Farmers’ Willingness to Adopt Clean Energy—Survey in Northeastern China

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Abstract. Among 1.38 billion people in China, approximately forty-two percent of the population reside in rural areas. Farmers’ willingness to adopt clean energy is crucial to policy makers, planners and business developers as China will begin its Paris Agreement implementation in 2020. For Chinese government, switching energy sources will be a monumental task. To understand farmers’ opinions, 527 farmers were surveyed in Jilin Province of Northeast China, and nearly 83% of them burn coal and dried stalk/straw to heat homes and cook food. Their willingness to adopt clean energy is assessed in four different areas: attitude towards behavior, subjective norms, perceived behavioral control, and socioeconomic characteristics. A binary logistic regression model is establish with one dependent variable (willingness to adopt clean energy) and twelve independent variables: 1. Quality of life, 2. Monthly expenses, 3. Environment benefits, 4. Government commitments, 5. Appraisal from neighbors and friends, 6. Local clean energy market maturity, 7. Switching costs, 8. Savings in labors, 9. Technical guidance and periodical maintenance instructions, 10. Age, 11. Education level, and 12. Household annual income. Our results indicate that nine variables (X₁ – X₅, X₇ – X₉ and X₁₂) have apparent impacts on the farmers’ willingness to adopt clean energies. The impacts from X₁, X₃ – X₅, X₈ – X₉ and X₁₂ are positive, while that from X₂ and X₇ are negative. Implications of the results are discussed, along with policy suggestions.

1. Introduction
As Chinese economy develops rapidly, its domestic energy consumptions increase greatly. Traditional energy sources include coal, oil, dried vegetation such as stalks and straws, and dried manure. With the coal alone, China accounts for nearly 50% of world annual coal consumptions. Worst of all, large percentages of domestic deposits are known as high-ash coals, and one-third are high-sulfur coals. Burning one ton coal emits 16 kg SO₂, 15 kg NOₓ and 200 kg ashes.

According to National Bureau of Statistics of China, total coal consumption in 2017 was 4.49 billion standard tones, which is approximately 60.4% of total annual energy consumptions. In comparison, total clean energy consumption was only 20.8%, including natural gas, hydroelectric, nuclear, wind and solar energies. In terms of CO₂ emissions, China exceeded 9 billion metric tons in 2017, more than the combined contributions from USA and European Union.
Among 1.38 billion people in China, approximately forty-two percent of the population reside in rural areas. Farmers’ energy consumptions increased two folds or more in the last twenty years as their incomes increased. Most farmers never stopped burning coal and dried vegetation/manure, while some urban areas switched from coal to natural gas. It will be a monumental task for the government to switch energy sources. In 2015, farmers burnt 81,100,000 tons of dried stalk and straw in open air, resulting in 34,500,000 ton carbon emission; and 74.1% occurred in northeastern China.

There are three provinces in that part of China: Heilongjiang, Jilin and Liaoning. Since Jilin is sandwiched between Heilongjiang and Liaoning, its energy consumption profiles may be representative for the northeastern region. A typical winter season lasts five months, with average temperatures below 10 degrees Celsius between November and March. Population in rural areas is approximately 12 million, and that in urban areas is 15 million. The provincial government has developed some clean energy sources mainly for the urban areas, including 44,440,000 kW wind power and 37,720,000 kW hydro power. For the rural areas, it is critical to study farmers’ willingness to adopt clean energy sources.

Existing literatures provided some data for rural Chinese energy consumptions.3-4 However, to our best knowledge, there have been no publications in open literature dealing with farmers’ willingness to adopt clean energy for northeastern China. Due to the social structures, Chinese farmers usually “accept” government rules, regulations and policies without any implementations if there were no practical benefits. For example, technologies to produce biogas from animal manures and stalks/straws were promoted many years ago. Farmers in northeastern part of the country did not adopt such technologies because the average temperatures are too low in the region. Thus, it is crucial to understand farmers’ willingness in order to truly implement Paris Agreement at the beginning of 2020.

