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SHAPING PUBLIC OPINION ON NUCLEAR POWER

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ABSTRACT

After the Fukushima Daiichi nuclear disaster, the public acceptance of nuclear power has dwindled to historical low. Governments were forced to cancel and postpone new projects or even shut down reactors in operation due to an increased anti-nuclear sentiment. This paper aims to provide an international perspective of how various factors can affect public opinion of nuclear power.

In this paper, we rebut the previous-held argument that nuclear education is conducive to the public support of nuclear power. It is found that the relationship between educational efforts and public support is captured by a downward-sloping line. The paper then assesses the effect on the public acceptance of demographics, socioeconomic status, political environment and risk orientation using correlation coefficients table. The largest public concern comes from the insecurity of nuclear power plants and radioactive materials. The health of an economy also plays a major role in determining people's attitude toward building new nuclear power plants.

The paper also suggests some solutions for each category of countries based on the research analysis.

INTRODUCTION

Nuclear power is a safe, clean and efficient source of energy, but it has also been bedeviled as an extremely dangerous and highly-polluted energy source among the general public. Following the Fukushima Daiichi nuclear disaster in March 2011, anti-nuclear movement and protest intensified in many regions around the globe. A total of more than one million people, involving Germany, Japan, India, France, Taiwan, Italy, Spain, Switzerland, the United States and the United Kingdom, had participated in either peaceful demonstrations or even violent rallies against the nuclear projects of their country within six months after the Fukushima accident. As a result to the protests, Germany has permanently shut down eight reactors and pledged to close all nuclear power plants by 2022. Belgium also pledged to phase out its nuclear plants by 2015. Other countries such as Japan, Spain, China and India, though not completely abandoning their existing nuclear projects, have either canceled or postponed the construction of new reactors. Many OECD countries intended to cut budget for nuclear power research and turned their interest to renewable energy or other clean energy such as natural gas or shale gas.

Without public acceptance, the future of nuclear power is gloomy.

To boost public acceptance and save the future of nuclear power, we must first study the factors that affect the public opinions on nuclear power. Much work has been done in the study of this area within a single country. In this paper, we have provided an international perspective on this issue. Due to the various demographics and socioeconomic situations, comparisons of such factors across different countries become more persuasive.

SCOPE

We have focused our research on fourteen countries with operating nuclear power plants, i.e. the United States of America, France, Japan, Russian Federation, Republic of Korea, India, Canada, China, the United Kingdom, Ukraine, Sweden, Germany, Spain and Belgium.

These countries are the top fourteen by the number of operational reactors according to IAEA sources. As Figure 1 indicates, they have a total of 389 operational reactors, which consists of 89% of the world total 437 reactors, contributing to 92% of the world total nuclear power plant net electrical capacity.

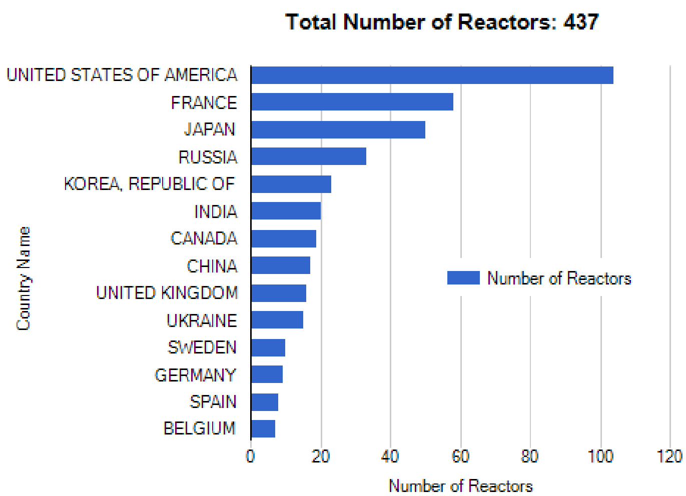

Figure 1: List of countries by number of reactors
Source: IAEA PRIS (Power Reactor Information System)

Up to December 2012, these fourteen countries have 58 new reactors under construction, which account for 85% of the world total, as well as 126 permanently shutdown reactors, which accounts for 88% of the world total. The fourteen countries all have various political systems, diverse cultural backgrounds and different degrees of economic development.

