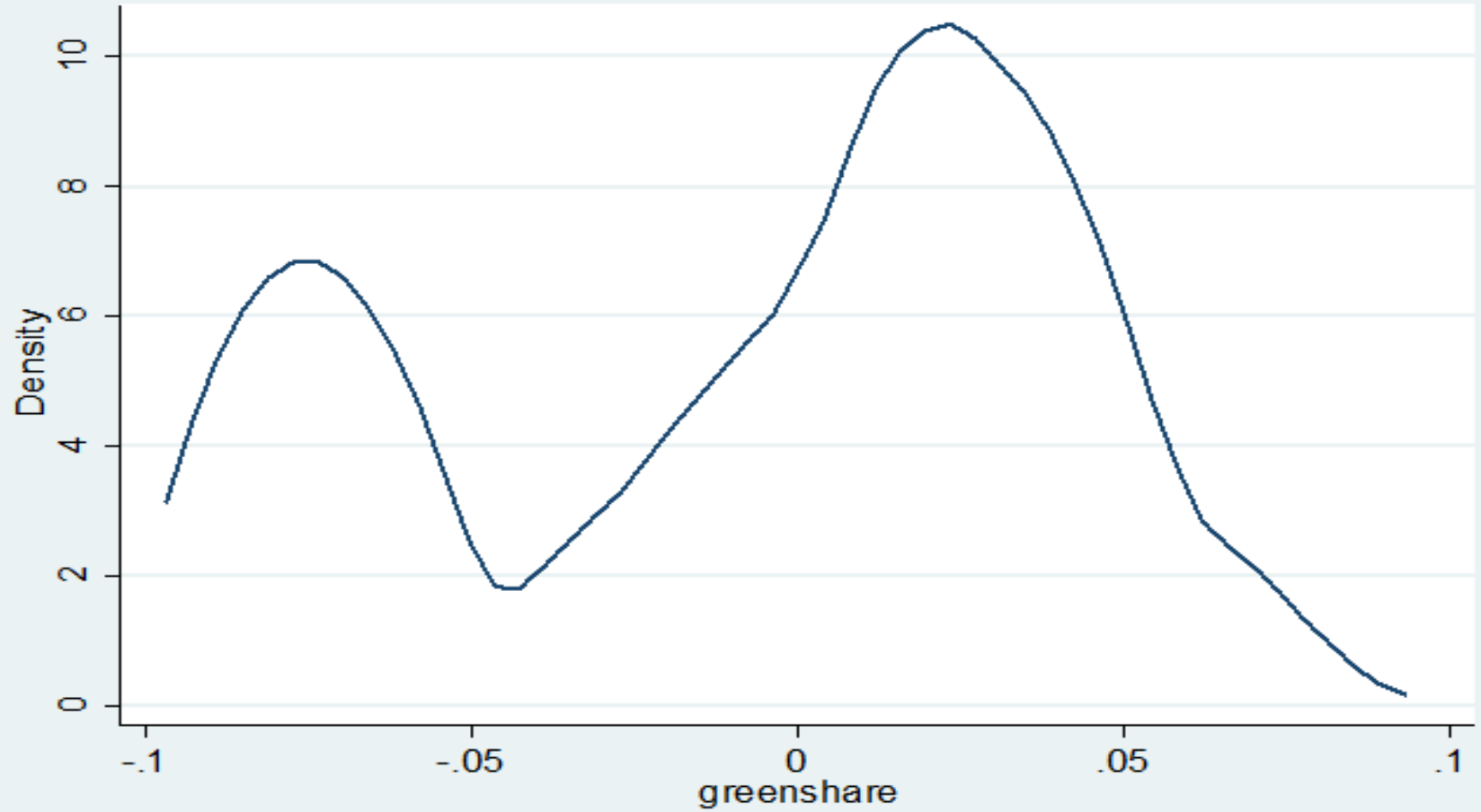
Individual parameter estimation for solar



