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Why support nuclear energy? The roles of citizen knowledge, trust, media use, and perceptions across five Southeast Asian countries

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ABSTRACT

Public support is important for countries that are at nascent stages of nuclear energy development. This study seeks to examine factors shaping public support for nuclear energy development in five Southeast Asian countries – Indonesia, Malaysia, Singapore, Thailand, and Vietnam. Using surveys (with n = 1,000 in each country), results show that the public indicates generally low levels of support for nuclear energy development across the five countries. This reflects the possible lingering impact of the Fukushima nuclear incident on public opinion. We further show that factors, such as trust in various stakeholders, media frames, and risk and benefit perceptions, are associated with public support for nuclear energy. More importantly, people use trust, and risk and benefit perceptions as perceptual filters to interpret the relationship between nuclear knowledge and their support for nuclear energy. The findings imply that policymakers should take these perceptual filters into consideration when communicating messages about nuclear energy development to the public.

1. Introduction

Nuclear energy, despite raised concerns over its safety and steep upfront costs, is a leading contender in many countries' endeavours towards securing a reliable energy source. The globally growing inclination towards nuclear energy is largely driven by the motivation to ensure a stable and affordable supply of energy, while aiding in the achievement of emission targets within ratified international agreements [1]. This energy situation has also been observed in the Southeast Asia region. Although there are currently no operational nuclear power plants in Southeast Asia (SEA), numerous SEA countries indicated strong interest in nuclear energy development [2]. To adopt nuclear energy, it is crucial to recognise the role of public opinion during the decision-making process as it was found to have significant bearing over the planning and development of nuclear energy [3–5].

Drawing on the knowledge deficit model, scholars have attributed the public's unsupportive attitudes towards science and technologies to their lack of scientific knowledge [6]. The scientific communities strived to enhance public understanding of science to boost support for science and technologies [7–9]. However, studies have shown that science knowledge exerts only limited influence on public support for emerging science and technologies [10]. In fact, another camp of scholars, the proponents of cognitive miser model, argued that people are cognitive misers [11]. People tend to minimize cognitive effort by relying on socio-psychological factors, such as value predispositions, perceptions, and heuristic cues from the media, when forming attitudes and opinion towards science and technologies [12]. These factors also serve as perceptual filters that influence the public's interpretations of nuclear-related knowledge and formation of attitudes towards emerging science and technologies [13,14].

To further investigate the arguments posited by both camps of scholars, this study seeks to examine how cognitive shortcuts and knowledge could affect public support for nuclear energy development in SEA countries that currently do not have an operating nuclear power plant. Specifically, this study seeks to understand the effects of nuclear knowledge and mental shortcuts such as value predispositions, heuristic cues from media content, and risk and benefit perceptions on public support for nuclear energy development across five countries – Indonesia, Malaysia, Singapore, Thailand, and Vietnam.

Although these five countries have expressed their interest in nuclear energy, they differ substantially in their degree of nuclear readiness. For example, countries such as Vietnam, Indonesia, Thailand, and Malaysia have well-explicated nuclear energy development plans, while Singapore currently do not have concrete plan for nuclear energy [15]. To the best of our knowledge, there is no cross-national comparisons study on public support of nuclear energy development in SEA countries.

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It is worthwhile to explore the potential factors that could affect public support for nuclear energy development in these countries; and which of these factors – cognitive shortcuts and knowledge – would exert greater influence on public support for nuclear energy development in each SEA country. Moreover, the divergent national development of nuclear energy across SEA might have important implications for how nuclear energy is accepted in each country. Therefore, this study also intends to compare and contrast the level of public support for nuclear energy development across the five SEA countries.

1.1. Context of Study: Five SEA countries

This study focuses on public support for nuclear energy development in Indonesia, Malaysia, Singapore, Thailand, and Vietnam. These five countries are neighbouring countries that share some commonalities in terms of historical background [16]. These countries greatly depend on one another in terms of natural resources and economic growth. They are also among those countries that are well-equipped with financial capabilities to adopt nuclear energy [16,17]. However, these countries differ in terms of their media consumption patterns, value predispositions, religiosity, trust in relevant authorities, and perception towards nuclear energy [16,18], which would affect public support for nuclear energy.