Therefore, it should be acknowledged that these fourteen countries are representatives of the world when studying nuclear power industry, because to study every nuclear country in the world is unrealistic, due to the work load and data availability, and unnecessary, due to the small tail they represent.

For non-time series data, we chose two time points to study, i.e. the year of 2008 and post-Fukushima 2011.

METHODS

All fourteen countries are divided into three group, i.e. Policy-driven group (PDG), Scarcity-driven group (SDG) and Technology-and-environment-driven group (TEDG).

Governments in policy-driven states have centralized power to implement the desired policy with little concern of the public opinions. Such countries tend to have a limited electoral process so that nuclear policy will not become a major concern of the ruling party. Here in Table 1, we list the fourteen countries accompanied by their respective democracy index, an index compiled by the Economist Intelligence Unit (EIU) which measures the state of democracy in 167 countries and regions in the world. According to the EIU's classification, eleven of the fourteen are full democracies or flawed democracies. China and Russia are authoritarian regimes, while Ukraine is a hybrid regime. Indeed, Chinese and Ukrainian government have encountered little resistance with respect to nuclear projects in the past decade. Russian government has seen several organized protests and demonstrations against nuclear projects recently, none of which, however, are significant enough to have impact on its nuclear policy. Hence, Ukraine, Russia and China are grouped into PDG states.

Table 1: List of countries by democracy index in 2011

Country	Rank	Democracy Index (2011)
Sweden	4	9.5
Canada	8	9.08
Germany	14	8.34
United Kingdom	18	8.16
United States	19	8.11
Japan	21	8.08
Korea	22	8.06
Belgium	23	8.05
Spain	25	8.02
France	29	7.77
India	39	7.3
Ukraine	79	5.94
Russia	117	3.92
China	141	3.14

Source: Economist Intelligence Unit

Scarcity-driven states develop nuclear power out of necessity. Such countries tend to be small and have limited natural resources. Thus the nuclear shares in electricity generation tend to be high. Figure 2 shows the percentage of electricity production from nuclear sources of the fourteen countries in 2011. Hence, we choose France, Belgium, Sweden, Republic of Korea, Spain and Japan to belong to the SDG. Notice that Ukraine has already been categorized into PDG. Japan actually had a higher nuclear share than that of the United States before 2011. Due to the earthquake and the subsequent Fukushima accident in March, Japan has taken effort in bringing down its nuclear dependence. All the six SDG states have extremely limited natural resources, especially fossil fuel. France even ended its coal mining completely in 2004.

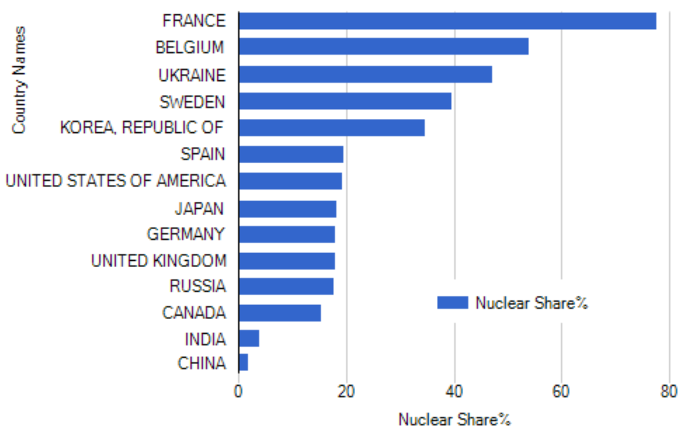

Figure 2: List of countries by nuclear share of electricity generation
Source: IAEA PRIS

Technology-and-environment-driven states develop nuclear power as an alternative clean energy to reduce carbon emission. Such countries have a decent amount of natural resources, but choose to take a more environment-friendly approach. Technology advantage is also a reason for TEDG countries to pursue their nuclear projects. Some of the TEDG states are even nuclear technology exporters.

