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Contingent Valuation Method of New and Renewable Energy as a Future Alternative in Korea

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Abstract

Environmental awareness is increasing all over the world. Concerns about the effects of global warming, such as rising sea levels, are inspiring growing interest in clean energy. The Fukushima nuclear disaster made renewable energy appear to be the main energy source of the future. This paper estimates the value of renewable energy as a substitute for nuclear energy by inferring Korean customers' willingness to pay (WTP) for it. We use the contingent valuation methodology (CVM) to determine the WTP of renewable energy and thereby estimate its value. We also identify the direct and social factors that influence the WTP and study the relationships between them through multiple regression analysis. The per capita value of renewable energy is found to be 38,921 won, and renewable energy was found to be affected chiefly by ethical factors. Moreover, constructing renewable energy facilities instead of nuclear facilities would require an additional 40 trillion won (approximately), complicating the promotion of renewable energy generation in view of Korea's public debt.

Keywords: *CVM, WTP, new and renewable energy, multiple regression analysis*

1. Introduction

Global warming is caused chiefly by the emission of greenhouse gases, which consist primarily of carbon dioxide (CO2). Many countries are seeking to develop alternatives to fossil fuel consumption. Sims et al. (2003) examined alternative energy options from a cost-effectiveness perspective, finding that nuclear power and renewable energy have similar cost-effectiveness and emission reduction potential [12]. However, since the Fukushima nuclear disaster, many countries have sought to diminish their ratio of nuclear power generation. In 2008, the Korean government announced a plan to increase the nation's share of the nuclear power generation to 41% by 2030 but then modified the plan in 2013 to maintain the current share of 22 to 29%. However, Korea experienced its worst ever power shortage in the summer of 2013 due to increasing annual power consumption, making it necessary to construct additional nuclear plants that can provide more energy inexpensively.

Though South Korea is not a signatory of the Kyoto Protocol, it passed the Low Carbon, Green Growth Act on April 14, 2010 to contribute to international efforts to respond to climate change. The act provides penalties and incentives meant to encourage energy companies to reduce greenhouse gas emissions; it also seeks to promote renewable energy development and increase the penetration ratio of renewable energy to strengthen Korea's energy independence.

Renewable energy has recently gained prominence as a form of environmentally friendly development because it is less likely to be depleted and generate greenhouse gas. However, renewable energy is considered a secondary form of energy for several reasons.

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The first is the high investment cost for technology development it requires compared to other power generation modes; the second concerns the problems posed by national conditions such as the country's terrain. The economic barriers to renewable energy will need to be removed before it will be viable as a replacement for nuclear or thermal power generation.

According to the Korea Hydro and Nuclear Power Company, the unit cost of nuclear power generation is 39.61 won, while that of renewable energy is 118.66 (using 2012 data). In other words, renewable energy is three times more expensive than nuclear energy. Moreover, adding 10GW of renewable energy requires an additional 17.1%, exceeding the current plan. The major cause of the cost increase is the need for an additional backup facility, as the power generation source does not operate sustainably.

Nevertheless, renewable energy remains in the spotlight as the option that can reduce greenhouse gas emissions and eliminate the anxiety caused by nuclear power plants, which has grown since the Fukushima crisis. Therefore, comparing renewable energy and nuclear power as alternative energy sources requires a consideration of more than just the unit cost of power generation. The social costs must also be considered. We must consider the impacts of direct costs as well as those of external factors such as social costs, especially given the high risks of nuclear power generation, when comparing nuclear and renewable energy.

This study analyzes external factors such as social costs to measure the perceived value of renewable energy.

2. New and Renewable Energy

Renewable energy is any energy source that is replenished by nature. Renewable energies are supplied three ways: the direct way, the indirect way, and other (non-direct and non-indirect) ways. The direct supply comprises thermal, photochemical, and photoelectric energy from the sun; the indirect supply comprises wind, hydropower, and photosynthetic energy stored in biomass; and all other renewable energies are supplied through environmental movements and mechanisms such as geothermal processes. Fossil fuels are not a form of renewable energy [4]. Renewable energy sources are described in detail below.

