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Factors Influence the Fate of Nuclear Energy in Taiwan: The Roles of Risks and Benefits Perception

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Abstract:

To help resolving a longstanding dispute over nuclear power in Taiwan, authorities decide put the fate of the power plant to a national referendum in the near future. Successfully resolving nuclear issues to achieve a balance between economic growth and social acceptance is critical to achieving government managerial effective. This study focus on publics risk and benefit perceptions toward nuclear power plant, and the antecedents of these perceptions, include clear nuclear policy, nuclear knowledge and trust. Data is collect from mail questionnaire across Taiwan. The results showed that peoples risk and benefit perceptions are both significant ways of influencing attitude toward the topic of ceasing or maintain nuclear power. This study shed some light on the importance of antecedence factors of risks and benefits and the way they are related to trust in government and level of nuclear knowledge.

Keywords:

Attitude toward Nuclear Power; Benefit Perception; Risk Perception

1. INTRODUCTION

Nuclear power has many advantages over non-nuclear power, including extremely low carbon dioxide emissions during its life cycle, supplement to solar and wind energy to produce sufficient energy to meet the worlds current needs, and currently still quite cheap source of power generation [1, 2]. However, most of the public is worried about reprocessing, waste management, and the costs of fuel cycle, including decommissioning of facilities. Those concerns cause perception of high level risk towards nuclear safety among the public.

After Japan Fukushima accident, several countries are discussing whether they will maintain their nuclear power plants in the next few decades. The economic development of a nation largely depends on how its energy requirements being satisfied; hence, the decision will influence their citizens quality of life and the level of industrialized, urbanized, and mobile societies [3]. Taiwan currently has three nuclear power plants in operation and one, the fourth plant, under construction with 97% completion and 41% completion for pre-op testing as of 30 April 2012 [4]. The fourth plant has encountered significant delays over the past decade and is facing numerous difficulties during pre-op testing over the past year. New target dates have not been set for commercial operation. A major challenge now is whether to proceed, or

suspend until a thorough safety evaluation is completed.

According an opinion poll in 2012, a little more than 89 percent of residents in Taipei, New Taipei City and Keelung are favor a nuclear energy-free Taiwan and 83 percent lack confidence in the governments ability to deal with a possible nuclear disaster. As for the opinion on the power plant being built in Gongliao, 54.4 percent of respondents said they support the plant if safety is not a concern, while 38.8 percent said the plant should not operate, regardless of its safety.

The use of Fourth Nuclear power is a major issue linked to national energy safety, the stability of power supply and public held value. To help resolving a longstanding dispute over nuclear electricity in Taiwan, authorities decide put the fate of the power plant to a national referendum. Taiwan government proposes to put the issue to a vote, asking the public to decide the fate of the island's controversial fourth nuclear power plant. Successfully resolving nuclear issues to achieve a balance between economic growth and social acceptance is critical to achieving managerial effectives. To be sure, citizen participation in decision process can increase public acceptance of policy, whereas the risks of weakening that quality may be as great, for delaying or distorting the pursuit of important public goals.

Therefore, in this paper, we will investigate several determinants of Taiwan publics attitude formation for the nuclear power and the propensity to the decision of cease nuclear power plants. This study focus on publics risk and benefit perceptions, and the antecedents of these perceptions, namely nuclear policy, nuclear knowledge and trust.

2. LITERATURE REVIEW AND DISCUSSION

Nuclear industries, academic fields, local community, environmental groups and the people who could be most affected by a problem with nuclear facilities, all have concerns or interests in risks and benefits of nuclear electricity. Risk perception is the subjective judgment of the probability as well as the consequences of accident happening and how concerned we are with the consequences of a negative outcome. Regardless of the high degree of achievement that rapid innovation of nuclear technology solves many of its technological constraints and safety issues, social acceptance for nuclear energy has been relatively low. Risk perception came to be seen as an obstacle to technology, most notably to nuclear technology.

2.1 How Governments Managerial Factors Influence Nuclear Risk-Benefit Perception

Our intention is to examine whether peoples nuclear facility risk-benefit perceptions can be explained by governments managerial factors. From previous studies [5–8], we found information on energy policy (the clarity of energy development), knowledge of nuclear (the ability to analyze information), trust government and industry is the most important factors which can influence the public perception of the nuclear power.