Based on theory of planned behavior, intentions to perform behaviors of different kinds can be predicted with high accuracy from attitude towards behavior, subjective norms and perceived behavioral control.5 Furthermore, socioeconomic characteristics such as incomes, ages and educational levels affect willingness to adopt renewable energy in various parts of world including Chinese urban residents.6-8 Thus, it will be useful to study farmers’ willingness in four categories: attitude towards behavior, subjective norms, perceived behavioral control, and socioeconomic characteristics.

For farmers, behavior and attitude are affected by behavioral psychology.9 They will have positive attitude if good results are expected. As income levels increase, farmers can pursued better life quality such as clean surrounding, neat houses and more leisure time. In cold climate such as northeast China, farmers may want to use less coal and dried vegetation in heating and cooking if they can afford the clean energy technologies. If the cost to purchase such technologies is too high, farmers may be hesitant to switch energy sources. Therefore, factors such as quality of life, monthly expenses, and environment benefits are included in our survey questionnaires.

Subjective norms reflect the perceived social pressures in considering certain actions such as adopting clean energy technologies. In an earlier study of adopting new energy vehicles in urban Chinese communities, subjective norms were found to have significant and positive effects on purchase intensions.10 Thus, it will be useful to investigate the government commitment, appraisals from neighbors and friends and local clean energy market maturity. If the Chinese government shows its commitment to clean energy or provides the subsidies for switching energy sources, what will be the reactions from the farmers? Would neighbors and friends affect farmers’ decisions? Are farmers satisfied with the maturity of local markets matter?

Using Ajzen’s theory of planned behavior,5 perceived behavioral control refers to farmers’ perceptions of their ability to adopt clean energy by considering their past experiences and anticipated obstacles. Such personal behavior is usually influenced by one’s confidence in taking such an action.11 With more confidence in completing a task, a person will likely to carry out the new task. Switching from coal and dried vegetation to clean energy will cost money, and farmers may not be
able to afford such financial charges. Planners and developers will need to understand farmers’ finance and opinions. Implementing clean energy technologies may save labors as farmers may not need to move heavy coal and bulky dried vegetation to homes. Do they truly believe such advantages? With newly developed technologies, farmers may want easy access to technical guidance and periodical maintenance instructions.

As for socioeconomic characteristics, there are three key factors: age, education level and household income. Chinese rural areas went through major changes in the last twenty years or so. Nowadays, younger farmers have more exposures to new technologies than their parents and grandparents. Would the younger generation prefer clean energy more than the older generation? How about education levels? Does the income matter?

To fully investigate farmers’ willingness, rural areas of Jilin Province were selected. To pre-screen survey questionnaires, a review panel was assembled, which consisted of four experts with each person specialized in energy, agriculture, psychology or marketing. After their reviewing, some of the earlier questions were deleted such as “number of farm animals” and “general government agricultural policies.” There were thirteen questions in the final version of the survey. The first question was to assess the willingness to adopt clean energy, and remaining twelve questions were related to quality of life, environment concerns, government commitment, appraisal from neighbors and friends, savings in labors, technical guidance and periodical maintenance instructions, household annual income, monthly expenses, switching costs, maturity of local clean energy markets, age, and education levels.

2. Survey and Data collections

Between January and March of 2018, five hundred and sixty eight (568) farming families in Yushu and Dehui counties were surveyed using random sampling methods. During face-to-face meetings, survey workers wrote down the answers in the questionnaire’s sheets when they interviewed the head of each household. Among all 568 sets, five hundred and twenty seven (527) sets were valid, and remaining forty one (41) sets were not valid due to various errors in data entries.

For these 527 families, energy sources for heating, cooking, lighting and household appliances include 36.1% dried stalk/straw, 47.1% coal, 11.7% electricity and 5.1% natural gas. Please note that nearly 83% energy sources are coal and dried stalk/straw. Opportunities to use solar source exist as annual solar irradiation time for Jilin is 2,600 – 3,000 hours. In the summer with dry weather and abundant solar irradiance, 90.7% of farming families in Jilin use solar hot water systems. In terms of the age groups, the percentages of using solar hot systems are 100% for the youngest group (25 and below), 97.9% for the second group (26 – 35), 92.6% for the third group (36 – 45), 91.6% for the fourth group (46 – 55), and 82.1% for the oldest group (56 and older). Comparing younger generations to older generations, the former adopted the solar hot water technologies in faster paces than the latter. Costs of these systems range from twenty Yuan to three hundred Yuan, and overall adoption rates are higher than those in the urban areas. Regarding solar PV installations, the average cost per household is between 15,000 and 30,000 Yuan, which is equal to annual incomes of some farming families. Thus, it will be interesting to see if incentives are needed to promote clean energy adoptions.