2.1. Biomass Energy

Biomass energy is generated from plant forms, such as wood, herbaceous crops, and forest residues and is essentially produced by photosynthesis [13]. Biomass energy can be converted into other energy forms, such as heat, electricity, and liquid fuels. It is easy to use because it can be burned (like fossil fuels) and used as a feedstock for conversion into other energy forms, such as liquid or gas fuels. Despite its benefits, however, biomass energy also has significant economic disadvantages. The costs of constructing biomass energy facilities are very high, and the costs of collecting and transporting the energy they generate can also be prohibitive [6].

2.2. Geothermal Energy

Geothermal energy is extracted from the thermal energy produced by the earth via steam turbines powered by steam rising from the ground at 140 to 260 degrees. It is regarded as a cost-effective, reliable, and environmentally friendly energy source [7]. Geothermal energy capacity grew by 2.6% (290 MW) to reach 11.4 GW by 2012. The projected generation from installed geothermal power plants is estimated at between 40 and 160 GW, and 800 GW from potential installed capacity is anticipated to be available for direct usage by 2050 [4].

2.3. Hydropower Energy

Hydropower is extracted from moving water contained by a dam, which generates energy that can be stored and converted into electricity via turbines. Hydropower is the most efficient way to convert energy into electricity (at 90% efficiency), as it transforms hydraulic energy into electricity directly [4]. The greater part of hydropower energy is generated from dams, the construction of which faces many impediments, such as their installation costs, operation and maintenance costs, the distances between them and energy consumers, and environmental issues [5,10].

2.4. Marine Energy

Marine energy is extracted from ocean waves, tides, salinity, and differences in ocean temperatures. Each source requires a different conversion technology. Marine energy has high potential as a renewable energy source given the tremendous size of the ocean resource [2]; however, it is still in the development phase. Its capacity was less than 3 MW per year from 2004 to 2009. However, marine energy capacity is increasing in the UK, the US, and Portugal and is expected to reach around 25 MW a year [4].

2.5. Solar Energy

Solar energy is generated by converting the sun’s energy into heat, which is then used to generate steam to spin a turbine and generator [13]. This energy consists of photovoltaic (PV) and concentrating solar power (CSP), which have been installed widely around the world over the last few decades due to its technical advantages [1]. Though it requires a large land area, it causes no serious negative environmental impacts. However, its energy conversion ratio is only about 15%.

2.6. Wind Energy

Wind energy is generated by turbines, mills, or pumps that convert the wind into useful energy. Wind turbines were developed for electricity generation at the beginning of the 20th century. The technology was improved in the early 1970s, and wind energy had become one of the most important renewable energy resources by the end of the 1990s [11]. Wind turbines are generally installed in onshore and offshore windy areas. Offshore wind energy technology is less mature than onshore technology and requires more investment [4]. Wind energy is regarded as clean energy that causes no environmental pollution; however, it causes 104 dBA of noise, and the turbines can catch only a fraction (about 40 to 50%) of the available energy [13].

3. Contingent Valuation Method and WTP

Table 1. Bidding Mechanism CVM Type

Method	Feature
Open-ended	We ask respondents to state their maximum WTP for the non-market goods or services to be valued
Bidding game	We ask questions until the respondents’ minimum WTP is determined

Payment card	We show respondents a payment card listing various dollar amounts and ask them to circle the amount they believe corresponds to the value of the goods or services
Dichotomous choice (DC)	We ask respondents about their willingness to pay single randomly assigned amounts on an all-or-nothing basis (i.e., "yes" or "no")

As there are no market data for free items such as public services, analyses such as the contingent valuation method (CVM) must be used. The CVM has been proposed for use in environmental contexts [9] and is one of the most widely used techniques for measuring and analyzing the value of public projects [16]. This economic technique, which uses surveys to valuate non-market goods and services, is often used in cost–benefit analyses of projects that impact the environment. It has also been accepted as a real estate appraisal technique [14].

