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Analysis on the Changes of Household Electricity Consumption over the Past Three Decades

Wen-Hsiu Huang

Department of Public Finance, Ling Tung University, Taiwan
Email: michelle@teamail.ltu.edu.tw

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Abstract

This study uses the Blinder-Oaxaca decomposition to investigate what are the main reasons that contribute to the changes of household electricity consumption. The household data in Taiwan over the period 1985-2015 are used. The empirical results indicate that the changes of household electricity consumption are driven by different factors across these three decades. The increase in household electricity consumption is mainly attributed to the changes in the coefficients effect of the determinants. In particular, the coefficients effect of household size plays the most important role. The declining of household size leads to electricity consumption per capita increases due to the loss of economies of scale. As for the contribution of the endowments effect, the number of air condition and household income are the most important factors. Moreover, the coefficients effect of household size is crucial both for high-income and low-income households. Therefore, the policy implication means that the electricity pricing policy should take household size into consideration so as to offer electricity-saving incentives for households with smaller family size. Besides, some strategies, such as improving energy efficiency of appliances and providing the subsidy for the investment in energy-efficient appliances, should have a higher priority.

Keywords

Electricity Consumption, Decomposition, Household, Cross-Sectional, Socio-Economic Characteristics

1. Introduction

With economic growth and industrial development, electricity consumption has increased rapidly in many countries over the past three decades. According to

the statistics from the Bureau of Energy, Ministry of Economic Affairs of Taiwan, the share of electricity in final energy consumption rose from 35% to 49% from 1982 to 2017. In 2017, total electricity consumption was 261,308 MWh, which was more than 6.4 times greater than electricity use in 1982. Between 1982 and 2017, the average annual growth rate of total electricity consumption was 5.5%. In 2017, Taiwan's per capita electricity consumption was 11.2 MWh, which was higher than the world average of 3.1 MWh per capita. It ranked first in Asia and the 12th in the world. The considerable growth trend of electricity consumption is also displayed in the residential sector. From 1982 to 2017, Taiwan's residential electricity consumption has increased by 500%. The residential sector is responsible for 19% of total electricity use, which is only second to the industrial sector (50%). The continuous rise in household electricity consumption is adverse to the aims of energy conservation and environmental protection. Since Taiwan is highly dependent on imported energy and under the risk of insufficient power supply, seeking effective strategies for reducing electricity use is an important target for policymakers. Thus, it is necessary to investigate what are the main reasons that contribute to the change of household electricity consumption.

Many studies have explored the possible factors that affect household electricity consumption. In general, household electricity consumption is associated with various factors, such as socio-demographic characteristics [1] [2] [3] [4] [5], economic ability [6] [7] [8] [9] [10], physical characteristics of the dwelling [2] [3] [11], residential location [5] [9] [12], environmental and climate factors [11] [13], the costs of energy use [7] [14] [15], urban form [16] and lifestyle factors [17]. Understanding the characteristics of household electricity consumption and its driving factors is vital for making proper strategies related to household energy savings. Most of these studies are based on the analysis of cross-sectional household data, which has an advantage over the aggregate time series mainly since it takes account of controlling heterogeneity in the households and deal with the effects of household characteristics on electricity demand [18].

Few studies have paid attention to the issues about household electricity consumption with the view of historical changes or intertemporal comparisons. Lacking the necessary data is the main barrier to studying household electricity consumption [1]. To compare the estimation results along the time dimension, Nesbakken [14], Kaza [19] and Huang [9] employed the cross-sectional household data from different years in order to depict the trends in the marginal effects of various variables on household energy consumption. However, since their studies are based on a repeated cross-sectional sample but not a panel data, tracking trends in the marginal impacts or behavioural changes only capture the impacts on a specific time point. On the other hand, although the longitudinal data can be used to capture the relationship across time and forecast the future trend, it is only suitable for applying in the estimation of the relationships between aggregate variables and electricity consumption. For instance, Holtedahl

and Joutz [20] examined the effects of household income, population growth, and electricity prices on residential demand for electricity. Hamdi *et al.* [21] explored the relationship between electricity consumption, foreign direct investment, capital and economic growth. Those studies may aim to identify the contribution of determinants or forecast future trends in household electricity consumption. But, it must be under the assumption that the relationship of dependent variable to its determinants is stable. Nevertheless, it is unlikely to satisfy this assumption, because the distributions of the determinants may change and structural changes may alter the impacts of determinants [22].

According to previous studies, it is necessary to consider the changes in the distributions of determinants when we explore household electricity consumption along the time dimension. The first reason is that the household structure and generations had changed over time. Some studies indicated that household size has gradually decreased [9] [19]. And, energy use behavior may differ between the younger and older generations [23]. The transitions in the distribution of household characteristics may lead to the change of household electricity consumption. The second reason is that technological progress affects energy efficiency and energy structure. Consequently, household appliance ownership and usage patterns may vary across time [24]. Therefore, accounting for the possible changes in the distributions of determinants and the shifts of the determinants contribution, we use the Blinder-Oaxaca decomposition to explain the changes in household electricity consumption in Taiwan over the period 1985-2015. We try to clarify that the change of household electricity consumption should be mainly attributed to the differences in the mean values of the predictors (endowments effect) or the differences in the contributions of the predictors (coefficients effect). We identify what are the main reasons that drive the increase of household electricity consumption. Furthermore, we also explore whether there are different decomposition results between the high-income and low-income households.