Table 2 gives the coal production of the eight non-SDG countries in 2011. We can see that all of the eight countries have abundant coal reserves and a significant annual coal production. The United Kingdom is also a top-20 oil production country, with 70.93% of the total electricity generated from oil, gas and coal sources. In fact, India, Germany, the US and UK all have their oil, gas and coal share in total electricity production exceeding 60%. Canada chiefly relies on hydroelectric sources; however, Canada still has the second most carbon dioxide emission per capita, whereas the United States is the largest. Therefore, we group the remaining five countries into TEDG—the United States, India, Germany, Canada and the United Kingdom.

Table 2: List of non-SDG countries by coal production percentage in 2011

Country	Rank	Coal Production (% of world total 2011)
China	1	49.5
United States	2	14.1
India	3	5.6
Russia	5	4
Germany	8	1.1
Ukraine	11	1.1
Canada	14	0.9
United Kingdom	25	0.3

Source: US Energy Information Administration

Table 3 is a summary of the classification of the fourteen countries.

Table 3: Categorization of the fourteen countries

Country	Category
China	PDG
Russia	PDG
Ukraine	PDG
Belgium	SDG
France	SDG
Japan	SDG
Korea	SDG
Spain	SDG
Sweden	SDG
Canada	TEDG
Germany	TEDG
India	TEDG
United Kingdom	TEDG
United States	TEDG

We do not adopt the usual approach of regional division of countries such as North America, Asia and Europe, since countries that are geographically close may have completely different reasons for developing nuclear power. Japan and China both locate in East Asia, while two countries have different political systems, different natural resource availability and different demographics, which all affect their respective nuclear policy. Even countries with similar demographics such as India and China may differ in their nuclear policy-making process. Hence, if one takes a holistic approach, examining the impact of many different kinds of social factors on public opinion, then categorizing nuclear countries by their fundamental driving force of nuclear power development is essential.

DATA SOURCES

We quote the supporting ratio of nuclear power development among the public collected from polls and surveys. Poll and survey results are undoubtedly the most direct reflection of public opinions; however, such results cannot fully captures the public acceptance of nuclear power and have many weaknesses when used to make comparisons. Therefore, we judge that poll and survey results, being secondary sources[1] as we are unable to conduct large-scale survey by ourselves, can only serve when compared across different countries at a specific moment.

The degree of public concern also matters. A country with 80% of people indifferent to nuclear power may have a much higher supporting ratio in a poll. Such supporting ratio does not necessarily reflect the public acceptance, as the line between "for" and "against" is not clear among indifferent group of people. Hence the supporting ratio accompanied by the degree of concern can provide a rather accurate measurement to the public acceptance of nuclear power.

The degree of concern is calculated by the number of appearances of certain keywords and topics in mass media during a certain period time. We choose one daily national newspaper with the most circulation for each country. We have excluded local newspapers and tabloids that focus mainly on celebrity gossip, crime stories or astrology. All the newspapers chosen must be respected and responsible mainstream media. Table 1 in Annex A lists the newspapers we have chosen to study.

In addition to the newspapers, eight keywords about nuclear topic are carefully chosen for each language to exclude any possible distracters, i.e. nuclear power, nuclear energy, nuclear plant, nuclear accident, nuclear reactor, nuclear radiation, nuclear waste and nuclear safety. Merely searching for "nuclear" may mistakenly include distracters such as nuclear weapon. Table 2 in Annex A lists all the keywords in nine languages involved. The search has been done in this country's own language within one database, i.e. Factiva.

IS EDUCATION THE SOLUTION?

Previous studies often hold two different assumptions for the degree of public acceptance—trust-based and technology-based [1]. Trust-based explanation suggests that when non-professional laymen examine the reliability of nuclear power technology, they are not trying to form an independent opinion, but rather are deciding which group of people to trust. Technology-based suggests the opposite that people are trying to decide for themselves which technology is acceptable. Those who advocate the technology-based explanation point out that education plays a key role in social enlightenment, transforming people into independent-thinking individuals. Hence they argue that education is one of the key factors that affect the public attitude toward nuclear power.