Generally, the CVM asks respondents how much money they would accept (or pay) as compensation for damages to (or to maintain) non-market goods or services. The WTA is the amount of money a user is willing to accept for non-market goods or services or to pay to endure something negative, such as environmental pollution or the invasion of privacy. Conversely, willingness to pay (WTP) reflects the inverse condition. Some CVM methods have been modified to measure consumer WTP. The net difference between WTP and WTA, generated through the trade in goods and services, is known as the "social surplus." Each approach has advantages and disadvantages as well as detractors [3] and supporters [8].

Our CVM occurred in five steps. First, we selected an appropriate research target, defined the valuation, and selected a non-market item. In step 2, we constructed a hypothetical market. This involved formulating a scenario corresponding to reality as closely as possible; the scenario had to include clear reasons for the payments that the respondents could fully understand and suggestions of payment methods corresponding to the respondents' selection.

In step 3, we designed the survey questionnaire in Table 1, which included open-ended questions, a bidding game, a payment card, and dichotomous-choice (DC) questions. The bidding game was a sequence of questions about maximum WTP and minimum WTA. The payment card displayed potential expenditures on goods and services, from which the respondents' WTP and WTA were inferred. The card had a range of values, from which the respondents had to choose. During the open-ended question segment, the researcher asked the respondents about their WTP and WTA directly. There were two types of dichotomous-choice (DC) question. Single-bound dichotomous choices (SBDC) offered little information and only one question, while double bound dichotomous choices (DBDC) included an additional follow-up question. For the WTP assessment, the respondents chose "No" if the price was higher than they were willing to pay and "Yes" otherwise.

Table 2. CVM Application Procedure

Steps	Contents
Step 1. Research target selection	Define the research question and select the non-market goods or services
Step 2. Scenario selection	Make a scenario
Step 3. Survey questionnaire design	Suggest the scenario and describe the goods or services to be valued Suggest the payment method
Step 4. Survey	Preliminary survey: extract the basic information to provide the information in the main survey Main survey: interviews are conducted with random samples of respondents
Step 5. Survey result analysis	Conduct statistical analysis of the collected data

In step 4, the survey was conducted on a random sample of respondents. In step 5, a statistical analysis was performed to estimate the average WTP and WTA and bid curves and to aggregate the data. The CVM application procedure is described in Table 2.

4. Measurement

4.1. Data

Table 3. Demographic Characteristics

Division		Frequency (N=190)	Percentage (100%)
Sex	Male	106	55.8%
	Female	84	44.2%
Age	Teenager	7	3.7%
	Twenties	128	67.4%
	Thirties	42	22.1%
	Forties	12	6.3%
	Over fifty	1	0.5%
Academic background	High school diploma	15	7.9%
	Attending university	58	30.5%
	College graduate	48	25.2%
	Attending graduate school	52	27.4%
	Graduate degree	17	8.9%

We collected respondents' WTP through a CVM survey. The sample comprised 190 respondents (106 men and 84 women). We divided the sample by sex, age, and academic background, as shown in Table 3. The data reflect the respondents' WTP as prompted by questions about renewable energy—specifically, the respondents' willingness to pay to replace nuclear power with renewable energy and their willingness to accept the additional costs of constructing renewable energy facilities. We also estimated the perceived value of renewable energy by measuring respondents' WTP.

The basic scenario for this survey was a series of WTP decisions concerning willingness to replace nuclear power with renewable energy as well as willingness to accept the additional costs considering the respondents' age, sex, and academic background. The researchers gave the respondents appropriate visual instructions for each scenario concerning renewable energy, and WTP responses were elicited by the DBDC questions. The bids of the DBDC questions required respondents to evaluate their WTP given how their choices reflected their willingness to replace nuclear power with renewable energy and their willingness to accept the additional costs.