In Table 1, socioeconomic data of 527 respondents are tabulated. In terms of farmers’ ages, the distributions are similar to those in other parts of rural areas where some young people have migrated to cities. For the educational levels, majority of them received educations at 9th grade or lower. The annual household income levels are comparable to those in rural areas, however, substantially lower than that in the Provincial Capital, Changchun. Among all respondents, 66% of the farmers are males and 34% are females. The reasons are related to the traditional social structures in which males are usually the heads of households.
Table 1. Socioeconomic Information of Respondents. (n = 527)

| Type                      | Selection | Frequency | Percentage (%) |
|---------------------------|-----------|-----------|----------------|
| Age                       |           |           |                |
| 25 and younger            | 37        | 7.0       |
| 26–35                     | 95        | 18.0      |
| 36–45                     | 120       | 22.8      |
| 46–55                     | 141       | 26.8      |
| 56 and older              | 134       | 25.4      |
| 9th grade or lower        | 377       | 71.5      |
| Education level           |           |           |                |
| 10th – 12th grade         | 86        | 16.3      |
| College Associate Degree or Higher | 64 | 12.2 |
| Below 10,000 Yuan         | 120       | 22.8      |
| Annual Household Income (RMB) |     |           |                |
| 10,000 - 29,999 Yuan      | 159       | 30.2      |
| 30,000 – 50,000 Yuan      | 171       | 32.4      |
| Higher than 50,000 Yuan   | 77        | 14.6      |

In Table 2, consumptions of different energy sources with different age groups are tabulated. Older generations tend to use more dried stalk/straw supplies presumably due to availability and extremely low monetary costs. Younger generations tend to use more coal, electricity and natural gas supplies presumably due to their purchasing powers. In terms of the heating cost per 5,000 kcal, coal is the lowest (0.80 Yuan), natural gas is the highest (3.34 Yuan) and electricity is slightly less than the natural gas (3.14 Yuan).¹²
Table 2. Energy Consumptions.

| Age         | Energy Source Type | Percentage (%) |
|-------------|--------------------|----------------|
| 25 and younger | Dried Stalk/Straw | 2.4            |
|             | Coal               | 67.8           |
|             | Electricity        | 20.6           |
|             | Natural Gas        | 9.2            |
|             | Dried Stalk/Straw  | 5.8            |
|             | Coal               | 66.9           |
| 26 - 35     | Electricity        | 17.3           |
|             | Natural Gas        | 10.0           |
|             | Dried Stalk/Straw  | 34.3           |
|             | Coal               | 48.5           |
| 36 - 45     | Electricity        | 11.7           |
|             | Natural Gas        | 5.5            |
|             | Dried Stalk/Straw  | 49.8           |
|             | Coal               | 38.0           |
| 46 - 55     | Electricity        | 9.2            |
|             | Natural Gas        | 3.0            |
|             | Dried Stalk/Straw  | 54.2           |
|             | Coal               | 35.8           |
| 56 and older| Electricity        | 7.8            |
|             | Natural Gas        | 2.1            |

3. Model and Results

A binary logistic regression model is established with one dependent variable (willingness to adopt clean energy) and twelve independent variables. Farmers’ willingness was first assessed in a binary format. Among 527 farmers, 338 selected yes and 189 selected no; or 64% yes and 36% no. Twelve independent variables include 1. Quality of life, 2. Environment concerns, 3. Government commitment, 4. Appraisals from neighbors and friends, 5. Savings in labors, 6. Technical assistance and yearly maintenance costs, 7. Household annual income, 8. Monthly expenses, 9. Switching costs, 10. Maturity of local clean energy markets, 11. Age, and 12. Education level. These variables are classified in four categories: attitude towards behavior (Variables 1-3), subjective norms (Variables 4-6), perceived behavioral control (Variables 7-9), and socioeconomic characteristics (Variables 10-12).