This paper takes the advantage of the Blinder-Oaxaca decomposition to detect the critical reasons for the change of household electricity use. The results highlight that demographic structure and socio-economic characteristics would have critical influence on household electricity use. The increase in household electricity consumption is mainly attributed to the changes in the coefficients effect of the determinants. In particular, the coefficients effect of household size plays the most important role. This study can provide new findings on the issue of household electricity consumption with a historical perspective. The application of decomposition technique not only allows us to distinguish the change of household electricity consumption into difference sources, but also reveals the relative importance of driving sources.

2. Methods and Data

2.1. Methods

We start our analysis by using the ordinary least squares regression to estimate

the effects of the predictors on household electricity consumption. The ordinary least squares regression can reflect the effects of individual factors on household electricity consumption. However, it cannot describe the relative importance of these factors in contribution to the change in household electricity consumption. Furthermore, we employ the Blinder-Oaxaca decomposition, based on linear regression and developed by Blinder [25] and Oaxaca [26], to study what factors contribute to the differences in the outcome variable between two groups. Given the two groups from period *t* to *s*, we estimate a regression model of the form:

$$Y_g = X'\beta_g + \varepsilon_g, g = s,t, \ E(\varepsilon_g) = 0 \quad (1)$$

where Y_g represents household electricity consumption of the two groups, and X is a vector of observable characteristics. β is the vector of parameter to be estimated, and ε is the error term. The mean outcome difference, denoted as D, can be expressed as follows:

$$D = E(Y_s) - E(Y_t) = E(X_s)'\beta_s - E(X_t)'\beta_t \quad (2)$$

$E(Y)$ is the expected value of the outcome variable. The contribution of group differences in predictors to the outcome difference can be represented as follows [27]:

$$D = \{E(X_s) - E(X_t)\}'\beta_t + E(X_t)'(\beta_s - \beta_t) + \{E(X_s) - E(X_t)\}'(\beta_s - \beta_t) \quad (3)$$

As the group means $\bar{X}_s$ and $\bar{X}_t$ are used as estimates for $E(X_s)$ and $E(X_t)$, the expression can be written as:

$$D = \bar{Y}_s - \bar{Y}_t = (\bar{X}_s - \bar{X}_t)'\hat{\beta}_t + \bar{X}_t'(\hat{\beta}_s - \hat{\beta}_t) + (\bar{X}_s - \bar{X}_t)'(\hat{\beta}_s - \hat{\beta}_t) \quad (4)$$

where $\hat{\beta}_s$ and $\hat{\beta}_t$ are the estimated coefficients, obtained separately from the two samples. The coefficients in the sample of the period *t* are used as the reference in Equation (4). If the coefficients in the sample of the period *s* are used as the reference, the decomposition can be expressed as another form:

$$D = \bar{Y}_s - \bar{Y}_t = (\bar{X}_s - \bar{X}_t)'\hat{\beta}_s + \bar{X}_s'(\hat{\beta}_s - \hat{\beta}_t) + (\bar{X}_s - \bar{X}_t)'(\hat{\beta}_s - \hat{\beta}_t) \quad (5)$$

The outcome difference is divided into three components. The first component is group differences in the mean values of the predictors, which can be referred as the endowments effect. For example, the distribution of household income and housing area may vary across time. The second component is differences in the coefficients of the predictors, which can be referred as the coefficients effect or marginal effect. For instance, household appliances may consume less electricity because of the improvement of energy efficiency. The third component is the interaction term that is due to the simultaneous effect of differences in endowments and coefficients, which is denoted as the interaction effect. Since this component is difficult to interpret, many researchers do not address it [28]. In this paper, we would not focus on this item either. The Blinder-Oaxaca decomposition has been widely applied in the studies of wage discrimination [25] [26] [28], health status differences [29], and education inequality [30] [31].

However, the Blinder-Oaxaca decomposition has not been applied to the issues of energy consumption. We extend the application of Blinder-Oaxaca decomposition to the analysis of household electricity use. This method can help us to investigate the determinants of household electricity consumption with a view of time dimension and illustrate the relative importance of driving sources.

2.2. Data

This study uses the household data which are obtained from Taiwan's Family Income and Expenditure Survey (FIES). This is a nationwide cross-sectional survey that has been conducted annually by the Taiwanese government, but households are not tracked. There are approximately 15,000 households involved in this survey for each year. The database of Taiwan's FIES contains household information such as demographic characteristics, property and facilities, income and expenditure. We use the household data in 1985, 1995, 2005, and 2015 so as to analyse the change of household electricity consumption for the periods: 1985-1995, 1995-2005, and 2005-2015. In particular, we aim to investigate what factors contribute to the change of household electricity consumption from 1985 to 2015.