Under the assumption that most of the nuclear laymen can form their own judgment and decision, then countries with higher education participation rate must have a higher rate of support. We want to test this hypothesis that higher level of education participation is linked with a higher supporting ratio by examining the relationship between overall education level and the public acceptance across different countries to see if the conclusion still holds internationally. As primary schools usually do not cover nuclear knowledge, we choose secondary school enrollment as an indicator of the country's overall educational efforts. Table 4 gives the gross enrollment percentage accompanied by public supporting ratio in the year of 2008 [2]. Supporting ratio data of Russia and Ukraine are not available and thus omitted from the table.

Table 4: Education participation vs. public acceptance

Year of 2008	Secondary school enrollment (% gross)	Supporting Ratio (%)
Spain	118.48044	30
France	112.71349	56
Belgium	111.18052	50
Germany	102.64455	50
Sweden	101.75019	64
Japan	101.33011	40
Canada	101.3154	44
United Kingdom	99.33575	58
United States	96.85551	75
Korea, Rep.	96.42227	59
China	78.49052	85
India	60.1621	89

Source: World Bank, IAEA

[1] This study mainly relied on data from secondary sources, such as publications by international organizations, for global analysis of public supporting ratio. Official publications like IAEA reports are preferred. For consistency, all data of a particular year are from a single source.

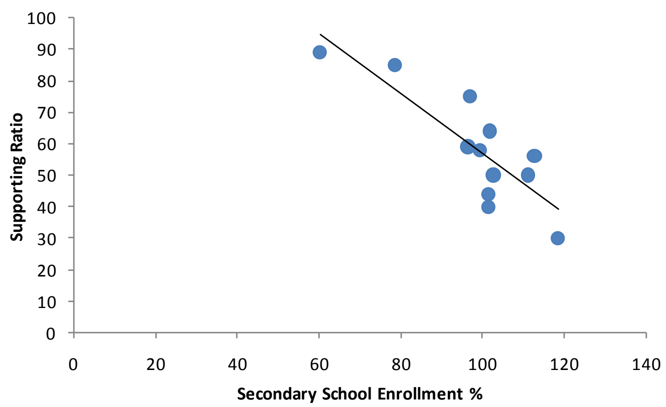

Figure 3: Education participation vs. public acceptance

The relationship between secondary school enrollment rate and the public support is clearly captured by a downward-sloping line. The correlation coefficient is -0.84, indicating a strong negative correlation. This result exhibits what is called “the boomerang effect” in social psychology that higher education level does not lead to a higher support of nuclear energy, but, in contrary, an even lower support.

Even nuclear-specific education shows a similar pattern. According to a report by OECD Nuclear Energy Agency, the efforts in popularizing nuclear science in OECD countries are significantly higher than those of developing countries, such as China and India. Still the citizens of the ten OECD countries show more opposition to nuclear energy than those in China and India. Thus, the hypothesis is rejected. The technology-based explanation that education level is positively correlated to nuclear power support ratio is not justified.

ANALYSIS

Researchers used to think that the public opposition arises from the misunderstanding and prejudice toward nuclear energy, as was indicated by the widely-held “information deficit model” of science communication, which attributes public skepticism to a lack of understanding. So much of the work has been done in the nuclear education that aims to demonstrate the safety of nuclear power plant through explaining the advanced technology we have. Yet these efforts are counter-productive, leading to more intense anti-nuclear sentiment and spawning more protests and demonstrations. As we look at the data of education outcomes, it is true that to change public opinion in a technological way is impractical. The improvement of nuclear safety technology has limited impact to ameliorate the public acceptance.

One may well ask why the information deficit model should fail to capture the public reaction and why the counterintuitive boomerang effect should happen. The information deficit model relies on a vulnerable assumption that the information receiver is **unbiased** and **rational**. However, the lay public often has preconceived first impression on nuclear power. In Hart and Nisbet’s study about the science communication on climate change issues, they have found that social identity and political partisanship increase the degree of political polarization on support for climate mitigation policies [3]. Upon learning a simulated story that climate change will increase the likelihood that West Nile virus can infect the outdoor working farmers, the Republicans and conservatives show more objection to the climate mitigation policies. Therefore, we hypothesize that social identity and political environment may also cultivate the public prejudice about nuclear power.

