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How Do Chinese Residents Expect of Government Subsidies on Solar Photovoltaic Power Generation?—A Case of Wuhan, China

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Abstract: This paper investigates local residents' expectations of the Chinese government subsidies on solar photovoltaic (PV) power generation. Residents' demographics including age, educational attainment, income level, gender, and employment fields are analyzed based on a survey study in Wuhan, China. Results of the regression analysis on the influence of demographic variables on residents' expectations indicate that: (1) residents with different demographics have significantly different expectations of the Chinese government subsidies for adopting PV power generation facilities; (2) income, education attainment, and residents' employment fields have a significant impact on their expectations of government subsidies. With these findings, this paper concludes with useful policy implications.

Keywords: solar energy; photovoltaic power generation; renewable energy; government subsidy; China

1. Introduction

With the prominence of global climate change, energy crises, and pressure to reduce carbon emissions, addressing these problems has become an important research task. Some conventional environmental policy approaches are unlikely to be sufficient to solve these energy issues [1]. Therefore, a growing number of researchers are attempting to solve the problems through carbon-pricing mechanisms [2], which have proven to be somewhat effective in reducing CO₂ emissions in China [3]. However, recent findings suggest that China's carbon market is in the early stages of its development [4]. It is still not yet mature for China to implement its carbon pricing policies. Although Li et al. [3] suggest as long as the government subsidies are provided for electricity production, carbon pricing policies can be introduced in the short-term, and some experts strongly believe that the effect of carbon pricing strategies is limited [5]. Tu et al. [6] suggest that a potential synergistic effect exists between carbon pricing and policies for renewable energy power subsidy. In contrast, several scholars argue that the higher the cost of a proposed climate policy, the lower its likelihood to be accepted by the public [7]. According to current conditions in China, it seems not practical to implement carbon pricing policies. Therefore, this study considers other alternatives, such as renewable energy subsidies is a possible way to solve energy crises and environmental problems in China.

Increasing the use of renewable energy is one such alternative to solve the climate change problem [8]. Solar energy has been widely recognized as one of the solutions to replace fossil fuels and PV technology shows a great potential for solar energy utilization. Recently, PV power generation has great prospects for development [9]. China's solar PV industry has experienced rapid development in recent 10 years and has achieved an important position in the world PV market. For example,

the newly-installed PV capacity has led to the reduction in cost. Despite the fact that the European countries have a long history of solar PV applications, China has its own unique development strategies and natural endowment in solar PV industry with a fast and smooth development [10]. Evidence reveals that the existing residential gross floor area in China amounts to 40 billion square meters, with an increasing speed of 1.6–2 billion square meters per year [11].

A growing research interest has focused on the level of residents' willingness to pay (WTP) for renewable energy. One of the main factors affecting residents' WTP includes income, gender electricity consumption, and electricity tariffs [12]. Other determinants which considerably influence WTP, as Uehleke [13] suggests, are personal norms, climate change skepticism, agreement with the government renewable energy law, and individual awareness. Herbes et al. [14] find that some consumers are more willing to pay for green energy products than non-green energy ones. Price and equipment issues, such as operations and maintenance are often seen as the barriers to purchasing green energy. As a result, lower price and government subsidies may encourage residents to purchase green energy [15]. The adoption of solar PV power generation is also affected by the social factors, such as social interaction (peer) effects [16,17] and social contagion [8].

The Chinese governments have been encouraging the deployment of renewable energy resources [18]. Energy subsidies have become one of the most popular tools for political energy policies [19]. Government subsidies for production are conducive to the development of renewable energy enterprises [20]. Nie et al. [21] argue that supporting output subsidies are beneficial for the environment and consumers. Nicolini et al. [17] also suggest that subsidy policies are effective in promoting renewable energy. Guo et al. [22] find that China's subsidy policies have removed the high-cost limitation and stimulated investment in the PV industry. Liao et al. [23] analyze the export effects of China's PV industry subsidies, and point out its importance in perfecting the subsidy mechanism of the PV industry. The Chinese government subsidies for the PV industry have brought a flourishing time for the substantial development of solar PV companies in China. In the long-term, nevertheless, governmental subsidies for solar PV companies should be maintained and strengthened [24]. Nomaguchi et al. [25] found that the combination of grid upgrades and subsidy policies are an effective way to promote the proliferation and diffusion of PV systems. Regarding residents' installing rooftop solar PV generation facilities, Elnokaly et al. [26] point out those government subsidies for residential solar energy can effectively encourage families to adopt this technology. Other studies show that tax rebate policies can also effectively increase the amount of residential solar PV power generations [27]. In summary, these studies indicate that government's subsidy policies have positive effects on the development of PV enterprises and residents' WTP for solar PV power generations.