However, the FIES database only collects household electricity expenditure, and household electricity use is not available. Therefore, the dependent variable needs to be calculated by using electricity prices, which are based on the progressive electricity tariff system. Thus, household electricity expenditure can be transformed into household electricity use. The electricity prices data are obtained from Taiwan Power Company, which is a state-owned company. The dependent variable can be defined as total annual electricity use per household and measured in kWh. Table 1 reports the descriptive statistics for household electricity consumption. The mean value of household electricity consumption increased from 2308 kWh in 1985 to 5227 kWh in 2005, and then declined slightly to 5019 kWh in 2015. The decrease of household electricity consumption may be related to the change of the electricity tariff structure. The brackets increased and the electricity tariffs were adjusted upward. Especially, higher prices were set for high electricity users. Furthermore, electricity tariffs continued to rise and adjust more frequently than before. Thus, in the 90th percentile, household electricity use decreased from 8005 kWh in 2005 to 7182 kWh in 2015.

Table 1. Descriptive statistics for household electricity consumption.

	1985 database	1995 database	2005 database	2015 database
Mean	2307.57	4507.42	5226.74	5019.21
Standard deviation	1186.04	2619.29	2557.09	1797.37
10th percentile	1220.83	2023.82	2598.57	2854.18
50th percentile	2072.26	4117.99	4869.93	4839.32
90th percentile	3627.10	7188.94	8004.57	7182.37

Notes: Household electricity consumption is measured in kWh.

The explanatory variables are classified into three categories: household head characteristics, household characteristics, and dwelling attributes. Household head characteristics include age, gender, and education. The age of household head is a continuous variable, which captures the life-cycle stage of a household and generation effects. Gender is represented by a dummy variable that takes value 1 for male and 0 for female. Education level is an ordinal variable, measured by the highest degree that household heads obtain. We assign scores 1, 2, 3, and 4, respectively, to the four levels: less than junior high school, junior high school, senior high school, and bachelors or graduate degree. Household characteristics include household size, the number of elderly members, the number of wage earners, and household income. Household size is defined as the number of household members. Some studies have shown that electricity consumption per capita may decline since family members can share appliances. The effect of economies of scale may exist in electricity consumption [12] [32]. The number of elderly members can represent the seniority effect on electricity use since the electricity consumption patterns may be different between order and younger generations. The elderly are defined as household members aged 65 years and older. We also consider the number of wage earners. As the number of wage earners increase, the economic ability of household would be improved. On the other hand, household with more wage earners may consume less electricity since individuals with a job spend less time at home. Another important variable to capture economic ability is household disposable income, which includes both regular and non-regular income after expenses, such as taxes, housing rent, interest and insurance payment. We transform household disposable income into a real term. Household disposable income is deflated by the consumer price index, whose base year is 2011.

Dwelling attributes contain ownership status, whether the house is used for business, the number of floors, housing area, and household appliance ownership. Ownership status is measured by dummy variable, valued at 1 if the house is owner occupied and 0 otherwise. Ownership status may influence households' incentive to invest in energy-efficient appliance and the willingness to buy appliances. We also consider that residential houses may be used for business if the member of households is self-employed. The house used for business may consume more electricity. We use a dummy variable, taking value 1 if the house is not used for business and 0 otherwise. In addition, we use dummy variables for the number of floors, which are classified into four categories: 1 floor, 2 to 3 floors, 4 to 5 floors, and more than 5 floors. The first category served as the reference category is omitted. Housing area is a continuous variable, measured by total housing area in square meters. Lastly, we also include the number of household appliances in the model. We consider the number of televisions, water heaters, air conditioners, and washing machines. The descriptive statistics for explanatory variables are reported as **Table 2**. The statistics show that the age of household head, the number of elderly members, the ratio of female-headed household, and the education level of household head exhibited an upward

Table 2. Descriptive statistics for explanatory variables.

Variables	1985 dataset				1995 dataset			
	Mean	SD	Max	Min	Mean	SD	Max	Min
Continuous/Numeric variables								
Age of household head	41.85	12.29	90	16	44.44	13.21	94	15
Household size	4.60	1.94	21	1	3.93	1.73	16	1
Number of elderly members	0.22	0.51	3	0	0.34	0.62	4	0
Number of wage earners	1.82	1.08	9	0	1.71	1.05	8	0
Household income (thousand NT dollars)	514.76	297.89	5061	1.59	981.10	624.73	13,413	5.69
Housing area (m^2)	99.71	52.70	892	1.50	122.56	68.84	2148	3.31
Number of televisions	1.05	0.33	5	0	1.29	1.02	8	0
Number of water heaters	0.72	0.53	4	0	1.02	0.39	5	0
Number of air conditioners	0.30	0.62	7	0	1.13	1.12	10	0
Number of washing machines	0.79	0.43	10	0	0.94	0.29	3	0
	N		%		N		%	
Dummy/Categorical variables								
Gender of household head								
Male	14,814		90.5		12,585		85.7	
Female	1562		9.5		2103		14.3	
Education level of household head								
Less than junior high school*	7691		47.0		4809		32.7	
Junior high school	2587		15.8		2553		17.4	
Senior high school	3477		21.2		4024		27.4	
Bachelors or graduate degree	2621		16.0		3302		22.5	
Ownership								
Own	12,687		77.5		12,247		83.4	
Rent	3689		22.5		2441		16.6	
Business use								
No	14,738		90.0		13,765		93.7	
Yes	1638		10.0		923		6.3	
Number of floors								
1 floor*	5650		45.8		2967		20.2	
2 - 3 floors	6633		35.7		6307		42.9	
4 - 5 floors	3611		16.9		3948		26.9	
>5 floors	482		1.6		1466		10.0	
Total observations	16,376				14,688			
Variables	2005 dataset				2015 dataset			
	Mean	SD	Max	Min	Mean	SD	Max	Min
Continuous/Numeric variables								
Age of household head	48.96	14.39	96	16	52.27	14.81	101	16
Household size	3.39	1.58	13	1	3.09	1.48	15	1