4.2 Methodology

We conducted a multiple regression on respondents' attitudes to renewable energy generation (i.e., willingness to replace nuclear power and willingness to pay the costs) that considered their sex and age in order to investigate their impact on, and relationships with, WTP. We employed the equation below:

$$WTP = \alpha + \beta_i AGREE_i + \gamma_k WILL_k + \theta_n DEMO_n + \delta GAIN + \epsilon$$

Here, the Agree variable reflects agreement with constructing renewable energy facilities; it is divided into environmental, psychological, economic, and ethical factors. The Will variable reflects willingness to endure losses, which is divided into willingness to accept the additional costs and willingness to replace existing nuclear power plants with renewable energy facilities. The Demo variable reflects demographic factors such as age, sex, and education. Finally, Gain reflects income level.

5. Results

Table 4. Multiple Regression Analysis Results

Variable		β	T	vif
The reasons in favor of renewable energy generation	Environmental factor	-35154	-1.705 *	1.323
	Psychological factor	-35296	-1.963 *	1.478
	Economic factor	-27570	-1.880 *	1.613
WTR *		-5526	-0.615	1.554
WTA **		33121	3.475 ***	1.627
Age		-2821	-0.277	1.425
Sex		1124	0.095	1.042
Academic background		-11323	-1.894 *	1.361
Income level		0.001	0.718	1.241

• (p<0.1), ** (p<0.05), *** (p<0.01)

Dependent variable = WTP
Excluded variable = ethical variable
* WTR = willingness to replace nuclear power with renewable energy
** WTA = willingness to accept the additional costs
R^2 = 0.131 (0.088)

The most significant favorable factor in renewable energy generation is the ethical factor—specifically, the sense of responsibility to future generations. This willingness to accept the costs of renewable energy development on behalf of future generations is more meaningful to respondents than economic factors. More highly educated respondents show a negative effect on WTP, probably because the more highly educated group considers factors other than the ethical factor.

The per capita value of renewable energy was measured at 38,921 won, and replacing nuclear power with renewable energy plants in Korea has been estimated to cost an additional 2 trillion won (38,921 won * a population of 50 million) annually. Annual sales of nuclear power totaled approximately 20 trillion won (based on 2012 sales), and the unit cost of renewable energy generation is typically three times more expensive; it would thus cost approximately 40 trillion won. As renewable energy generation is still more expensive than nuclear power, promoting it would be difficult given Korea's public debt.

6. Conclusion

Our study investigated the perceived value of renewable energy by examining individuals' WTP through DBDCs provided by a CVM. We found a strong willingness to accept the additional costs of constructing renewable energy facilities: most respondents want to replace nuclear power with renewable energy, primarily for ethical reasons (rather than economic ones). They are willing to accept the costs on behalf of their descendants. The more highly educated respondents show a negative effect on WTP, likely because they tended to consider factors other than ethical ones.

We estimated the per capita value of renewable energy at 38,921 won; replacing nuclear power with renewable energy plants in Korea would carry an additional cost of about 2 trillion won annually. Annual sales of nuclear power total approximately 20 trillion won (based on 2012 sales)), and the unit cost of renewable energy generation would be three times more expensive that generating nuclear power, costing approximately 40 trillion won.

This paper helps us determine the perceived value of renewable energy and the factors that affect it, an important issue given Korea's frequent energy shortages and anxiety due to the Fukushima nuclear disaster. We have identified the value of renewable energy in terms of both its direct costs and social costs using a multiple regression. As renewable energy generation is still more expensive than nuclear power, promoting it would be difficult given Korea's public debt.

This study has a limitation. Survey respondents should ideally be working people, as they determine the market value of renewable energy. However, many of our respondents were in their twenties. Only 28.9% of our participants were workers (i.e., in their thirties, forties, or over fifty), while 67.4% were in their twenties, biasing our results towards those in their twenties. Future research should distribute the ages of survey respondents more evenly.

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