Moreover, there are discrepancies in terms of readiness to adopt nuclear energy among these five SEA countries [16]. The readiness to adopt nuclear energy not only depends on the accumulation of nuclear power technology and experience but is also determined by the future energy demand of the country. Among the other countries in SEA, Indonesia has the greatest experience and infrastructure in nuclear technology [19,20]. Indonesia currently owns four experimental nuclear complexes in Serpong, Bandung, Yogyakarta, and Pasar Jum'at for research and development purposes [21]. Indonesia had planned for four large scale nuclear reactors in operation in 2025 to support the country's electricity demand that was projected to increase about 80% from 2019, however, this plan has been cancelled [19,20]. For Malaysia, the country's energy demand was projected to increase by 4 percent per year from 2013 to 2040 [22]. Malaysia plans to adopt nuclear energy by 2025 as part of its climate change action plan [23] and to meet the country's energy demand. Malaysian Nuclear Agency (MNA) conducted numerous public awareness campaigns and published books on nuclear science to educate the public about nuclear energy [24]. However, following the Fukushima nuclear reactor meltdown, Malaysia's nuclear development plans have been postponed due to public resistance and criticism over the dangers of nuclear energy [23,25].

Singapore is a city-state that occupies a land area of 719.1 km^2 [26] with an estimated population size of 5.54 million [27]. Singapore largely relies on natural gas for energy generation which was imported through piped network from Malaysia and Indonesia [28]. Besides piped natural gas, Singapore also imports liquefied natural gas from around the world today [29]. The country's energy consumption was projected to increase 3.6 percent a year between 2013 and 2040 [30]. Due to the lack of natural resources, the Singapore government has considered nuclear energy as an alternative energy source [31]. However, findings from an extensive study conducted in 2012 concluded that the risks of existing nuclear technology outweighed its benefits, given the country's small land area and high population density [32]. Despite this, Singapore recognises that newer nuclear power plant designs that are being developed have the potential to be much safer, and hence is monitoring the progress of these technologies to keep its options open for the future. In fact, the Singapore government has set up a $63 million Nuclear Safety Research and Education Programme to conduct research and education in nuclear safety, science, and engineering [2].

Thailand, on the other hand, was projected to have a slower rate of energy consumption (3.3%) per year between 2013 and 2040 [33]. Thailand also owned the first nuclear research reactor in the region since 1962 [34]. The country has shown interest in nuclear energy and conducted various economic and technical assessment [35] in preparation for the construction of nuclear power plant. Thailand's nuclear energy plan was stalled due to public opposition after the Fukushima nuclear incident [36]. Vietnam has planned to build the first nuclear reactor in Southeast Asia in 2020 to address the growing energy demands and diversify its energy sources [37]. The country has signed intergovernmental agreement with Russia and Japan in 2010 to construct the first and second nuclear power plant in Ninh Thuan province [38]. However, the plan was deferred indefinitely in November 2016 due to the economic conditions and lower demand projections in the country [38].

Given the varying levels of nuclear readiness, it is important to gauge the level of public support for nuclear energy development across the five SEA countries, and the potential determinants of public support for nuclear energy in each country. Findings from this can provide both theoretical and practical contributions. Theoretically, this study contributes to research on the cognitive miser model and the concept of perceptual filters by applying them to an understudied context. Practically, the findings can help policymakers to take into account public's considerations when implementing nuclear energy related public outreach and education programs.

2. Literature Review

2.1. Factors influencing public support for nuclear energy

2.1.1. Beliefs and value predispositions: Religious beliefs and trust in various entities

Religious beliefs can affect people's attitudes towards science and technologies [39]. For example, conservative Christians tend to disapprove of embryonic stem cell research [40]. Similarly, strong religious beliefs were negatively related to public support for nuclear energy [41,42]. Religiosity may shape people's attitudes toward a technology because religious beliefs guide individuals' lives by providing meanings of the world. When people feel a normative gap between their religious beliefs and applications of science, people tend to reject science [8]. For those who hold a strong religious belief, technologies that are "unnatural" [43] or that interfere with the state of nature are generally intolerable. Therefore, we propose that religiosity could negatively predict support for nuclear energy.

Trust in scientists and scientific community has been found as a key predictor of public support for science and technologies: People who trust scientific authority tend to show higher levels of acceptance and support for emerging science and technologies [10,44–47]. Feelings of trust towards science community could enhance public acceptance of nuclear energy [48–51]. Furthermore, trust in various stakeholders in nuclear energy, such as nuclear scientists [41,52], nuclear power plant operators [52], government agencies in charge of regulating the technology [41,46,48,53], also consistently and positively predict public support for nuclear energy. Hence, we hypothesize that trust in university scientists, business leaders, government, and international institutions are positively associated with support for nuclear energy.