Continued

Number of elderly members	0.46	0.71	3	0	0.59	0.77	4	0
Number of wage earners	1.48	1.03	7	0	1.41	1.06	7	0
Household income (thousand NT dollars)	963.95	669.34	11,185	3.47	928.56	665.39	21,216	10.08
Housing area (m^2)	140.56	75.48	1322	6.31	146.49	76.56	1124	9.92
Number of televisions	1.49	0.72	7	0	1.57	0.79	9	0
Number of water heaters	1.03	0.35	4	0	1.07	0.33	6	0
Number of air conditioners	1.82	1.32	11	0	2.29	1.35	11	0
Number of washing machines	0.98	0.23	4	0	1.01	0.21	4	0
	N		%		N		%	
Dummy/Categorical variables								
Gender of household head								
Male	10,655		78.0		11,632		70.4	
Female	3011		22.0		4888		29.6	
Education level of household head								
Less than junior high school*	3410		25.0		2973		18.0	
Junior high school	2210		16.2		2458		14.9	
Senior high school	4033		29.5		5026		30.4	
Bachelors or graduate degree	4013		29.4		6063		36.7	
Ownership								
Own	11,921		87.2		13,892		84.1	
Rent	1745		12.8		2628		15.9	
Business use								
No	13,024		95.3		15,916		96.3	
Yes	624		4.7		605		3.7	
Number of floors								
1 floor*	1828		13.4		1630		9.9	
2 - 3 floors	6013		44.0		6717		40.7	
4 - 5 floors	3386		24.8		4749		28.7	
>5 floors	2439		17.8		3424		20.7	
Total observations	13,666				16,520			

Notes: SD means standard deviation. * is used as the reference category.

trend, while household size and the number of wage earners gradually declined. As for dwelling attributes, housing area and the number of household appliances showed an increasing trend. It is worth noting that household income increased from 515 thousand NT dollars in 1985 to 964 thousand NT dollars in 2005, and then decreased to 929 thousand NT dollars in 2015. This phenomenon reflected the stagnation of real income in Taiwan for the past decade.

3. Empirical Results

3.1. Estimation Results of the Ordinary Least Squares Regression

We first use the ordinary least squares regression to estimate the effects of possi-

ble factors on household electricity consumption. We focus on the household datasets in 1985, 1995, 2005, and 2015, which represent four time points from different decades. Table 3 reports the estimation results of the ordinary least squares regression. The results show that the effects of household head characteristics are not significant in 1985 and 1995. The age effect only is significantly negative in 2015, suggesting that the elder-headed households consume less electricity than the younger-headed households. The gender variable has significantly positive effects on household electricity use in 1995 and 2005. This result verifies that gender differences exist in household electricity use. Male-headed households have more electricity use than female-headed households. It is worth noting that education level of household head has positive effects on household electricity consumption. This result reflects that the increase of education level may contribute to the improvement of economic ability. Therefore, the education variable displays a positive relationship with household electricity use.

The effects of household size on household electricity consumption are significant and positive for the four datasets. The effects of household size have increased with time. This result reflects the fact that household size had decreased from 4.6 persons in 1985 to 3.1 persons in 2015. Since the decline of household size would result in a loss of economies of scale, the effects of household size on

Table 3. Estimation results of ordinary least squares regression.