2.1.1 Energy policy in Taiwan

In light of Japans Fukushima Nuclear disaster on March 11, 2011, the government reviewed Taiwans energy situation, and formulate the New Energy Policy to "ensure nuclear energy security, steadily reduce nuclear energy dependence, create a friendly low-carbon green energy environment, and gradually move towards a nuclear-free homeland " (Bureau of Energy, 2013). Taiwan is insufficient in natural resources, and constrained by limited environment carrying capacity; how to efficient use of limited resources to

support sustainable green energy to create a win-win-win solution in energy, environment, and economy is still unclear and vague.

Compared to other countries, Taiwans energy development faces more severe challenges for it long depends on imported energy up to 99%. After considering cost-efficiency, environmental impact and potential for development, Taiwan has put natural gas and renewable energy high priority in the energy supply structure in the future. To meet the challenge of high energy prices and global warming, nuclear energy is inevitable to become an important role in energy structure by now; about 19% Taiwans electricity is from nuclear fuel. However, the lack of a solution for the disposal of nuclear waste remains a serious problem for the nuclear industry. There is no clear policy for plutonium from reprocessing to waste disposal can cause public perception of risk.

Berg and Damveld [5] recognized that the lack of a clear policy on the future of nuclear energy made it difficult for the public to develop trust. Clear policies are crucial to let public knowing future energy development and knowing the role of nuclear in the energy structure. Most people in Taiwan unaware of the future energy policy and suspicious about the security of energy supply. The public ought to be aware of impact of long-term economic, environmental and energy-security interests along the path of energy policy. There is a strongly support that clear policy, in general, has an effect on perceptions of risk and benefit [5, 6, 8]. From above discussion, this study proposes:

H1: The clearer of nuclear energy policy, the higher mitigation of risk perception of nuclear energy.

H2: The clearer of nuclear energy policy, the higher benefit perception of nuclear energy.

2.1.2 Nuclear knowledge

The capability to process information has been a main factor to influence potential attitudes toward nuclear power and it is presumed to be related to level of education. However, Hursti and Magnusson [9] found that the direction of knowledge effect is somewhat ambiguous, because level of education could result in a better capacity to identify risks as well as benefits. Knowledge itself is an instrument for affecting attitudes and building image. Therefore, bureaus should fully disclose the information on nature of benefits and risks about nuclear power. In this way, public can construct their knowledge about nuclear and are better informed about nuclear issues and more aware of its benefits [10].

Perceived knowledge about nuclear technology is also expected to have an influence on risk-benefit perceptions. In general, people perceive less risks that are familiar to them than those that are exotic [11], suggesting a negative relationship between perceived knowledge and perceived risk. Thus the low level of the publics knowledge about nuclear technology suggests that their risk judgment may not base on facts. Therefore, this study proposes:

H3: The more knowledge of nuclear technology, the less risk perception of nuclear energy.

H4: The more knowledge of nuclear technology, the more benefit perception of nuclear energy.

2.1.3 Trust

Desvousges et al. [12] and Mushkatel et al. [13] have found that no matter what peoples stance on nuclear energy, the degree of trust in the government appears to be a key determinant affecting attitudes toward nuclear technology. Fischer [14] and Cohn [15] also indicated that trust and credibility of information are elements of successful communication to public policy, which can mitigate public risk perception and increase benefit perception. Unfortunately, the same studies also show that government representatives and government scientists are amongst the least trusted sources. Not only must the public

receive the information but they must see the information as credible and relevant to their thoughts and responses about nuclear issues. Transparency, inclusive and interactive information can clarify misconception of nuclear and increase the public's confidence in governments ability to manage risks and commitment to provide correct risk information [7].

In line with the previous findings [8, 14, 16], we found distrust is the most important factor contributing to the anti-nuclear, and the antecedents of perceived risk. Scientific facts, no matter how technically supported they are, may not be considered credible by all stakeholders, because interpretations of data and a study's limitations legitimately vary. Without a shared understanding of a study's analysis, assumptions, interpretations, and limitations, the public has no way of fairly comparing one study with another [17].

Besides the scientific evidence, sustained economic growth and stable improvements in the operation of nuclear power plants with good operation records can change the public benefits perception toward nuclear energy. In general, people will regularly seek new nuclear-related information or receive information, and they must process it. Thus, risk-benefit perceptions are supposed to be related to peoples trust in the source of information. So, trust in these organizations should lead to higher benefit and lower risk perceptions. H5: The higher degree of trust in authority, the lower level of risk perception of nuclear energy.