To the best of our knowledge, few studies have focused on the relationship between different types of residents and their expectations of government subsidies in solar PV industry. With the focus on the perspective of diverse residential demographics in China, our study has adopted one-way analysis of variance (ANOVA) and regression analysis in an attempt to fill this research gap by conducting a survey study among X residents. Results of this study will reveal the general characteristics of what various types of residents expect of government subsidies. Importantly, our study proposes policy recommendations for facilitating the development of solar power generation in China.

2. Research Hypotheses

This paper investigates residents' expectation of Chinese government in solar PV generation and perceptions of how residents should be subsidized for accepting an alternative energy source. Specifically, the definition of expectation of government subsidies refers to public demand for subsidies for solar PV power generation. The initial investment for installing a solar PV generation facility could be a heavy financial burden for a family; therefore, the consideration between individuals' PV adoption or WTP and their demographic factors is important.

In order to reveal the influence of demographic variables on residents' expectations of government subsidies, which will indirectly influence their intention to install solar PV generation facilities, this paper aims to examine whether residents' different demographic attributes have an impact on their expectations of government subsidies in both of cost and the time period of expecting a return on investment, as illustrated in Figure 1.

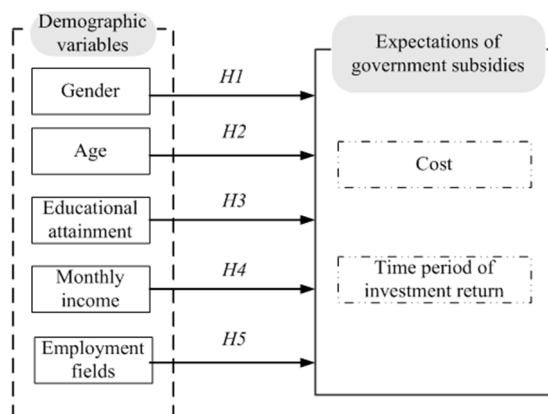


Figure 1. Proposed research model.

Based on the literature review, we proposed the following hypothesis:

Hypothesis 1 (H1). Different genders have different impacts on the expectations of government subsidies.

Hypothesis 2 (H2). Different ages have different effects on the expectations of government subsidies.

Hypothesis 3 (H3). Different educational attainment has different effects on expectations of government subsidies.

Hypothesis 4 (H4). Different monthly income has different effects on expectations of government subsidies.

Hypothesis 5 (H5). Different employment fields have different effects on expectations of government subsidies.

3. Method

3.1. Survey Design and Data Collection Procedures

This study designed a paper-and-pencil questionnaire containing the measures of demographics and expectations of government subsidies and included X questions. The independent variables are socio-demographics including gender, age, education attainment, monthly income, and employment fields. The dependent variable of "people's expectations of government subsidies" was measured by two questions "What is your range of costs for installing solar power generation facilities?" and "What is the life-time range of solar power facilities you can accept?" Both questions were used to measure the strength of people's expectations of government subsidies.

The research group randomly launched participants at several locations, such as supermarkets, institutions, office buildings, residential quarters, and some other densely-populated areas in Wuhan, China to receive a wide distribution of residents' employment fields and diverse respondents. It is important to note that all the respondents surveyed here were the residents who have not installed any solar PV generation equipment, but they had some level of knowledge in solar energy or solar PV generation-related equipment. Before asking participants to fill out the survey, the research team provided a poster to explain the knowledge of solar PV generation equipment in order to filter out those who did not know anything about solar PV. A total of 360 questionnaires were handed out and

328 received, providing a response rate of 91.11%, among which 301 are valid, accounting for 91.77%. A small gift was provided to compensate the participants after the study.

3.2. Statistical Analyses

Based on the principles (1) the lower the cost that residents can pay for installing solar PV power generation facilities, the higher their expectations of government subsidies; (2) the shorter the cost recovery period that residents can accept, the higher their expectations.

Utilizing SPSS 20.0 software, we used a single factor analysis of variance (one factor ANOVA) and Dunnett's T3 test to analyze our samples. We then conducted a regression analysis of demographic variables affecting residents' expectations of government subsidies which would influence their adoption of solar PV power generation facilities.

4. Results and Analyses

As shown in Table 1, in the demographic variable of gender, males slightly outnumber females 51.50% to 48.50%, respectively; in the variable of age, youths and middle aged participants are the main drivers for solar PV power generation adoption when those aged between 20 and 49 constitute 92.69%; in the dimension of income, the percentage of those earning 1000–6999 RMB per month is 86.70%. From a general perspective, the samples are fairly typical and representative of the Chinese population in Wuhan (see Table 1).