Variables	1985		1995		2005		2015	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Intercept	757.13**	52.19	658.80**	146.37	793.80**	2.68	1624.67**	109.40
Age	0.71	0.63	2.18	1.62	2.68	1.68	−1.86*	0.95
Gender	12.17	24.02	−16.51	49.98	85.66*	43.11	73.00**	22.70
Education	−10.95	7.30	8.18	18.37	32.70	19.81	39.83**	12.05
Household size	130.74**	4.66	320.06**	13.30	461.49**	15.25	510.85**	9.83
Number of elderly members	−21.35	14.19	−51.80	30.38	−60.49*	29.14	59.85**	15.43
Number of wage earners	−49.21**	8.36	−50.21*	21.72	101.97**	23.57	70.64*	13.84
Income	0.92**	0.03	0.71**	0.04	0.50**	0.03	0.28**	0.02
Owner occupied	−9.93	17.55	26.64	47.40	86.45	53.48	173.32**	28.49
Without business use	−267.64**	23.37	−328.71**	70.15	−445.80**	81.99	−176.80**	53.77
2 - 3 floors	48.02**	18.11	145.04**	50.47	250.15**	63.24	173.34**	37.45
4 - 5 floors	226.86**	21.44	701.83**	54.91	583.87**	63.08	277.63**	39.22
>5 floors	463.33**	45.21	709.66**	71.66	607.04**	68.48	266.01**	41.56
Housing area	1.87**	0.16	0.62*	0.29	1.69**	0.27	0.60**	0.16
Number of televisions	152.82**	22.44	334.90**	33.24	290.92**	26.98	181.81**	14.34
Number of water heaters	75.27**	15.34	122.10**	47.69	81.81	52.93	63.00*	33.14
Number of air conditioners	639.89**	13.77	753.21**	19.24	434.61**	16.43	289.30**	9.29
Number of washing machines	156.40**	17.78	404.03**	63.17	424.38**	77.62	205.69**	49.64
Adjusted R^2	0.45		0.39		0.39		0.49	

Notes: S.E. means standard error. *, and ** represent 5% and 1% significance levels, respectively.

household electricity use would be stronger as the number of household members decreased. As expected, household income had significantly positive effects on household electricity use. The effects of household income were significant for the four datasets and gradually decreased with time. This result was consistent with the findings of Park and Heo [33] and Huang [9]. These studies show that, as the level of income increases, income elasticity for energy becomes smaller [6]. The effect of number of elderly members is significantly negative for the 2005 dataset, whereas the effect is significantly positive for the 2015 database. The findings are consistent with the results of previous studies, indicating that the seniority effects on electricity consumption are divergent. One the one hand, the elderly may spend more time at home and consume more electricity. On the other hand, the elderly would tend to be thrifty in electricity use due to economic experience [9] [34]. Also, the effects of number of wage earners are diverse across these datasets. The increase in the number of wage earners would improve the economic ability of households and induce the demand for electricity. However, an individual with a job may spend less time at home and consume less electricity. Therefore, our results show that the effects of number of wage earners are significantly negative for the 1985 and 1995 datasets, while the effects are significantly positive for the 2005 and 2015 datasets. As for the effects of dwelling attributes, we find that houses used for business would consume more electricity than those houses without business use. As expected, the number of floors, housing area, and the number of household appliances have significantly positive impacts on electricity use. Among these appliances, the marginal effect of air conditioners on electricity use is greater than that of other appliances. Furthermore, the marginal effects displayed a downward trend, which may be related to technological progress in electricity-saving, such as the increased adoption of more efficient equipment and improved housing structure.

3.2. The Changes of Household Electricity Consumption

This study employs the Blinder-Oaxaca decomposition to investigate what factors contribute to the change of household electricity consumption from 1985 to 2015. We also analyse the change of household electricity consumption for the three periods: 1985-1995, 1995-2005, and 2005-2015. The change of household electricity consumption is decomposed into three parts: endowments effect, coefficients effect, and interaction effect. Specifically, when we focus on the change of household electricity consumption from 1985 to 2015, the endowments effect reflects the increase of household electricity consumption in 1985 if the group in 1985 had the same the characteristics with the group in 2015. The coefficients effect reflects the change of household electricity consumption in 1985 if the estimated coefficients in 2015 were applied to the sample in 1985. **Table 4** reports the results of Blinder-Oaxaca decomposition.

Table 4. Results of blinder-oaxaca decomposition.

Variables	(A). Differences between 1985 and 1995			(B). Differences between 1995 and 2005		
	Endowments effect	Coefficients effect	Interaction effect	Endowments effect	Coefficients effect	Interaction effect
Intercept		−93.34			135.00	
Age	1.85	61.34	3.79	9.87	22.34	2.28
Gender	−0.58	−25.95	1.37	1.27	87.55	−7.88
Education	−3.65	39.45	6.38	1.94	58.78	5.81
Household size	−88.68**	871.61**	−128.41	−170.66**	555.20**	−75.41**
Number of elderly members	−2.61	−6.71	−3.72	−6.11	−2.98	−1.02
Number of wage earners	5.40**	−1.82	0.11	11.38*	260.08**	−34.50**
Income	429.78**	−111.49**	−101.00**	−12.09*	−202.82**	2.30
Owner occupied	−0.59	28.33	2.16	1.03	49.87	−1.86
Without business use	−9.95**	−54.97	−2.27	−5.21**	−109.73	1.11
2 - 3 floors	1.17*	39.29*	2.36	1.54	45.15	2.47
4 - 5 floors	10.95**	104.73**	22.93**	−14.75**	−31.71	−8.07
>5 floors	32.61**	7.25**	17.34**	55.82**	−10.24	19.37**
Housing area	42.89**	−125.69**	−28.81**	11.09*	131.93**	−8.07
Number of televisions	36.00**	192.33**	42.89**	67.11**	−56.82	19.37**
Number of water heaters	22.50**	33.73	13.99	0.70	−41.07	−8.81
Number of air conditioners	529.29**	34.46**	93.73**	521.34**	−360.42**	−0.23
Number of washing machines	24.47**	194.83**	38.74**	16.38**	19.19	−220.52**
Total	1030.85**	1187.40**	−18.41	490.64**	549.28**	−320.60**
Sum of three components		2199.84			719.32	