In this binary study, there are only two levels for the dependent variable: Yes or No. For a logistic regression model, a mathematical equation is expressed in Eq. (1).\(^\text{13}\)

\[
\text{Logit}(y) = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \epsilon_i \quad (1)
\]

where \(y\) is the dependent variable, \(X_i\) is a vector of observations of independent variables, \(\beta_i\) is a vector of parameters to be estimated, \(\epsilon_i\) is a random error term for \(i^{th}\) variable and is assumed to follow a standard normal distribution. In Table 3, the dependent and the independent variables are tabulated.
### Table 3. Descriptions of variables.

| Description                        | Variable | Meaning and evaluation of variables                                                                 | Mean  | Standard deviation |
|------------------------------------|----------|-----------------------------------------------------------------------------------------------------|-------|--------------------|
| Quality of Life                    | X<sub>1</sub> | “In comparison with traditional energy, clean energy can improve quality of life.” No=0, Somewhat=1, Likely=2, Most likely=3, Definitely=4 | 2.469 | 1.085              |
|                                    |          | “In comparison with traditional energy, clean energy require additional monthly out-of-pocket expenses.” Much less=0, Less=1, Same=2, More=3, Much more=4 | 2.397 | 0.758              |
| Monthly Expenses                   | X<sub>2</sub> | “In comparison with traditional energy, clean energy can reduce environment pollution.” No=0, Somewhat=1, Likely=2, Most likely=3, Definitely=4 | 2.298 | 1.125              |
| Environmental Benefits             | X<sub>3</sub> | “The government's commitments to clean energy are important.” Strongly disagree=0, Disagree=1, Neither agree nor disagree=2, Agree=3, Strongly agree=4 | 2.467 | 1.114              |
| Government Commitments             | X<sub>4</sub> | “Appraisal from neighbors and friends affect farmers' willingness.” Strongly disagree=0, Disagree=1, Neither agree nor disagree=2, Agree=3, Strongly agree=4 | 2.325 | 1.103              |
| Appraisal from neighbors and friends | X<sub>5</sub> | “Are you satisfied with maturity of local market?” Very unsatisfied =0, Unsatisfied =1, Neutral=2, Satisfied=3, Very Satisfied=4 | 1.689 | 0.980              |
| Local Clean Energy Market Maturity | X<sub>6</sub> | “How much would you be able to pay for the switching cost of converting from a traditional energy to a clean energy?” All=0, Most =1, Half=2, Small part=3, Very little=4 | 2.158 | 0.945              |
| Switching Cost                     | X<sub>7</sub> | “Whether can you have more time in doing other things by using clean energy?” Definitely Not=0, No=1, Neutral=2, Yes=3, Definitely Yes=4 | 2.547 | 1.179              |
| Saving in Labor                    | X<sub>8</sub> | “Easy access to proper technical guidance and periodical maintenance instructions would influence your decision.” Definitely Not=0, No=1, Neutral=2, Yes=3, Definitely Yes=4 | 2.412 | 1.123              |
| Easy Access to Proper Technical Guidance and Periodical Maintenance Instructions | X<sub>9</sub> |                                                                                                   |       |                    |
Since this study is an exploratory attempt to assess farmers’ willingness, the internal consistency of data was tested and Cronbach’s Alpha value was found to be 0.66, which is acceptable for this type of research.\textsuperscript{14}

Using SPSS 24.0, logistic regressions were performed and results are tabulated in Table 4. When the p-value is less than 5% or the Wald value is larger than 3.84, the result is significant.