Table 1. The distribution of samples.

Features		Frequency	Ratio
1. Gender	Male	155	51.50%
	Female	146	48.50%
2. Age	Under 19	0	0.00%
	20–29	125	41.53%
	30–39	104	34.55%
	40–49	50	16.61%
	Above 50	22	7.31%
3. Educational attainment	Below secondary school	4	1.33%
	Vocational school/high school	21	6.98%
	Professional training/college	47	15.61%
	University	134	44.52%
	Graduate school	95	31.56%
4. Monthly income	Less than 999 RMB	5	1.67%
	1000–2999 RMB	68	22.59%
	3000–4999 RMB	119	39.53%
	5000–6999 RMB	74	24.58%
	Greater than 7000 RMB	35	11.63%
5. Employment fields	Traditional energy industry	27	8.97%
	New energy industry	31	10.30%
	Construction industry	22	7.31%
	Service sector	31	10.30%
	Financial industry	38	12.62%
	Education industry	36	11.96%
	Government departments	63	20.93%
	Information industry	31	10.30%
	Manufacturing industry	5	1.66%
	Others	17	5.65%

Source: derived from the sample data by the authors using SPSS 20.0.

First, we use the Chinese questionnaire data for gender, age, educational attainment, monthly income, and employment fields to sample the data for homogeneity testing, but the result is uneven. Therefore, we use Dunnett's T3 test to analyze the sample. Then, we use a regression model to analyze the population variables that affect residents' expectations of government subsidies.

4.1. Analysis by Age

By analyzing the age demographic variable, we have the following findings (see Tables 2 and 3).

Table 2. Description of different ages.

Age	N	Mean	Standard Deviation	Standard Error
40–49	50	2.58	0.69	0.06
30–39	104	3.00	1.35	0.29
Above 50	22	3.25	0.83	0.08
20–29	125	3.84	0.89	0.13
Total/Average	301	3.05	0.95	0.06

Source: derived from the sample data by the authors using SPSS 20.0.

Table 3. Public's subsidies expectations of different ages.

Age	N	Subset for Alpha = 0.05		
		1	2	3
40–49	50	2.58		
30–39	104		3.00	
Above 50	22		3.25	
20–29	125			3.84
Sig.		1.00	0.14	1.00

Source: derived from the sample data by the authors using SPSS 20.0.

The mean values of residents' expectations of government subsidies by age group is ranked as follows in ascending order: 40–49 (2.58), 30–39 (3.00), above 50 (3.25), and 20–29 (3.84). Since residents able to adopt solar power generation facilities would presumably have a certain economic status and independent housing, this survey does not include residents aged under 19.

The maximum mean value (20–29 group) is 48.84% higher than the minimum mean value (40–49 group). There is a significant difference among the three age groups, 40–49, 20–29, and the rest, but little difference is found between those groups of over 50 and those of 30–39. This may be explained by the fact that residents aged 20–29 are lacking in economic ability, making them sensitive to the higher costs of adopting solar power generation facilities; residents of the 40–49 group have substantial economic strength, and are more willing to try new energy. Residents over the age of 50 are mostly retired workers and more conservative in their values regarding solar PV, so it is not easy for them to accept this type of new energy product.

4.2. Analysis by Educational Attainment

In terms of the education variable, our analysis has resulted in the following findings (see Tables 4 and 5).

Table 4. Description of different educational attainment.

Educational Attainment	N	Mean	Standard Deviation	Standard Error
Secondary School	4	4.25	0.50	0.25
Vocational school/high school	21	3.86	0.66	0.14
Professional training/college	47	3.64	0.64	0.09
University	134	2.78	0.89	0.08
Graduate School	95	2.58	0.87	0.09
Total/ Average	301	2.95	0.95	0.06

Source: derived from the sample data by the authors using SPSS 20.0.

Table 5. Public's subsidies expectations of different educational attainment.

Educational Attainment	N	Subset for Alpha = 0.05	
		1	2
Graduate School	95	2.58	
University	134	2.78	
Professional training/college	47		3.64
Vocational school/high school	21		3.86
Secondary School	4		4.25
Sig.		0.51	0.12

Source: derived from the sample data by the authors using SPSS 20.0.