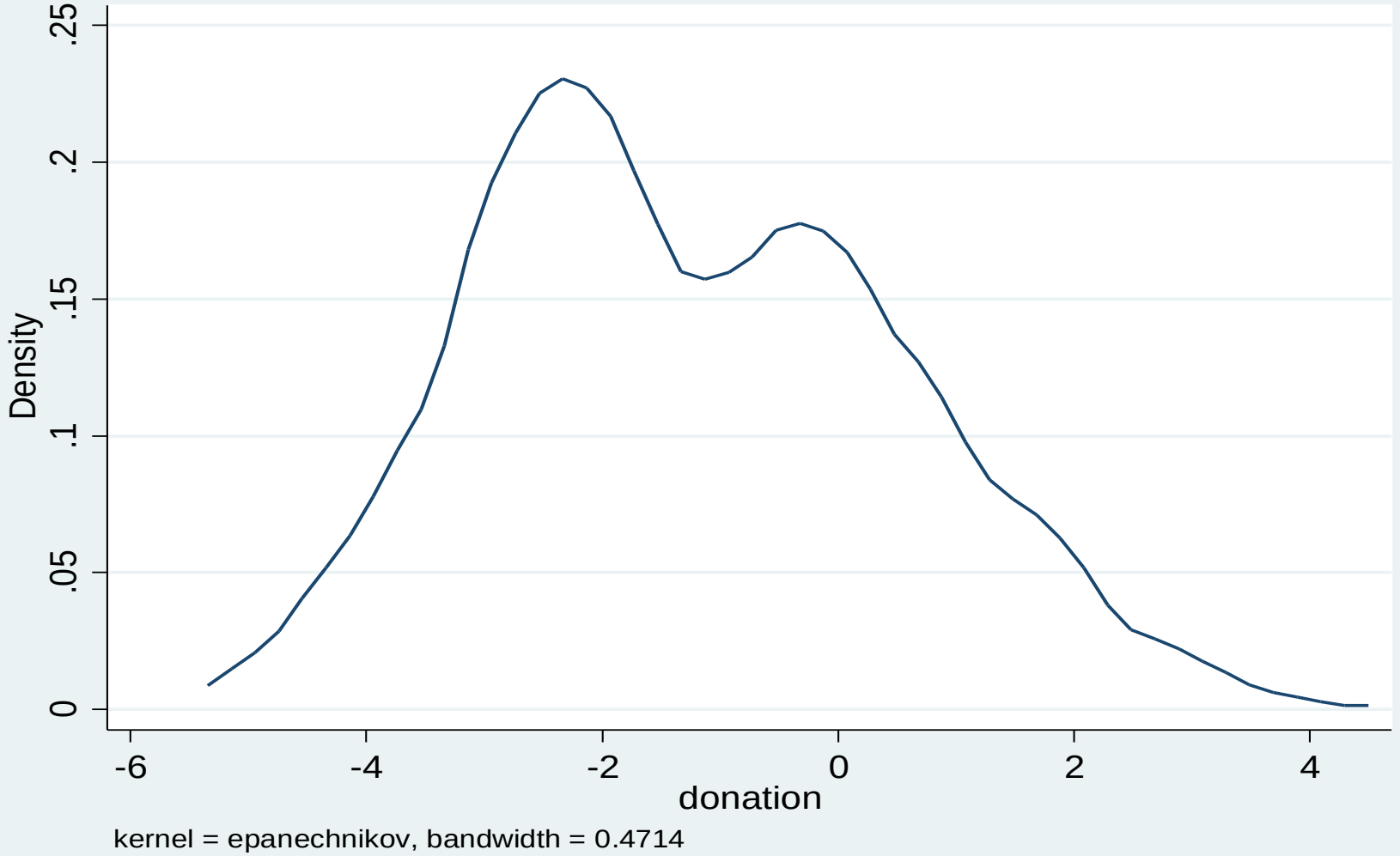
Individual parameter estimation for bio-energy