In fact, the information receiver is not only biased, but also irrational. We can see the irrationality of lay public by comparing the distinctive ways of understanding risk between the public and the professionals. Nuclear professionals analyze the risk through Probabilistic Risk Assessment (a.k.a. PRA), using Markov methods, fault trees and event trees to analyze the reliability of a multi-component system. By comparing the social benefits and the downside risk, professionals then form their own opinion toward building a nuclear power plant. Therefore, for these professionals, technology improvement and its education are conducive to their reasoning, leading to a higher support ratio, but only among industry professionals. However, people are not always “rational players” who calculate the expected benefits and costs before making a decision. The general public does not look into or cannot understand the meaning of data and statistics, such as a Core Damage Frequency of 10^{-7} per reactor-year. Instead, their decisions are more affected by some subtle social, cognitive and emotional factors.

Hence we focus our study on how demographics, socioeconomic status, political environment and risk orientation can affect the public psychology. For each dimension, we have chosen two or three variables to represent. In demographics, we focus on the proportion of female, aged[2] and urban citizens. Economy is one of the most important factors that voters assess the effectiveness of the administration. An economic woe may have some impact on the public attitude toward nuclear energy. Unemployment rate, GDP growth rate and the personal income we deem will most likely affect voters’ attitude toward large and costly projects such as nuclear power plants. We also want to learn how a country’s political environment can shape its public attitude. This includes the public perceptions of the quality of policy formulation and implementation, the credibility of the government’s commitment to such policies and the degree of independence from both domestic and foreign political pressure. As people get to know most of the nuclear power information through media, the transparency, freedom and accountability of media may also affect the public attitudes. Last but not least, risk orientation plays a significant role in the case of nuclear power. A risk-averse person will have a totally different outlook from a risk-neutral person. Since it is impossible to measure each individual’s risk profile, we use a 2005 report by GlobeScan, which surveyed approximately 1000 adult respondents in each of the 18 countries about their

[2] Those over 65 years old. This demarcation is based on UN’s classification of an aged society.

perception of the security of the nuclear facilities and radioactive materials [4]. We also collected the data of all historical civil nuclear reactor accidents which have an INES level above 4 (included)[3] and study how a country's nuclear history may perpetually transform the risk orientation of its citizens.

RESULTS

Results are presented in Annex B. Comparing Table 1 and Table 2 in Annex B, we found that pre-Fukushima [2] and post-Fukushima [5] results reveal a shockingly similar pattern. For demographic data, the proportion of female, senior and urban citizens has a strongly negative correlation with the public attitude. This shows that females, old people and city residents tend to hold a negative view toward nuclear power. These groups are often characterized as conservative and resistant to major changes. However, in SDG countries, the data show no significant evidence that senior and urban citizens tend to oppose nuclear power.

Unemployment rate has a negative correlation with public support, especially for SDG countries. Spain had the lowest support ratio of only 30% in 2008, partly because of its highest unemployment rate of 11.327%. Outraged public gave no support for costly projects such as nuclear power plant, despite its long-term profitability. GDP growth rate is positively correlated to public support in all three groups, showing that a happy voter tends to be more tolerant. Three BRIC countries all have a higher-than-average support ratio. Although GDP growth rate has impact on public attitude, no significant relationship between GDP per capita and support ratio can be found. The past does not count, but the trend matters.

We also found that, among PDG and SDG countries, a more effective government will enjoy a higher support ratio, while in PDG and TEDG countries, free media often lead to a low support ratio, as people can access to more information about nuclear safety and its potential environmental harm due to the radioactive nuclear waste.

Perceived nuclear insecurity has the largest correlation coefficient among all factors in all three groups. This shows the largest concern of public is the security of nuclear power plants and radioactive materials. Despite the advanced safety technology, potential risk of a terrorist attack still exists. Impact of a domestic nuclear accident seems to have no strong correlation with the public attitude. Rather, nuclear accident has a strong international impact to all the countries in the world instead of only the country where the accident happened. Figure 4 shows the average annual media coverage on nuclear issues and Table 5 gives the media coverage of each country. We can see that the media coverage about nuclear issues soared in 2011 after the Fukushima accident.