H6: The higher degree of trust in authority, the higher level of benefit perception of nuclear energy.

2.2 Risk/Benefit Perceptions and National Referendum on Nuclear Plant

The fourth nuclear power plant in Taiwan has been plagued by delays since construction began in 1999. Earlier this year, the Taiwan Cabinet proposed putting the plants fate to a referendum amid nuclear safety concerns that have grown since the Fukushima nuclear disaster. It is important to consider the level of public participation and the effectiveness of such participation to a given problem. In general, concerns for decision quality recommend less involvement, and concerns for acceptance recommend more [18].

Nuclear energy has already brought many economic benefits. However, the advance of technology produces high levels of uncertainty related to health, environmental, ethical, and societal aspects of human life. Individual often has both positive and negative attitudes towards nuclear emery at the same time. Usually, attitudes towards an object will guide behavior. However, when people hold ambivalent attitudes, this relationship diminishes [19]. Thus, some individuals might strongly have negative attitude toward nuclear, but nevertheless fail to support the cease the fourth nuclear power plant if their attitudes are ambivalent. Ambivalent attitudes may also be more susceptible to information or persuasion.

Media kept broadcasting previous accidents such as Ukraines Chernobyl and the Three Mile Island accident in the United States. In turn, the public is increasingly afraid of another nuclear disaster and magnifies perception of risk toward nuclear energy. From Lee, et al. [8] and Fan [6] showed that most people in Taiwan characterizing nuclear power as associated with health risks, environmental risks and safety risk resulted in a conception of risks outweighed benefits. However, these risk perceptions and benefit perceptions will guide Taiwan people do their choice on referendum. In general, when choosing between alternatives, individual will do the cost-benefit analysis for each option. In order to make sense, a chosen policys benefits should exceed its costs. Therefore, this study proposes:

H7: The more benefit perception of nuclear power plant, the more positive attitude toward maintaining it.

H8: The more benefit perception of nuclear power plant, the more negative attitude toward stopping it.

H9: The more risk perception of nuclear power plant, the more negative attitude toward maintaining it.

H10: The more risk perception of nuclear power plant, the more positive attitude toward stopping it.

Table 1. **SUBJECTS PROFILES (N=231)**

Gender	Freq	%
Male	105	46.0
Female	126	54.0
total	231	100.0
Age	**Freq**	**%**
2029 years old	53	23
3039 years old	70	30
4049 years old	70	30
50 years old and up	37	17
total	231	100.0

3. RESEARCH METHOD

3.1 Samples and Data Collection

The research is based on a nationally representative sample of adults aged 22+, and used quota sampling to obtain a representative sample of the northern Taiwan population. The total number of responses was 240. The total response rate was 36%. The quotas were set by gender (4654%), and age (23% 2029 years old, 30% 3039 years old, 30% 4049 years old, and 17% 50 years old and up), as **Table 1** . After removing participants who provided incomplete data, 231 questionnaires were used in the final data analysis.

3.2 Questionnaire and Variables Measurement

According Lee, Wang, Chuang and Lin [20] study of Taiwan nuclear policy, we designed questions to measure clear energy policy, nuclear knowledge, citizen trust in authority. Three statements were adapted from previous research regarding attitude [7, 21] to measure public attitude toward the issues of maintain nuclear power and cease nuclear power. The risk perception and benefit perception for nuclear power were measured on a 4item scale separately, based on Siegrist, Cvetkovich, and Roth [22] study. Seven response categories were used to measure question items that ranged from strongly agree to strongly disagree.

4. RESULTS

Purification of the scales was based on item-to-total correlations and factor loadings. These two criteria resulted in four items deleted from scale (shown in **Table 2**).

4.1 Measurement Tests

This study use Harman single-factor test to address the issue of common method variance. The result shows the single factor of exploratory factor analysis is 37.82%, not accounting for the majority of the variance in our measures [23]. So, there is no substantial degree of common method variance exists. This study followed the two-stage methodology (a measurement model and structure model) by using AMOS 8.0 for data analysis. The adequacy of the measurement model was evaluated using Confirmatory Factor

Analysis (CFA). Satisfactory model fits are indicated by the value less than 3 of χ^2/df (χ^2 = 309.14, df = 185, χ^2/df = 1.67), RMSEA=0.05, GFI=0.90, AGFI=0.86, CFI=0.96 and NFI, IFI greater than 0.90. The statistics are almost within the acceptable range, which indicates a good mode fit.