### Table 4. Variables in Equation (1).

| \( \beta_i \) | Standard Deviation | Wald | df | p-value | Exp(\( \beta_i \)) |
|----------------|--------------------|------|----|---------|------------------|
| \( X_1 \)      | 1.569              | 0.488| 10.334 | 0.001   | 4.804            |
| \( X_2 \)      | -1.125             | 0.529| 4.513  | 0.034   | 0.325            |
| \( X_3 \)      | 1.335              | 0.415| 10.360 | 0.001   | 3.799            |
| \( X_4 \)      | 2.465              | 0.639| 14.894 | 0.000*  | 11.764           |
| \( X_5 \)      | 1.176              | 0.418| 7.930  | 0.005   | 3.241            |
| \( X_6 \)      | 0.524              | 0.343| 2.329  | 0.127   | 1.688            |
| \( X_7 \)      | -1.071             | 0.511| 4.397  | 0.036   | 0.343            |
| \( X_8 \)      | 1.396              | 0.386| 13.077 | 0.000   | 4.041            |
| \( X_9 \)      | 1.857              | 0.595| 9.732  | 0.002   | 6.402            |
| \( X_{10} \)   | -0.222             | 0.295| 0.567  | 0.452   | 0.801            |
| \( X_{11} \)   | 0.666              | 1.042| 0.408  | 0.523   | 1.947            |
| \( X_{12} \)   | 1.866              | 0.583| 10.250 | 0.001   | 6.461            |
| Constant \( \beta_0 \) | -18.173          | 3.372| 29.043 | 0.000   | 0.000            |

*The actual value is less than 0.001 as three digits are kept after the decimal point.

In Table 5, statistical test results of regressions are tabulated. The \( R^2 \) values for Cox/Snell and Nagelkerke tests are 0.693 and 0.951, respectively. Thus, model fitting is appropriate, and relationships between the dependent variable and independent variables do exist. Further, the sig. value for Hosmer/Lemeshow test (H-R Test) is 1.000, indicating a good fit.\textsuperscript{13} That is, for H-R test, if the sig. value is larger than a threshold (such as 0.05), the predicted value and observed value of the dependent variable have no significant difference and are close, implying a good model fitting. For
Omnibus tests of model coefficients, $\chi^2$ value is 622.222, with $p$-value < 0.001. Statistically speaking, the model is valid.

| Table 5. Model summary and Test. |
|----------------------------------|
| Cox and Snell $R^2$ | Nagelkerke $R^2$ | Hosmer and Lemeshow Test (sig) | Omnibus Tests of Model Coefficients ($\chi^2$) |
|---------------------|------------------|-------------------------------|---------------------------------|
| 0.693               | 0.951            | 1.000                         | 622.222                         |

Referring to Table 4, among twelve independent variables, nine of them ($X_1 - X_5$, $X_7 - X_9$ and $X_{12}$) have apparent impacts on the farmers’ willingness to adopt clean energies, with $p$-value equal or less than 0.05 (5% of confidence levels). For the “attitude towards behavior” category, Quality of Life ($X_1$), Monthly Expenses ($X_2$) and Environmental Benefits ($X_3$) have apparent impacts on the willingness. Impacts of $X_1$ and $X_3$ are positive ($\beta_1 = 1.569$ and $\beta_3 = 1.335$), but that of $X_2$ is negative ($\beta_2 = -1.125$). In terms of quality of life and environment, farmers truly express their willingness as $p$-value for $X_1$ and $X_3$ are 0.001. By expressing their desires for better life and environment, farmers look forward to more comfortable and clean livings. Please note that younger generations pay more attentions to life quality issues as the cross-correlation coefficient between age ($X_{10}$) and life quality ($X_1$) is $-0.21$ as illustrated in Table 6. However, most farmers believe that clean energies will cost more than traditional energies as the mean value of $X_2$ is 2.397 in Table 3; and high costs negatively affect farmers’ willingness since they may not be able to afford the additional monthly expenses. Similar “attitude-behavior gap” was observed in developed countries.\(^{15}\)

For the “subjective norms” category, all $\beta$ coefficients for $X_4$, $X_5$ and $X_6$ are positive, with two of them being apparent ($\beta_4 = 2.465$ and $\beta_5 = 1.176$). Once the government shows its commitment to clean energies, farmers are willing to adopt them. Such commitments include various aspects such as price subsidies and solar/wind power grid feed-in tariffs. Positive assessments from neighbors/friends definitely affect farmers’ opinions towards adoptions. Based on Table 3, the mean value of $X_6$ is 1.689, and farmers believe that the local clean energy market is not mature. Due to the immaturity, farmers show their reluctances to adaptations. For technology and market developers, it is important to assure the maturities of markets for the agricultural sectors. Comparing to western countries, this category is much more important in Chinese society.\(^{16}\) Thus, for policy makers and planners, it is important to show government commitments in rural Chinese areas. For business developers, it is rather critical to methodically establish the positive appraisals by truly introducing suitable and reliable clean energy technologies.