- (1) The mean values of residents' expectations of government subsidies from different educational attainments are ranked as follows in ascending order: graduate degrees (2.58), university (2.78), professional training (college) (3.64), vocational school (high school) (3.86), or secondary school (4.25).
- (2) The maximum mean value (secondary school) is 64.80% higher than the minimum mean value (graduate degrees), indicating that there is a significant difference in the expectations for government subsidies between residents from different educational attainments. This may be because residents of different educational attainments have different knowledge and self-cultivation. Those residents receiving relatively less education may have a lack of awareness for the value of solar PV products and most of them have relatively low income, making these products less affordable; those with more education have better knowledge reserves, potentially have a better understanding of solar PV products, and most of them have higher income, making them more willing to adopt PV products, and expect less in terms of government subsidy.
- (3) As suggested by the results, residents are demarcated by their educational attainments, thus the higher the educational level, the lower the expectations of government subsidies.

4.3. Analysis by Monthly Income

We then analyzed the monthly income dimension, with the following findings (see Tables 6 and 7).

Table 6. Description of different income levels.

Monthly Income	N	Mean	Standard Deviation	Standard Error
Under 999 RMB	5	3.80	0.84	0.37
1000–2999 RMB	68	3.65	0.57	0.07
3000–4999 RMB	119	3.20	0.81	0.07
5000–6999 RMB	74	2.24	0.74	0.09
Above 7000 RMB	35	2.09	0.78	0.13
Total/ Average	301	2.95	0.95	0.06

Source: derived from the sample data by the authors using SPSS 20.0.

Table 7. Public's subsidies expectations of different income levels.

Monthly Income	N	Subset for Alpha = 0.05		
		1	2	3
Above 7000 RMB	35	2.09		
5000–6999 RMB	74	2.24		
3000–4999 RMB	119		3.20	
1000–2999 RMB	68		3.65	3.65
Under 999 RMB	5			3.80
Sig.		0.51	0.07	0.53

Source: derived from the sample data by the authors using SPSS 20.0.

- (1) The monthly income has a negative correlation with residents' expectations of necessary government subsidies to install solar PV facilities. The mean values of residents' expectations of government subsidies by different income groups are ranked as follows in ascending order: over 7000 RMB (2.09), 5000–6999 RMB (2.24), 3000–4999 RMB (3.20), 1000–2999 RMB (3.65), and under 999 RMB (3.80). The maximum mean value (under 999 RMB) is 82.19% higher than the minimum mean value (over 7000 RMB).
- (2) Residents of different income levels have significantly different expectations of government subsidies on solar PV installations.

There is little difference in the expectations of government subsidies between residents with a monthly income under 999 RMB and those with 1000–2999 RMB, who belong to the same high expectations group. Similarly, residents with a monthly income of 5000–6999 RMB and over 7000 RMB have little difference. The difference between the low group and the high group is significant, and the higher the income, the lower the expectations of government subsidies. The results suggest that residents are demarcated by the income level of 3000 RMB, namely those under 2999 RMB and those over 3000 RMB. The former, representing the low-income consumer group, are limited by their economic ability and sensitivity to the installing costs. Thus, they are not willing to pay for installing solar PV facilities, so they have high expectations of government subsidies. The latter, representing the high-income consumer group, which has better economic ability and can afford to pay for the initial costs of solar power generation facilities, have lower expectations of government subsidies.

4.4. Analysis by Gender

We also conducted an independent sample T test on the gender variable with the following results (see Table 8).

The mean value of men is 2.94, and that of women 2.95; with 0.35% difference between them. Women have very slightly higher expectations of government subsidies than men. However, the difference is very small. It may be explained by the fact that women are in charge of the daily affairs of the family.

Table 8. Description of different genders.

Subject	Gender	N	Mean	Standard Deviation	Standard Error
Expectations for government subsidies	Male	155	2.94	0.98	0.08
	Female	146	2.95	0.92	0.08

Source: derived from the sample data by the authors using SPSS 20.0.

4.5. Analysis by Employment Fields

Finally, we conducted an analysis from employment fields, with the following findings (see Tables 9 and 10).

- (1) The mean values of residents' expectations of government subsidies from different employment fields are ranked as follows in ascending order: new energy field (2.45), government department (2.51), information field (2.61), financial field (2.68), education field (3.00), construction field (3.14), manufacturing field (3.40), service field (3.61), traditional energy field (3.67), and others (3.71). The maximum mean value (others) is 51.16% higher than the minimum mean value (energy field).
- (2) According to the significant expectations of government subsidies, all employment fields can be divided into two groups. Traditional energy field, service field, manufacturing field, construction field, and others are the higher subsidy expectation group, while the remaining areas, the new energy field, financial field, education field, government department, and information field are in the lower group. The difference between the groups is significant ($\alpha = 0.05$), while the difference within the group is non-significant. This may be because residents of government departments and those in the new energy field have easier access to new energy policies and knowledge, and have slightly lower expectations of government subsidies; residents in the traditional energy field, manufacturing field or other fields, however, have high expectations of government subsidies due to insufficient knowledge of new energies.