All indicator factor loadings have a significant t-value ranging from 0.68 to 0.97 on their respective constructs. The square of a factor loading provides the amount of variance in the observed variable that the underlying construct is able to explain. The composite reliability values have a range from 0.81 to 0.92, whereas the whole range of average variance extracted is from 0.63 to 0.80 for each latent construct. These results confirm the convergent validity of the indicators as suggested by [24]. This study adopted the chi-squire difference in all two-factor CFA tests that restricted the factor inter-correlations to unity. All chi-square differences in two-factor CFA tests were significant (greater than 3.84), and latent construct AVE values exceed shared variances between all possible pairs of constructs [24]. The above evidences supported reliability, convergent and discriminate validity for all research scales. The result is shown in **Table 2** . **Table 3** shows all constructs have sufficient discriminant validity since the square root of each latent constructs AVE (values on the diagonal) is larger than the correlation of the specific construct with any other constructs in our research model.

4.2 Model Assessment

Satisfactory structural model fits are indicated by the value less than 3 of χ^2/df (χ^2=334.42, df=193, χ^2/df=1.73), RMSEA=0.056, GFI=0.89, AGFI=0.86, CFI=0.97 and NFI=0.92, IFI=0.97. The results of hypotheses testing are presented in **Table 3** , which provides initial evidence for our conceptual model. This table presents the estimated coefficients for the structural model, together with the R 2 indicator for each latent endogenous variable, and the associated t-values of the paths of the research model (asterisks represent significant paths). This study split the data along gender to test factor structure equivalence. The chi-square (df) for unconstrained and constrained model are 603.7 (370) and 623.2 (392) separately, with $\delta\chi^2/df$ (χ^2=19.5, df=22, p-value=0.614). The results showed groups are not different at the model level, achieving configurable invariance.

4.3 Path Analysis

In this study, the hypothesized relationships were examined through path analysis models and the results were shown in **Table 2** . The results of the relationship between clear policy and nuclear risk perception (β=0.05; p=0.56) had no statistically significant, failing to support H1. The same result also appeared on the path between clear policy and nuclear benefit perception, with β=-0.07; p=0.32, failing to support H2. Nuclear knowledge had a significant positive effect on perception of nuclear benefit, with a path coefficient of 0.42 (p = 0.01), providing empirical support for H4. On the contrary, nuclear knowledge did not have statistically significant on reducing perception risk of nuclear power (β=-0.05, p=0.59), failing to support H3. From **Table 4** , public trust had a significant influence on perception of nuclear risk (β=-0.30; $p < 0.001$), supporting H5. Meanwhile, public trust had a positive effect on perception of nuclear benefit, with β=0.35; $p < 0.001$, supporting H6.

All the perception paths, with the exception of that linking nuclear risk perception and the attitude toward maintain nuclear power, were significant ($p < .05$). Nuclear benefit perception had significantly positive effect on the attitude toward maintaining nuclear power (β=0.81; $p < .001$), whereas having negative influence on the attitude toward ceasing nuclear power (β=-0.67; $p < .001$). As of the risk perception, reducing nuclear risk perception cannot increase public attitude toward maintaining nuclear

Table 2. **THE RESULT OF THE CFA ANALYSIS**

Constructs	Item	loading	Item reliability	C.R	Mean (std)	AVE	H.S.V.
Clear Policy	1	.69	.48	.91	3.88 (1.42)	.77	.22
	2	.96	.92				
	3	-	-				
	4	.96	.92				
Nuclear Knowledge	1	-	-	.81	4.59 (1.27)	.68	.33
	2	-	-				
	3	.79	.62				
	4	.86	.74				
Trust	1	.88	.77	.91	3.15 (1.48)	.72	.35
	2	.85	.72				
	3	.81	.66				
	4	.86	.74				
Perception Benefit	1	.91	0.81	.87	4.87 (1.30)	.63	.59
	2	.85	.72				
	3	.68	.46				
	4	.71	.50				
Perception Risk	1	-	-	.90	5.69 (1.17)	.75	.16
	2	.78	.61				
	3	.97	.94				
	4	.83	.69				
Maintain Nuclear Power	1	.92	.85	.90	4.97 (1.49)	.75	.59
	2	.92	.85				
	3	.74	.55				
Cease Nuclear Power	1	.75	.56	.92	4.40 (1.40)	.80	.29
	2	.95	.90				
	3	.96	.92				