Individual parameter estimation for green electricity share



Individual parameter estimation for donation



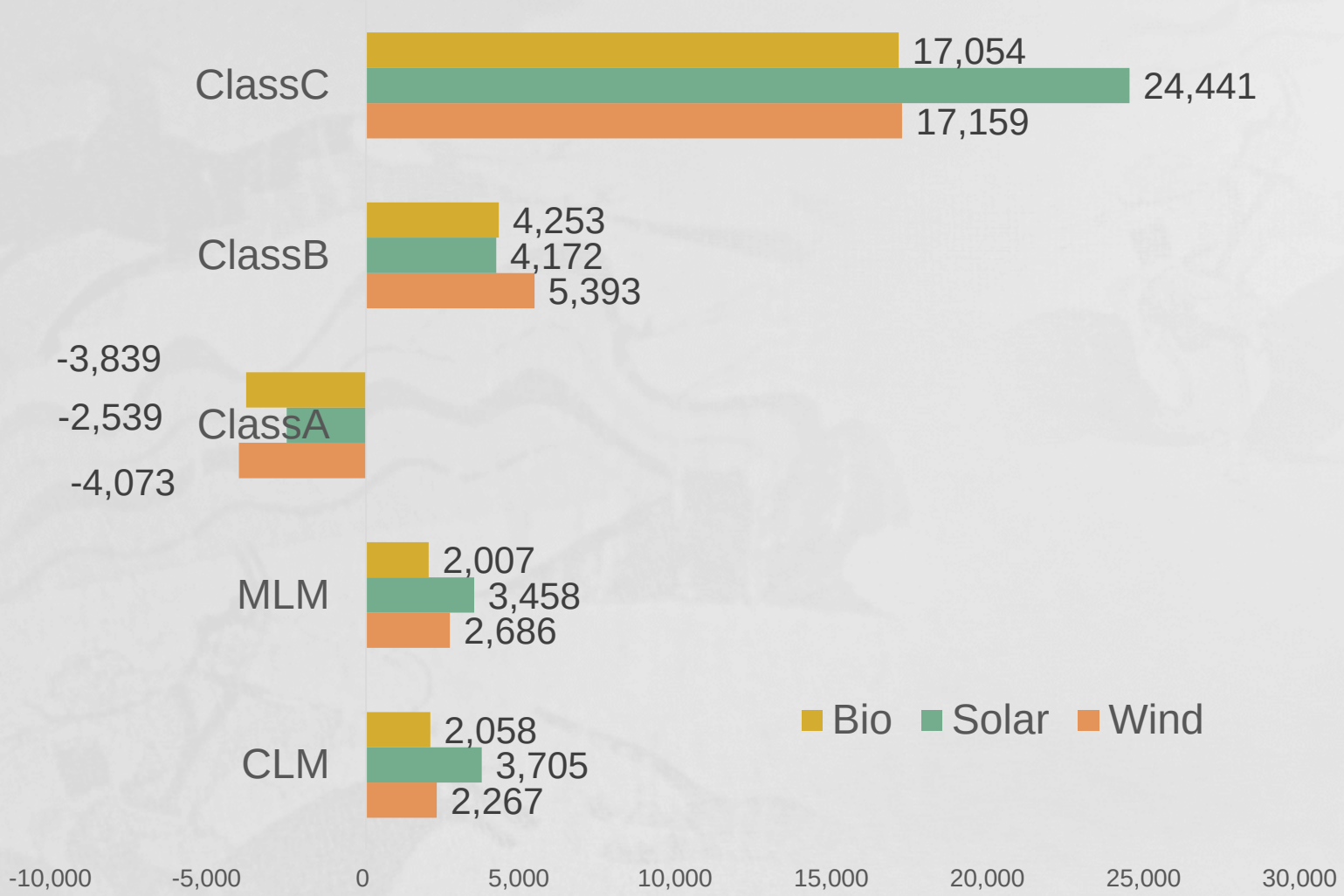
Estimation results for LCM

Class type	Class A	Class B	Class C
Attribute	Coefficient	Coefficient	Coefficient
Wind power	-1.5804(0.3991)***	6.7113(1.8963)***	1.0244(0.1794)***
Solar PV	-0.9852(0.3204)***	5.1913(1.3365)***	1.4591(0.1756)***
Bio energy	-1.4897(0.3269)***	5.2926(1.3258)***	1.0181(0.1750)***
Tariff premium	-0.0004(0.0001)***	-0.0012(0.0003)***	-0.0001(0.0000)***
Green share	0.0133(0.0069)*	0.0112(0.0103)	0.0018(0.0019)
Sales of certificate	0.5090(0.1834)***	-0.7698(0.3022)**	0.2017(0.0491)***
Class membership			
Income	-0.1341(0.0555)**	-0.0627(0.0743)	-
Constant	0.5495(0.3626)	-0.2571(0.5149)	-
Class share	0.3360	0.2290	0.4350
Log likelihood	-1228.96		
N. of obs.	5,088		

Estimation results for Hybrid

Class type	Class A	Class B	Class C
Mean	Coefficient	Coefficient	Coefficient
Wind power	-2.8506(1.0848)***	23.2309(6.6593)***	1.8398(0.3443)***
Solar PV	-3.1080(1.2409)**	16.8241(4.6749)***	3.3503(0.3909)***
Bio energy	-2.6870(0.9022)***	18.0848(5.0307)***	1.9769(0.3431) ***
Tariff premium	0.0006(0.0001)***	-0.0022(0.0006)***	-0.00003(0.000028)
Green share	0.0083(0.0091)	0.0323(0.0111)***	0.0020(0.0027)
Sales of certificate	0.7449(0.6937)	-2.7384(0.8252)***	0.6368(0.1728)***
S.D.			
Wind power	0.8680(1.1166)	0.0068(0.9914)	1.0208(0.3608)***
Solar PV	3.5115(1.1483)***	0.1930(1.0059)	1.4048(0.3570)***
Bio energy	0.7818(0.7953)	-0.6108(1.1746)	0.7258(0.3408)**
Green share	0.0139(0.0061)**	0.0315(0.0152)**	-0.0066(0.0051)
Sales of certificate	1.7153(0.7848)**	-0.7334(0.9416)	1.4504(0.2494)***
LR	26.27***	4.8700	45.28***