Table 5: List of countries by media coverage

	2008	2009	2010	2011	2012
Japan	1961	1952	2162	10008	7943
US	481	718	949	2394	978
UK	524	835	780	1241	922
Germany	284	290	254	1103	236
Spain	341	343	247	585	177
India	230	210	205	495	509
Sweden	181	162	275	478	155
China	175	204	242	426	239
France	122	102	76	312	111
Canada	190	153	153	221	104
Korea	34	37	55	165	103
Ukraine	98	78	72	91	88
Belgium	8	14	8	24	9
Russia	3	4	6	8	6

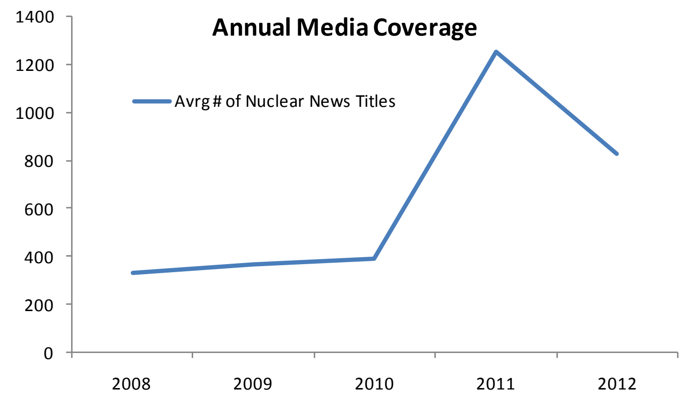

Figure 4: Average annual media coverage on nuclear issues

CONCLUSIONS

General education and nuclear technology education has long been regarded as the solution to ameliorate public opinions toward nuclear power. Our study has shown the opposite that education level is negatively correlated to public support of nuclear power. The largest concern of the public arises from the security of our nuclear power plants and radioactive materials. The health of an economy also plays a major role in determining people's attitude toward building new nuclear power plants.

Hence to boost public support for nuclear power, governments should increase the security expense in guarding the nuclear facilities and reassure their citizens the security of all nuclear power plants and radioactive materials. These measures, if taken, can soothe the public concern about a potential terrorist attack. For policy-driven and scarcity-driven states, governments can improve their policy-making process and make sure its implementation. Transparency and

[3] An INES level 4 event is an *accident* with local consequences, while an INES level 3 event is only a serious *incident*.

supervision are also needed to increase the credibility and trust in government's commitment. In TEDG countries, we see much exaggeration by nuclear critic about the potential threat of nuclear power and much resistance that comes from the lobbying power of the nuclear opponents. Freedom of speech shall be respected, but unfounded rumors ought not to be encouraged.

Although nuclear education has been proved to be ineffective in promoting public support of nuclear power, we can still improve the way of science communication. To reduce the perceived risk of nuclear power among the public, the government must also be aware of the fact that the information receivers prefer vivid stories to tedious statistics. In a research conducted by John de Wit and his co-workers, it is found that personal stories can affect people more effectively than statistical evidence because narrative evidence is less affected by defensive message processing caused by self-beliefs [6]. In a recent Chinese documentary film, a nuclear power plant operator gives a personal testimonial that he had absorbed a radiation dose equivalent to only one cigarette for working in the Daya Bay Nuclear Power Plant for five years. The film also includes footage that he and his three-year-old daughter playing in the family backyard. Though rigorously speaking, personal stories are not representative, this documentary succeeded in convincing its viewers that nuclear power plant is safe and environment-friendly.

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ANNEX A

LIST OF NEWSPAPERS AND KEYWORDS SEARCHED

Table 1: List of newspapers chosen

Country	Newspapers
China	人民日报
Russia	Комсомольская правда
Ukraine	Ukrainian News (in Russian)
Belgium	Le Vif/L'Express
France	Le Figaro
Japan	読売新聞
Korea	朝鮮日報
Spain	El Pais
Sweden	Aftonbladet
Canada	The Toronto Star
Germany	Süddeutsche Zeitung
India	The Times of India
United Kingdom	The Times
United States	The Wall Street Journal

Table 2: List of keywords searched in the 14 countries' respective native languages