Table 3. **CONSTRUCT AVE ANALYSES AND INTER CONSTRUCT CORRELATIONS**

	A	B	C	D	E	F	G
Maintain Nuclear Power(A)	0.87						
Nuclear Knowledge(B)	0.47	0.82					
Clear Policy(C)	0.26	0.46	0.88				
Cease Nuclear Power(D)	-0.38	-0.35	-0.16	0.89			
Trust (E)	0.59	0.45	0.47	-0.48	0.85		
Perception Benefit(F)	0.77	0.58	0.34	-0.54	0.57	0.79	
Perception Risk(G)	-0.24	-0.18	-0.14	0.40	-0.35	-0.27	0.86

power, but can decrease public attitude toward ceasing nuclear power (β=0.37; $p < .001$). In comparison, benefit perception is a greater effect on the attitude of maintain nuclear power and ceasing nuclear power than risk perception, with parameter comparison t=8.36 and t=9.16 separately, supporting H7, H8 and H10.

Table 4. **PATH COEFFICIENTS**

Paths	Decision made by government	
	β	p-value
Clear Policy → Benefit perception	-.07	0.317
Nuclear Knowledge → Benefit perception	.42*	0.001
Trust → Benefit perception	.35*	0.001
Clear Policy → Risk perception	.05	0.564
Nuclear Knowledge → Risk perception	-.05	0.594
Trust → Risk perception	-.30*	0.001
Benefit Perception → Maintain Nuclear Power	.81*	0.001
Risk Perception → Maintain Nuclear Power	-.03	0.560
Benefit Perception → Cease Nuclear Power	-.67*	0.001
Risk Perception → Cease Nuclear Power	.37*	0.001
endogenous variable :	R^2	
Benefit perception	.60	
Risk Perception	.13	
Maintain Nuclear Power	.61	
Cease Nuclear Power	.36	

5. CONCLUSION

Surveys conducted in northern Taiwan indicate that peoples risk and benefit perceptions are both significant ways of influencing attitude toward the topic of ceasing or maintain nuclear power. This study shed some light on the importance of antecedence factors of risks and benefits and the way they are related to trust in government and level of nuclear knowledge. The results of study are important to the industry and to policy makers as well as academics. Trust in information provided by government and industry is likewise a very important determinant of risk and benefit perceptions; once more, the Taiwanese lack greater trust in government is associated with lesser acceptance of continue nuclear power operation.

In line with the previous findings, we hypothesize risk/benefit perception and distrust is the most important factor contributing to the attitude toward nuclear power in Taiwan. This low trust in Taiwan (see in **Table 2**) is associated with higher perceived risks and lower perceived benefits. People tend to exaggerate fears due to inadequate or incorrect information. High levels of nuclear knowledge are associated with a greater perception of nuclear power benefits and less concern about the risk. This study implied that additional nuclear knowledge can help people understand true risk and hence lessen their fears. In this way, public is better informed about nuclear issues and is more aware of its benefits [10].

The findings suggest some ways by which greater acceptance of nuclear power could be promoted by greater education on nuclear technology and development of greater trust in government and industry. None of these takes is easy or be done in short-term period to promote a more favorable attitude to nuclear technology. Trust and risk communication are issues that have been recognized as important in recent years. This research supports the significance of trust building and nuclear education.

In general, it is the best degree when technology supports the program and scientific facts reduce the risk assessment, given that it can reduce the risk perception. Every formal process encounters unexpected problems need technology to support and clarify the questions. Therefore, applied scientism in nuclear safety can reinforce the accuracy of information on publics credibility.

Future research can consider the effect of risk communication, the influence of expert opinion into

the study of risk/benefit perception. Moral concerns, such as risk-benefit distribution, the new value of ”environmental justice” and ”generational justice, and the disparity between urban and rural also recognize as the main factors to form the attitude toward nuclear facilities [6, 25]. For further study, these factors should be considered into the research framework for the fate of nuclear energy in Taiwan.

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