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Study on the Social Welfare Function and Its Application for Electric Power Universal Service Based on Prospect Theory

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Abstract

Electric power universal service is a procedure of government public policies. Due to the different subjective induction for individuals, the social welfare of electric power universal service doesn't meet the axiom of individuals' utility sum, which is a principle of traditional utility theory. Influencing factors of individuals' welfare effectiveness are analyzed in this paper. According to income levels and electricity consumption of residents, as well as real-life improvement and wellbeing for future, prospect theory is applied to study residents' welfare induction of the service. Taking for example by Atkinson's welfare function and Bernoulli – Nash' welfare function, welfare function of electric power universal service is constructed. The case study shows that residents' welfare induction of the service more depends on relative changes of influencing factors, especially in remote areas.

Keywords: Electric power universal service; prospect theory; welfare function

1. Introduction

Electric power universal service is a procedure of government public policies, which is to aim at maximizing social welfare. It should be taken account of various factors that affect residents' welfare induction when we analyze the welfare utility of this policy. Residents' welfare induction on this policy is based on real-life improvements and future life expectations with the feature of "look ahead". This behaviour is exactly in line with the principle of prospect theory in behaviour economics. Value function of prospect theory can measure residents' welfare implementation. Owing to pay more attention on the relative changes of residents' wealth rather than final state, this theory can be used to measure residents' welfare increase volume of electric power universal service.

Literatures [1]-[2] analyzed social welfare utility of telecommunications universal service and pointed out the general conditions of social welfare for remote areas; literature [3] explored the way of social welfare index; literature [4] evaluated the social value of electric power universal service from both perspectives of implementation efficient and coordination with regional economic development.

Based on the above researches, we analyzed in-depth the economic and non-economic welfare influencing factors for electric power universal service and explored residents' welfare utility of the service implementation in this paper. Based on Yunnan province of China, an empirical analysis of social welfare is studied.

2. Influencing Factors of Electric Power Universal Service

The social welfare influencing factors can be divided into two parts: economic and non-economic factors. Economic welfare can be measured in monetary units; non-economic welfare can improve residents' happiness index but can't be directly measured in monetary units. According to the prospect theory, the relative growth rate of welfare is more valued by residents, so it is more important to concern

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about the relative changes of welfare effectiveness [5].

From the perspective of recipient residents' welfare, the influencing factors for the service are mainly as followings: the first one is the income level of residents; the second is the electricity consumption of residents; and finally, the relative changes of the household appliances.

3. Welfare Influencing Factors Based on Prospect Theory

3.1. Prospect Theory

Prospect theory is scientific research result of psychology and praxiology. It is improved from traditional expected utility theory by Kahneman and Tversky [6]. According to welfare utility of electric power universal service, value function is applied to calculate economic and non-economic welfare influencing factors based on prospect theory. There are three characteristics of value function: a. gains and losses are relative to reference point Δx_i b. decision makers are risk averse in face of income but risk appetite for losses; c. decision makers are more sensitive in face of losses than income and this sensitivity meets law of diminishing [7]. Given all characteristics above, Kahneman and Tversky took value function as power function form, i.e.

$$v(x_i) = \begin{cases} \Delta x_i^{\alpha} & , \Delta x_i \geq 0 \\ -\theta(-\Delta x_i)^{\beta} & , \Delta x_i < 0 \end{cases} \tag{1}$$

Formula (1) indicates changes of value influencing factors. α and β reflect sensitivity of gains and losses respectively; $\alpha < 1$ and $\beta < 1$ reflect sensitivity decrement. θ expresses level of loss aversion. $\theta > 1$ means more sensitive in face of losses than income [8]. According to literature [9], Kahneman and Tversky gave estimated value of parameters in value function, which are $\alpha = \beta = 0.89, \theta = 2.25$.

3.2. Welfare Influencing Factors of Electric Power Universal Service

From the above analysis, welfare influencing factors for electric power universal service should include inductions of recipient residents' economic and non-economic welfare factors. In analysis of welfare effectiveness of the service, $\Delta x_i = x_i - \overline{x}_i$; where $\overline{x}$ is value before electric power universal service implementation; x_i is impact factor value after implementation of the service; Δx_i is the changes of factor value. According to prospect theory, v_1, v_2, v_3 indicate value functions of each factor and their attribute weight vector is $\Pi = (\pi_1, \pi_2, \pi_3)$, π_i is the weight of value function v_i, $\pi_i \geq 0$ and $\sum_{i=1}^{3} \pi_i = 1$. Based on utility theory, utility function of electric power universal service is

$$u(x) = \pi_1 v_1 + \pi_2 v_2 + \pi_3 v_3 \tag{2}$$

4. Social Welfare Function of Electric Power Universal Service

As we know from the welfare economics, Atkinson's social welfare function divided a society member into two parts: the rich and the poor, and took inequality parameter as index in order to highlight income distribution in line with equality and fair. When index of aversion inequality parameter is bigger, weight on the utility level of the poor is greater, and thus it is more emphasis on the utility of the poor [8]. Engel coefficient can express economic development of region and living standards of residents; its value is less than 1. Taking Engel coefficient as welfare index can highlight welfare impact of backward areas on the whole society. In addition, Bernoulli and Nash regard social welfare function as product of all members of society; in a certain level of social welfare, the smaller the social welfare diversity is, the greater for the product of social welfare in view of social equity.