Variables	(C). Differences between 2005 and 2015			(D). Differences between 1985 and 2015		
	Endowments effect	Coefficients effect	Interaction effect	Endowments effect	Coefficients effect	Interaction effect
Intercept		830.87**			872.53**	
Age	8.88	−222.69*	−15.05*	7.45	−107.97*	−26.88*
Gender	−6.47*	−9.87	0.96	−2.44	55.02	−12.20
Education	7.37	18.76	1.61	−8.71	104.75**	40.40**
Household size	−139.82**	167.47**	−14.96**	−198.00**	1750.02**	−575.67**
Number of elderly members	−7.79*	55.39**	15.49**	−7.87	17.88**	29.94**
Number of wage earners	−6.63**	−46.44	2.04	19.75**	217.98**	−48.11**
Income	−17.63**	−211.22**	7.75**	381.36**	−330.69**	−265.83**
Owner occupied	−2.71	75.78	−2.73	−0.66	141.97**	12.13**
Without business use	−4.62**	256.37**	2.79*	−16.97**	81.76	5.76
2 - 3 floors	−8.35**	−33.79	2.57**	0.07	50.76**	0.19
4 - 5 floors	23.18**	−75.88**	−12.16**	15.19**	11.20*	3.39
>5 floors	17.48**	−60.86**	−9.82**	82.79**	−5.81**	−35.09**
Housing area	10.04**	−156.44**	−6.60**	87.78**	−129.34**	−60.68**
Number of televisions	24.15**	−162.82**	−9.06**	79.31**	30.62	15.04
Number of water heaters	3.80	−148.44*	−6.73*	26.43**	−99.61**	−48.56**
Number of air conditioners	201.86**	−264.96**	−67.49**	1269.40**	−106.62**	−695.49**
Number of washing machines	10.39**	−215.14*	−5.35*	34.64**	38.78	10.92
Total	113.12**	−203.91**	−116.74**	1769.13**	2593.23**	−1650.73**
Sum of three components		−207.53			2711.64	

Notes: *, and ** represent 5% and 1% significance levels, respectively.

The results show that the coefficient effect is greater than the endowments effect for each period, suggesting that the increase in household electricity consumption is mainly attributed to the changes in the coefficients effect of the determinants. For instance, since the household electricity consumption had increased 2712 kWh from 1985 to 2015, the differences in coefficients resulted in an increase of 2593 kWh, which was greater than the endowments effect (1769 kWh) and interaction effect (−1651 kWh). Even though the mean value of household electricity consumption declined slightly from 5227 kWh in 2005 to 5019 kWh in 2015, the decrease in household electricity use was still primarily driven by the coefficient effect.

We further observe the coefficients effect of these determinants. We find that the coefficient effect of household size plays the most important role, except for the period 2005-2015. The decrease of household size leads to electricity consumption per capita increases due to the loss of economies of scale. Thus, the coefficients effect of household size is significantly positive, reflecting that one additional household member may make household electricity use increase much more than before. Another important factor is the number of air conditioners. During the period 2005-2015, the number of air conditioners had the largest coefficient effect that brought about the decrease of household electricity use. In addition, other household appliances also exhibited significantly negative coefficients effects. It is obvious that, during the period 2005-2015, the decrease of electricity use was mainly induced by the differences in coefficients effects of household appliances. This result may be related to two possible reasons. One reason is that newly purchased appliances are more energy efficient. Another reason is that the additional household appliances may be non-primary use or used as supplements. Thus, the marginal effects of the increase of household appliances decline.

As for the contribution of endowments effects, the number of air conditioners is the most important factors. For each period, the endowments effects of number of air conditioners are significant and greater than that of other factors. However, the endowments effects of household income are divergent over these three segmented periods. Household income has a significantly positive endowments effect for the period 1985-1995, whereas the effects become significantly negative for the periods 1995-2005 and 2005-2015. The negative endowments effect of household income may reflect the declining trend of real household income. As shown in **Table 2**, real household income had decreased from 981 thousands NT dollars in 1995 to 929 thousands NT dollars in 2015. Nevertheless, the endowments effects of household income had led to a high increase of electricity use between 1985 and 2015. As people pursue material life, it is vital to improve energy efficiency of appliances and create the incentives for investing in energy-saving equipment. Besides, it should be noted that the endowments effect of household size is significantly negative, which suggested that household electricity use would decrease as the mean value of household size declined. However, because the coefficients effect of household size is positive and the absolute

value is greater than that of endowments effect. Therefore, we still can perceive that household electricity use would increase as household size continues to decline. As for the interaction effect, since it is difficult to interpret this component and the interaction effect is less than the other two effects, we would not address it in this study.