2.1.2. Media use

Media use may shape public attitudes towards science and technologies [12,44,54]. As specific science knowledge is usually acquired from the mass media [55] and mass media tend to provide the audience with interpretations and evaluations of science, media portrayals of science can play a role in influencing public opinion about science. People who are frequently exposed to such media portrayals of science may internalise the evaluations provided by the media. Ho and colleagues [10] empirically demonstrated that public attitudes towards stem cell research were significantly shaped by cues provided by the news media, namely media frames, in which people who were frequently exposed to positive media frames tended to show positive attitudes towards the technology. However, past studies tend to focus on public attention to

news rather than the general information about nuclear energy [10,56,57]. News content are usually written in a specific format and are fact-checked and refined by the news editor. Media information, on the other hand, can be in various forms ranging from social media posts to television programs. As such, it is important to differentiate and compare how public attention to nuclear energy related news and nuclear energy related information could affect their support for nuclear energy. Therefore, we propose that attention to nuclear related news and nuclear related information could positively predict support for nuclear energy.

2.1.3. Nuclear knowledge

The science literacy model assumes that knowledge bolsters public acceptance of science technologies [40]. In the context of nuclear energy, however, empirical studies have shown mixed findings regarding the effects of knowledge on acceptance of the technology. Scholars [58,59] demonstrated that those who are knowledgeable about science tend to show positive attitudes towards nuclear energy. Conversely, Perko, Adam, and Stassen [60] found that knowledge was associated with negative attitudes towards nuclear energy. As often seen in opposition movements against controversial technologies, those who are knowledgeable about certain technology are not always supporters of the technology [61]. People need a certain level of science knowledge to make decision about nuclear energy. Ho and colleagues [62] attributed these mixed findings to the measurements of knowledge – general science knowledge versus domain specific knowledge. Majority of the studies [59,63] have focused on the effects of general science knowledge, while some have focused on the effects of nuclear knowledge [64,65]. This study seeks to fill in the gap by examining the effects of nuclear knowledge on public support for nuclear energy development.

2.1.4. Risk and benefit perceptions

Risk perception of nuclear energy refers to individuals' belief about the severity and threat of nuclear energy [66], while benefit perception refers to individuals' belief about the advantages associated with nuclear energy [67]. Past research on public perceptions of nuclear energy has consistently demonstrated that public support for the energy source is guided by people's perceptions of benefits and risks [68]. Risk perception is negatively related to public support for science and technologies such as nuclear energy [69,70]. Perceived benefit, in contrast, has a positive influence on public acceptance of nuclear energy [71,72]. Research also demonstrated that perceived benefits lead to more likelihood to accept [73] and less willingness to oppose nuclear energy [74]. Hence, we propose that benefit perception could positively predict support for nuclear energy, while negative perception could negatively predict support for nuclear energy.

2.2. Moderation Effects: Value predispositions as perceptual filters

Scholars argued that individuals not only rely on value predispositions, beliefs, and perceptions as cognitive shortcuts during the decision-making process, but also draw on them as perceptual filters that influence their interpretations of knowledge and formation of attitudes towards emerging science and technologies [75]. In other words, these cognitive shortcuts are also the perceptual filters that could moderate the effects of knowledge on public support for emerging science and technology. For example, Ho and colleagues [41] found that knowledge was interpreted through the lens of religious guidance. They revealed that among people with high level of knowledge, the less religious people would have greater support for nuclear energy as compared to highly religious people. Similarly, value predisposition such as trust in relevant authorities is also often used by laypeople as an interpretive tool to make sense of new technologies [75]. The trust confidence and cooperation model [76] posited that when people think that they are not familiar with a certain technology, they tend to use the feeling of trust to determine their attitude towards the technology. Kahan and colleagues [77] also observed that people with a lower level of knowledge on nanotechnology tended to rely on trust to make their decision on the acceptance of the technology. Drawing on the concept of perceptual filters, this study posits that religiosity, trust in various stakeholders, and risk and benefit perception can serve as perceptual filters when individuals to interpret nuclear related knowledge. We propose the following research questions:

H1: Religiosity moderates the relationship between nuclear knowledge and support for nuclear energy.

RQ1: Does trust in various stakeholders have a different impact on the association between nuclear knowledge and support for nuclear energy in the five southeast Asian countries?