For the perceived behavioral control category, the $\beta$ coefficient for $X_7$ is negative ($\beta_7 = -1.071$) and that for $X_8$ and $X_9$ are positive ($\beta_8 = 1.396$ and $\beta_9 = 1.857$). Referring to Table 3, the mean value for $X_7$ is 2.158, and most farmers do not want to pay for the 50% of the switching costs (from the traditional energy to the clean energy sources). Since farmers are worried about the out-of-pocket switching costs, policy makers, manufactures and installers should provide grants, rebates and other incentives. The mean value of $X_8$ is 2.547 in Table 3; and farmers believe that the clean energy adaptation will lead to savings in labors. The government’s policies should encourage farmers to use clean energies. The mean value for $X_9$ is 2.412. Farmers really want to obtain proper technical guidance and periodical maintenance instructions. Manufacturers and installers should provide easy-to-read users’ manuals and hold workshops in rural areas. Comparing to a study in Texas, the perceived high costs in clean energy technologies will slow down the processes for adoptions.\(^{17}\) Thus, it will be important to provide accurate information to farmers. Furthermore, demonstrations and workshops are useful vehicles to promote the technologies.
For the socioeconomic characteristics category, the $\beta$ coefficient for $X_{10}$ is negative and that for $X_{11}$ and $X_{12}$ are positive. The most significant factor is household annual income ($X_{12}$) with $\beta_{12} = 1.866$. That is, stronger purchasing power may lead to more adaptations of clean energies. Since $\beta_{10} = -0.222$, one can deduce that younger generations have tendencies to adopt clean energies, which may be partially explained by their income levels. Referring to Table 6, the cross-correlation coefficient between $X_{10}$ and $X_{12}$ is $-0.37$. So, younger generations have higher income levels, and higher income levels lead to more desires for clean energies. Additionally, younger farmers may be exposed to more technologies. Since $\beta_{11}=0.666$, higher education levels lead to more preferences to clean energies. The cross-correlation coefficient between $X_{11}$ and $X_{12}$ is 0.52. Farmers with higher education levels may have more incomes and more exposures to new technologies, and may have more desires to adopt clean energies. Interestingly, the results here are consistent with earlier studies. The household income level is a strong indicator for the willingness to adopt clean energy.

Table 6. Variable Correlation Coefficients.

|     | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|----------|----------|
| $X_1$ | 1     |       |       |       |       |       |       |       |       |          |          |          |
| $X_2$ | 0.10  | 1     |       |       |       |       |       |       |       |          |          |          |
| $X_3$ | 0.46  | 0.06  | 1     |       |       |       |       |       |       |          |          |          |
| $X_4$ | 0.42  | 0.06  | 0.40  | 1     |       |       |       |       |       |          |          |          |
| $X_5$ | 0.42  | 0.12  | 0.39  | 0.33  | 1     |       |       |       |       |          |          |          |
| $X_6$ | -0.07 | -0.07 | -0.00 | -0.00 | 0.02  | 1     |       |       |       |          |          |          |
| $X_7$ | -0.12 | -0.39 | -0.11 | -0.08 | -0.11 | 0.06  | 1     |       |       |          |          |          |
| $X_8$ | 0.45  | 0.09  | 0.43  | 0.43  | 0.41  | -0.03 | -0.14 | 1     |       |          |          |          |
| $X_9$ | 0.35  | 0.09  | 0.37  | 0.35  | 0.35  | -0.01 | -0.10 | 0.41  | 1     |          |          |          |
| $X_{10}$ | -0.21 | 0.08  | -0.10 | -0.23 | -0.24 | 0.18  | 0.11  | -0.15 | -0.12 | 1        |          |          |
| $X_{11}$ | 0.26  | -0.05 | 0.20  | 0.27  | 0.26  | -0.17 | -0.25 | 0.21  | 0.16  | -0.53    | 1        |          |
| $X_{12}$ | 0.44  | -0.03 | 0.39  | 0.43  | 0.41  | -0.09 | -0.31 | 0.43  | 0.35  | -0.37    | 0.52     | 1        |