In accordance with Atkinson theory, we divide recipient into two groups which are low-income urban group and residents in remote areas, based on the supply cost of electric power universal service. *a* and

b are Engel coefficients of these two kinds residents. Atkinson's welfare function is used to emphasize issue of fairness and focus on welfare of low-income people; Bernoulli – Nash' welfare function which is in multiplicative form is conducive to reduce welfare differences and increase total welfare [10]. We synthesize the two forms of welfare functions and construct the social welfare function of electric power universal service as follows:

$$W = U_A^{\ a} U_B^{\ b} \tag{3}$$

where U_A and U_B represent welfare effectiveness of low-income urban group and residents in remote areas respectively. Put utility function (2) into equation (3) and obtain the overall social welfare function.

5. Empirical Analysis

In this paper, we select basic data of one region in Yunnan Province. Residents' income is obtained from China Statistical Yearbook 2011 and two regions' Engel coefficients are a=0.356 and b=0.410; household electricity consumption data is obtained from China Electric Power Yearbook 2011; the number of household appliances is gain by sample survey on residents. From the analysis above, electric power universal service is mainly affected by income levels, household electricity consumption and the number of household appliances, x_1 is the value before implementation of the service; x_i is the impact factor value after implementation. The results are as follows.

Table 1. Sample statistics of residents' household appliances

Electrical appliances	Lamp bulb	TV	Electric cooker	Air condition	Washing machine	Refrigerator	Induction cooker	Water dispenser	Computer
per household ownership of group A	8.40	1.02	1.05	0.74	1.04	0.63	0.83	0.51	0.78
per household ownership of group B	6.30	0.72	0.82	0.06	0.43	0.25	0.13	0.22	0.07

Table 2. Sample statistics of resident in region A

$\bar{x}_1$ Million	x_1 Million	$\bar{x}_2$ Kw·h	x_2 Kw·h	$\bar{x}_3$ Unit	x_3 Unit
1.7175	2.0000	450	500	15	17

Table 3. Sample statistics of resident in region B

$\bar{x}_1$ Million	x_1 Million	$\bar{x}_2$ Kw·h	x_2 Kw·h	$\bar{x}_3$ Unit	x_3 Unit
0.5153	1.0000	250	350	9	13

In summary, steps of welfare effectiveness research on electric power universal service based on prospect theory are as follows:

Step A: Determine relative matrix of welfare influencing factors of electric power universal service ΔX and obtain value matrix of the two regions V;

$$\Delta X_A = (0.2825, 50, 2); \Delta X_B = (0.4847, 100, 4)$$

$$V_A = (0.3246, 32.5150, 1.8532); V_B = (0.5249, 60.2560, 3.4343)$$

Step B: Determine weights of each factor and get weight matrix Π;

$$\Pi = (0.2, 0.4, 0.4)$$

Step C: Get utility function $U = V\Pi$ of electric power universal service based on value matrix and weight matrix given above;

$$U_A = 13.8122; U_B = 25.5811$$

Step D: Obtain gross social welfare according to social welfare function of electric power universal service.

$$W = U_A^{\ a} U_B^{\ b} = 2.5464 \times 3.7779 = 9.6199$$

Electric power universal service is mainly affected by income levels, household electricity consumption and the number of household appliances. People usually concern changes of wealth rather than final state. As $U_A < U_B$, the utility of electric power universal service in remote areas is bigger than in urban areas and it is need to strengthen electric power service facilities construction in remote areas. Welfare induction of residents is more dependent on improvements of real life and better expectation for the future. Electric power universal service can enhance happiness index of residents and increase utility of social welfare.

6. Conclusion

In this paper, welfare influencing factors of residents for electric power universal service is analyzed and residents' welfare sensor is depicted using prospect theory. Social welfare function is built and empirical case is studied to analyze welfare utility effect of electric power universal service implementation. Results show as follows:

a) We divide recipient group into two, which are low-income urban group and residents in remote areas by cost of electric power universal service. Take examples by Atkinson's welfare function and Bernoulli – Nash' welfare function, welfare function of electric power universal service is constructed.

b) According to prospect theory, residents' welfare induction on government policy is based on real-life improvements and future life expectations with the feature of "look ahead". Value function of prospect theory can measure residents' welfare implementation. Through focusing on changes of wealth rather than final state, it is able to measure residents' welfare increase volume of electric power universal service.

c) As $a<b$, i.e. Engel coefficient in urban areas is smaller than in remote areas. Taking Engel coefficient as welfare index can highlight welfare impact of backward areas on the whole society. In addition, $U_A < U_B$, the utility of electric power universal service in remote areas is bigger than in urban areas. Therefore, it is supposed to strengthen electric infrastructure in remote areas

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