Table 9. Description of employment fields.

Employment Fields	N	Mean	Standard Deviation	Standard Error
Traditional energy	27	3.67	0.56	0.11
New energy	31	2.45	0.85	0.15
Construction	22	3.14	0.89	0.19
Service sector	31	3.61	0.80	0.14
Financial	38	2.68	0.96	0.16
Education	36	3.00	1.01	0.17
Government department	63	2.51	0.74	0.09
Information	31	2.61	0.80	0.14
Manufacturing	5	3.40	0.55	0.25
Others	17	3.71	0.59	0.14
Total/ Average	301	2.94	0.93	0.05

Source: derived from the sample data by the authors using SPSS 20.0.

Table 10. Public's subsidies expectations of different employment fields.

Employment Fields	N	Subset for Alpha = 0.05	
		1	2
New energy	31	2.45	
Government department	63	2.51	
Information	31	2.61	
Financial	38	2.68	
Education	36	3.00	3.00
Construction	22	3.14	3.14
Manufacturing	5		3.40
Service sector	31		3.61
Traditional energy	27		3.67
Others	17		3.71
Sig.		0.10	0.08

Source: derived from the sample data by the authors using SPSS 20.0.

4.6. Regression Analysis of Residents' Demographic Variables and Expectations of Government Subsidies

To find the population factors for residents' expectations of government subsidies to adopt solar power generation facilities and further define their degrees and significance, we use different population factors as independent variables, taking residents' expectations of government subsidies as

the dependent variable (questions are based on a five-point scale: the lowest expectation is set to 1, the lower expectation is set to 2, the general expectation is set to 3, the higher expectation is set to 4, and the highest expectation is set to 5). The dependent variable (residents' expectations of government subsidies), as well as age, monthly income, and education level are continuous variables, while gender (male or female) is a dichotomous variable. Therefore, we analyzed with linear regression models.

Based on the results of the model from the regression coefficients and significance levels, we can see that monthly income, educational attainment, and age have significant influences on residents' expectations of government subsidies to adopt solar power generation facilities. Monthly income, educational attainment, and age are significant at 5% and the coefficient is negative, indicating that the higher monthly income, or the higher educational attainments or the older the age, the lower expectations of government subsidies, *ceteris paribus*. Regarding the regression coefficients and significance levels, Monthly income has the most significant influences on residents' expectations of government subsidies (see Table 11).

Table 11. Results of linear regression (stepwise).

Model	Unstandardized Coefficient		Standardized Coefficient	<i>t</i>	Sig.
	B	Standard Error			
(Constant)	6.22	0.22		28.73	0.00
Monthly income	−0.41	0.05	−0.42	−8.94	0.00
Education attainments	−0.32	0.05	−0.31	−6.96	0.00
Age	−0.24	0.05	−0.24	−5.33	0.00

Source: derived from the sample data by the authors using SPSS 20.0.

5. Conclusions and Discussions

5.1. Conclusions

From the above analyses, we can draw the following conclusions:

- (1) There are significant differences among different types of residents in their expectations of government subsidies that would be necessary to adopt solar power generation facilities. Among them, there is a negative correlation between monthly income, educational attainment or age and residents' expectations of government subsidies, i.e., the higher the monthly income, the higher the educational attainments, or the older the age, the lower the expectation of government subsidies.
- (2) Monthly income, educational attainment, and age have significant influences on residents' expectations of government subsidies. There are also significant differences among residents' different employment fields. However, the difference between men and women is not significant.

5.2. Discussions

(1) Limitations

Scholars believe there are some defects in the subsidy policy. Subsidies can be very costly [27,28] or regressive [29]. However, according to the current status of the economic development in China, residents are unlikely to pay for the high cost of solar PV equipment and the subsidy policy is effective only for a short period of time.

There are some limitations and uncertainties in the survey process. For example, the surveyed residents are willing to accept the survey because they have a certain understanding of solar PV power generation and may have some environmental awareness. The authors may ignore some residents with a lack of awareness for environmental protection.

(2) Comparative analysis

Most scholars focus on the factors that affect the WTP for renewable energy [15,30], while we focus on the factors that influence residents' expectations of government subsidies for renewable energy. Uehleke [13] argued that gender had a significant impact on WTP; in our study, however, gender was found to have little effect on the results.

(3) Research prospect

In the future, we plan to conduct further research on the influence of residents' preferences on the environment or the social influence on residents' adoption of solar PV power generation equipment.

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