In the last twenty years or so, rural areas in Northeastern China went through rapid changes. As shown in Table 4, farmers with high income levels displayed more willingness to adopt clean energy. How about possible generation gaps? In Table 2, Younger generations utilized less coal and dried vegetation for heating and cooking. In Table 6, the cross-correlation coefficients between $X_{10}$ (age) and $X_{11}$ (education level) $X_{12}$ (income level) are both negative. That is, younger generations obtained higher education levels, and have higher incomes than older generations. It may be important to further focus on younger generations if policy makers and planners want to find catalysts to speed up the adoption rates for clean energy technologies.
Costs include both $X_2$ (monthly expenses) and $X_7$ (switching cost). Both variables have negative $\beta$ coefficients, indicating that higher costs would lead to lower adoptions. Thus, technology and market developers should pay attentions to cost reductions; and policy makers should provide incentives.

Developers/installers may want to use existing rural community structures to provide proper technical guidance and periodical maintenance instructions as $\beta_9$ indicated. Other related issue is the market maturity ($X_6$). Promoters of clean energy technologies should be patient with farmers. After 1949, the mechanized farming technologies were promoted three times. After farmers received proper technical assistances and gained real confidences, such technologies were finally and completely adopted twenty years ago in the survey areas.

4. Conclusions and Discussions

Chinese farmers in still use traditional energy sources for heating and cooking. As revealed by this study, 83% of the families use coal and dried vegetation. It is a monumental task to adopt clean energy technologies. Farmers’ willingness is assessed in four different areas with twelve independent variables: attitude towards behavior ($X_1 - X_3$), subjective norms ($X_4 - X_6$), perceived behavioral control ($X_7 - X_9$), and socioeconomic characteristics ($X_{10} - X_{12}$); and analyzed via binary logistic regressions. In terms of $\beta$ value ranking, following seven factors have apparent and positive impacts to the willingness: government commitment ($X_4$), household annual income ($X_{12}$), technical guidance and periodical maintenance instructions ($X_9$), quality of life ($X_1$), savings in labors ($X_8$), environmental benefits ($X_3$), and appraisals from neighbors and friends ($X_5$). Educational levels ($X_{11}$) and local market maturity ($X_6$) have some positive, but not apparent effects. Monthly expenses ($X_2$) and switching costs ($X_7$) have apparent and negative impacts. Ages of respondents ($X_{10}$) have negative, but not apparent impacts. That is, younger generations are more interested in the clean energy than older generations.

To entice farmers to adopt clean energy technologies, policy makers should consider new approaches to positively affect farmers’ willingness. For example, incentives and rebates can reduce monthly expenses ($X_2$) and switching costs ($X_7$). The government commitment ($X_4$) is crucial to achieve long lasting effects in rural areas. As household incomes ($X_{12}$) steadily increase, farmers will be able to switch to clean energy from coal and dried vegetation. Before implementing Paris Agreement in 2020, the Chinese government will have to address the farmers’ concerns. Government officials should encourage technology developers to reduce equipment costs and provide technical guidance and periodical maintenance instructions ($X_9$). Planners and business developers should gradually increase local market maturity. Since young farmers have tendency to learn new technologies, they may be able to attend workshops and training session to become “certified installers.” Local governments should encourage farmers to open new business and/or participate in the “clean energy co-ops.” By combining their resources and talents, farmers may become new entrepreneurs and technologists. Furthermore, central and local governments should encourage banks to consider long term loans to “co-ops” and become business partners. Developers should establish model villages to showcase successes. An interesting topic is related to the genders as our preliminary investigation did not show apparent effect of such factor. Currently, we are conducting broader studies with much larger sample bases. We also intend to systematically examine the effects of education levels, family size and member age distributions, relatives in urban areas, and their smart phone usages.

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