On the whole, our results reveal that the changes of household electricity consumption are driven by different factors across these three periods. During the period 1985-1995, household electricity use exhibited a more substantial increase. The most important endowments effects were originated from the increase in the number of air conditioners and household income. Regarding to the coefficients effect, the decrease of household size played the most critical role for triggering the rising of household electricity use, since electricity consumption per capita would increase. During the period 1995-2005, household electricity use showed a more moderate increase. The main endowments effect was caused by the number of air conditioners, while the coefficients effect derived from the decrease of household size dominated over that of other factors. However, the endowments effect of household income became negative due to the declining trend of real household income. During the period 2005-2015, household electricity use displayed a downward trend. A more notable phenomenon was the negative coefficients effects of household appliances, which may be related to the improvement of energy efficiency.

3.3. Analysis for the Groups of High-Income and Low-Income Households

The results of the endowments effects show that the increase of household income had induced residential demand for electricity between 1985 and 2015. Our results are consistent with the findings of previous studies, such as Vassileva *et al.* [10] and Du *et al.* [15]. Vassileva *et al.* [10] indicated that household income is one of the most important factor determining household electricity use. Du *et al.* [15] found that income variable has a significant impact on residential electricity consumption. Because household income is a critical determinant of household electricity use, we further explore whether there are different decomposition results between the high-income and low-income households. Due to the limited space, we focus on the change of household electricity consumption for the period 1985-2015. **Table 5** reports the results of Blinder-Oaxaca decomposition for high-income and low-income households.

The results reveal that the change of household electricity use is mainly attributed to the coefficient effects both for the high-income and low-income households, indicating that the marginal effects of the determinants differ greatly over the past three decades. It is remarkable that the greatest contribution to the coefficient effects in terms of the absolute value is household size. For the high-income and low-income households, household size explains 60% (=1650.39/2767.33) and 76% (=1545.98/2043.57) of total coefficients effect, respectively. This finding is consistent with our previous results. The decrease of

Table 5. Results of blinder-oaxaca decomposition: high-income and low-income households.

Variables	High-income households			Low-income households		
	Endowments effect	Coefficients effect	Interaction effect	Endowments effect	Coefficients effect	Interaction effect
Intercept		1331.86**			889.54**	
Age	37.16	−273.47	−35.03	−33.90*	−131.50	−51.38
Gender	−4.15	47.23	−7.40	3.46	33.88	−11.61
Education	−12.48	66.84	18.21	−4.61	20.94	5.71
Household size	−203.96**	1650.39**	−389.97**	−157.01**	1545.98**	−751.56**
Number of elderly members	1.51	29.21*	28.51*	−8.04	28.51*	48.15*
Number of wage earners	30.78**	430.36**	−39.95**	−3.09	−61.32	39.06
Income	455.99**	−395.36**	−371.03**	144.24**	−59.12	−23.37
Owner occupied	−21.27**	314.42**	31.98**	1.45	66.85	2.12
Without business use	−44.19**	344.56*	28.84**	−2.55	−184.89	−8.01
2 - 3 floors	−3.50	13.89	−2.50	5.31	10.12	4.88
4 - 5 floors	22.69**	−70.55**	−13.38	10.02**	−0.31	−0.28
>5 floors	127.81**	−38.67**	−93.74*	4.08	0.43	10.95
Housing area	142.62**	−285.61**	−114.10**	53.90**	−73.35*	−44.74*
Number of televisions	87.95*	−98.33	59.59	78.46**	−115.50*	−36.71*
Number of water heaters	15.41	−127.20	−25.71	39.28**	24.53	−35.09
Number of air conditioners	1613.41**	−298.41**	−990.18**	616.55**	−6.86*	−155.54**
Number of washing machines	18.98**	−70.50*	−9.14	57.46**	55.65	42.21
Total	2264.77**	2767.33**	−1925.00**	805.00**	2043.57**	−895.02**
Sum of three components		3107.10			1953.55	

Notes: *, and ** represent 5% and 1% significance levels, respectively. We focus on the period 1985-2015.

household size is adverse to the aim of electricity conservation no matter for high-income or low-income groups. In addition, some demographic and socioeconomic characteristics, such as the number of wage earners, household income, owner-occupied and business use variables, only exert significant effects for the high-income group but not significant for the low-income group. The results reflect the fact that the high-income group are usually related to a higher level of electricity use, and high electricity consumption would be more likely attributed to the change in the marginal effects of demographic characteristics.

As for the endowments effects, number of air conditioners and household income are the most important factors contributing to the increase of household electricity use. As shown in Table 5, the endowments effect of number of air conditioners in the high-income group is 1613.41, which is far higher than that in the low-income group (616.55). This phenomenon reveals that the difference of electricity use between the high-income and low-income households may be originated from the number of air conditioners. In addition, better economic

ability and a larger housing area also contribute to the increase of electricity use for the high-income households.