Language	Keywords
中文	"核电" or "核能" or "核电站" or "核事故" or "核反应堆" or "核辐射" or "核污染" or "核安全"
Español	"Energía nuclear" or "Central(es) nuclear" or "Accidente(s) nuclear" or "Reactor(es) nuclear" or "Radiactividad" or "Residuo radiactivo" or "seguridad nuclear"
English	"Nuclear power" or "nuclear energy" or "nuclear plant(s)" or "Nuclear accidents" or "nuclear reactor(s)" or "nuclear radiation" or "nuclear waste" or "nuclear safety"
Русский	"Ядерная энергия" or "Атомная электростанция" or "Радиационная авария" or "Ядерный реактор" or "Радиоактивный распад" or "Радиоактивные отходы" or "Ядерная безопасность"
日本語	"原子力" or "原子力発電所" or "原子力事故" or "原子炉" or "放射性崩壊" or "放射性廃棄物" or "原子力の安全性"
Deutsch	"Kernenergie" or "Kernkraftwerk(e)" or "nuklearen Unfälle(n)" or "Kernreaktor(en)" or "Radioaktivität" or "Radioaktiver Abfall" or "Sicherheit von Kernkraftwerken"
한국어	"원자력" or "원자력 발전소" or "핵 사고" or "원자로" or "방사성 감쇠" or "방사성 폐기물" or "원자력 안전"
Français	"Énergie nucléaire" or "Centrale(s) nucléaire" or "Accident(s) nucléaire" or "Réacteur(s) nucléaire" or "Radioactivité" or "Déchet radioactif" or "Sûreté nucléaire"
Svenska	"Kärnenergi" or "Kärnkraftverk" or "kärnkraftsolyck(a/or)" or "Kärnreaktor(er)" or "Radioaktivitet" or "Radioaktivt avfall" or "kärnsäkerhet"

ANNEX B

CORRELATION COEFFICIENTS TABLE[4]

Table 1: Pre-Fukushima correlation with public attitudes

2008	Female	Senior	Urban	Unemployment	Economy Growth	GDP per capita[5]	Government Effectiveness	Media Freedom	Perceived Nuclear Insecurity	Impact of Domestic Nuclear Accidents[6]
All Countries	-0.7302	-0.7083	-0.6078	-0.3826	0.3882	-0.2852	-0.0387	-0.2643	-0.7435	-0.0881
PDG	-0.9994	-0.9458	-0.9843	-0.9999	0.9159	-0.6277	0.9375	-0.8335	-0.9859	-0.9968
SDG	-0.3578	-0.4083	0.1992	-0.5264	0.0589	0.1572	0.6670	0.1469	-0.5913	0.0115
TEDG	-0.7473	-0.8078	-0.7297	-0.0559	0.5292	-0.6223	-0.8293	-0.9206	-0.6050	-0.0620

Table 2: Post-Fukushima correlation with public attitudes

2011	Female	Senior	Urban	Unemployment	Economy Growth	GDP per capita	Government Effectiveness	Media Freedom	Perceived Nuclear Insecurity	Impact of Domestic Nuclear Accidents
All Countries	-0.4276	-0.5681	-0.3970	0.0464	0.2637	-0.2081	-0.1217	-0.0665	-0.4394	-0.0909
PDG	-0.9993	-0.9294	-0.9796	-0.9929	0.9866	-0.5777	0.8949	-0.8381	-0.9859	-0.9968
SDG	-0.7120	-0.0495	-0.0799	-0.3319	0.7087	0.4819	0.7388	0.4581	-0.3972	-0.1849
TEDG	-0.6609	-0.8378	-0.4994	0.9630	0.3260	-0.4532	-0.6522	-0.7104	-0.6709	0.2483

Sources: World Bank, IMF WEO, IAEA, GlobeScan, Ipsos, CIA World Factbook.

[4] Indian unemployment rate is estimated number by CIA. Ukrainian public support ratio is interpolated.
[5] Converted to dollars using the IMF's implied purchasing power parity rates for each country.
[6] The INES level takes a logarithm approach. Therefore, if an event is INES Level n, which happened t years ago, the impact is calculated as $(10^n)e^{-t}$.