Log likelihood	-176.6560	-99.2598	-492.1021
N. of obs.	1,740	1,356	1,992

WTPs for renewable electricity



Political preference for energy sources

- Respondents (33%) whose political preference is progressive prefer wind or solar PV with higher green electricity share, and displayed a positive preference for the donation of green certificates.
- On the other hand, politically neutral respondents (47%) prefer only solar PV, and do not prefer donating green certificates.
- Conservative Respondents (20%) indicate negative preferences for wind, solar PV, green electricity share, and the donation of green certificates to low income households.

Pro-renewable vs. anti-renewable group

- According to the LCM, class A (33.6%) revealed negative preference on renewable energy, while class B (22.9%) shows strongly positive preference.
- Class C (43.5%) has positive but weak preference.
- Thus, Korean electricity consumers can be separable to an anti-renewable energy group vs. pro-renewable energy group.
- The pro-renewable energy group is divided into renewable-enthusiastic vs. renewable-moderate group.

Price gap bet. RECs and green certificates

- Households WTPs for the green certificates by energy sources, solar PV, wind, and bio energy are estimated as 10.83~11.6, 8.06~8.93, and 7.25~7.54KRW/kWh, respectively.
- In 2018, average REC price in Korean was about 98KRW/kWh, while the U.S. REC price was $0.31 and $0.7/MWh .
- Therefore, Korean companies, as potential buyers of the green certificates, would have incentives to participate in the green certificate market as the price of green electricity is much less than the current Korean RECs.

Thanks for paying attention to my presentation!