Since household size plays an important role both in the high-income and low-income groups, we further estimate the Pearson's correlation coefficients so as to observe how the relationships between household size, income and electricity use would differ across the household groups. We focus on the four subsamples, including the high-income group in 1985, the high-income group in 2015, the low-income group in 1985, and the low-income group in 2015. Table 6 shows the results of Pearson's correlation coefficients. We obtain the following results. First, as for the low-income group, the correlation coefficients between household income and household size are stronger than that in the high-income group. This result implies household size matters for household income particularly for the low-income group, because an additional family member may increase household income. Second, for the high-income and low-income groups in 2015, the correlation coefficients between household income and household electricity use were smaller relative to that in 1985. This result reflects that the marginal effects of household income would be smaller as the income level is higher. Third, as for the high-income and low-income groups in 2015, the correlation coefficients between household size and electricity use are 0.441 and 0.448, respectively. It is worth noting that the correlation coefficients between household size and electricity use are greater in 2015 than that in 1985, suggesting that household size has a stronger connection with household electricity use than before no matter for the high-income and low-income groups. The main reason would be attributed to the decrease of family size.

In sum, our results indicate that the increase of household electricity consumption in Taiwan over the past three decades can be explained by two important reasons. The first reason is that the decline of household size has weakened economies of scale in electricity consumption. An additional family member induces a higher level of household electricity use than before. To some extent, the basic subsistence level of electricity consumption per capita has increased

Table 6. Results of Pearson's correlation coefficients.

Subsample	household income versus household size	household electricity use versus household size	household income versus household electricity use
High-income group in1985	0.101*	0.073*	0.279*
High-income group in 2015	0.007	0.441*	0.088*
Low-income group in 1985	0.435*	0.413*	0.410*
Low-income group in 2015	0.375*	0.448*	0.328*

Notes: * represents 1% significance levels.

over time. The second reason is the increase of the number of air conditioners. Because households pursue a better material life and the temperature continues to rise due to global warming, air conditioners become the necessary appliances for households. Therefore, when we make strategies for reducing electricity consumption, these two critical factors should be taken into account.

In the aspect of electricity demand-side management, it is important to make use of the pricing strategies. In Taiwan, the electricity pricing policy is based on increasing-block pricing. The electricity prices are specified into different blocks and increases with blocks according to the amount of electricity use [35]. However, in the residential sector, the charge is based on electricity use per household but not per capita. Therefore, to offer electricity-saving incentives for these households with smaller family size, the electricity pricing policy should take household size into consideration. Another important issue should be paid attention to is the increasing demand for air conditioners. Some strategies, such as enhancing energy efficiency of air conditioners, improving housing structure with better insulation, and providing the subsidy for the investment in energy-efficient appliances, should have a higher priority. Since Taiwan is highly dependent on imported energy and under the risk of insufficient power supply, it is important to understand the reasons that contribute to the increase of household electricity use. Then, it can help us to make effective strategies to reduce residential electricity consumption.

4. Conclusions

This study employs the Blinder-Oaxaca decomposition to investigate what are the main reasons that contribute to the change of household electricity consumption in Taiwan over the period 1985-2015. The change of household electricity consumption is decomposed into three parts: endowments effect, coefficients effect, and interaction effect. Our results verify that the changes of household electricity consumption are driven by different factors across these three decades.

During the period 1985-1995, household electricity use exhibited an upward trend. The main endowments effect was caused by the number of air conditioners and household income. The coefficients effect originated from the decrease of household size played the most critical role. During the period 1995-2005, household electricity use showed a more moderate increase. The main endowments effect was caused by the number of air conditioners, while the coefficients effect derived from the decrease of household size dominated over that of other factors. However, the endowments effect of household income became negative due to the declining trend of real household income. During the period 2005-2015, household electricity use displayed a downward trend. A more notable phenomenon was the negative coefficients effects of household appliances, which may be related to the improvement of energy efficiency.

Apparently, the increase in household electricity consumption is mainly at-

tributed to the changes in the coefficients effect of the determinants. In particular, the coefficients effect of household size plays the most important role. The decrease of household size leads to electricity consumption per capita increases due to the loss of economies of scale. As for the contribution of the endowments effect, household income and the number of air condition are the most important factors. When we observe the decomposition results of the high-income and low-income households, it is also evident that the coefficients effects of household size are crucial to the increase of electricity use. The decrease of household size is adverse to the aim of electricity conservation no matter for high-income or low-income groups. Moreover, the correlation coefficients between household size and electricity use are greater than before. Thus, high electricity consumption would be more likely attributed to the change in the marginal effects of demographic characteristics. Therefore, with the changes of demographic structure and socio-economic characteristics, identifying the characteristics that affect household electricity consumption would be an important issue.

From a historical view, our results highlight that demographic structure and socio-economic characteristics would have critical influence on household electricity use. In Taiwan, as the government makes policies for reducing household electricity use, the main obstacles would be the decline of household size and the high dependency on air conditioning. Therefore, the policy implication means that the electricity pricing policy should take household size into consideration so as to offer electricity-saving incentives for these households with smaller family size. Besides, some strategies, such as enhancing energy efficiency of air conditioners, improving housing structure with better insulation, and providing the subsidy for the investment in energy-efficient appliances should have a higher priority for the policymakers.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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