RQ2: Does risk perception have a differential impact on the association between nuclear knowledge and support for nuclear energy in the five southeast Asian countries?

RQ3: Does benefit perception have a differential impact on the association between nuclear knowledge and support for nuclear energy in the five southeast Asian countries?

3. Method

We hired a market research firm to administer 1,000 interviewer-led door-to door (DTD) survey questionnaire in each country after obtaining ethical approval from the University's Institutional Review Board (IRB). The questionnaires were designed in English and translated into local language(s) in each country. To ensure the quality of translations, the translated questionnaires were back translated and checked against the English questionnaire. Using the legal voting age as the basis for the recruitment of respondents, across the five countries, (1) Indonesian citizens and permanent residents who were at least 17 years old and above; (2) Malaysian citizens and permanent residents who were 21 years old and above; (3) Singaporean citizens and permanent residents who were 21 years old and above; (4) Thai citizens and permanent residents who were 18 years old and above; and (5) Vietnamese citizens and permanent residents who were 18 years old and above, were eligible to participate in the survey.

3.1. Indonesia

We collected data in Indonesia from 28 June 2018 to 24 August 2018. Participants were remunerated with housewares worth USD 1.50 upon completion of the questionnaire. The study attained a response rate of 34.14% with a margin of error of approximately $\pm$ 3% at the 95% confidence level, based on the American Association for Public Opinion Research (AAPOR) Formula 3.

We used the data from the Indonesia Census [78] to generate a sample frame, and recruited the participants using a three-step sampling method. To create the sample frame, we choose the capital city of Indonesia, Jakarta and 8 regions based on the geographical demarcation of Indonesia major islands. Next, we selected one province from each region based on its population size, cultural influence and historical significance. Within each province, we selected districts to include both urban and rural areas. After creating the sample frame, we first allocated sample size for each province based on its actual population size. At the second step, interviewers looked for a starting point by searching for a landmark, such as community building, public building, and village administrative office. By applying the left-hand or right-hand rule, interviewers begun knocking on households. If a unit was a business entity after verification, it was not accounted for as a valid household for selection.

The last step was to choose a respondent in the household based on the next birthday rule. If the specific respondent is not home at that moment, a repeat visit was made on a different day. The total number of visits per household amounts to three before the household was tagged as 'non-response' listing. If the specific respondent rejected the survey, the household was tagged as 'rejected.' If no one in the household fulfils

the screening criteria for residency and age, the household was tagged as 'failed screener.' When any of the three scenarios occur, the interviewers will move onto the next available address listing. After a household interview was completed, interviewers would skip two households before knocking on the next valid household. The interviewers completed 8 to 10 surveys within a particular cluster before moving to the next cluster.

The breakdown of the sample's age, gender, and regional population closely reflected that of the national population. Of the 1,000 Indonesian respondents, 50.2% were male and 49.8% were female. As for ethnicity, 72.9% were Javanese, 5.2% were Malay, 4.0% were Buginese, 3.6% were Batak, and 14.3% were from other ethnic groups. Participants' age ranged from 17 years to 71 years, and the median age was 37.5 years (M = 37.06, SD = 12.83). The median annual household income was between Rp 3,000,000 – 4,999,999 (approximately USD 202 – 337) (SD = 1.29) and the median education level was the completion of senior secondary education (SD = 0.91).

3.2. Malaysia

We conducted the DTD survey in Malaysia between 28 June and 30 August 2018. Respondents who completed the survey were remunerated with stationaries worth US$1.80. A response rate of 34.77% was achieved by using the AAPOR Formula 3, with a margin of error of approximately ± 3% at the 95% confidence level.

To create a sampling frame, we first selected the capital of Malaysia – Kuala Lumpur – as one of the clusters for the door-to-door survey. Next, we stratified Malaysia into five main geographical regions – Northern, Central, Southern, East Coast, and East Malaysia – as designated by the Government of Malaysia in the Third Malaysia Plan [79]. Then, a state was selected based on the population size, cultural influence, and historical background. Within each state, coverage was spread into urban and rural districts to ensure a wide coverage. The selected states for each region were Kuala Lumpur (Capital), Penang (Northern region), Selangor (Central region), Johor (Southern region), Terengganu (East Coast region), Sarawak (East Malaysia region), and Sabah (East Malaysia region). In each state, household clusters were randomly selected using the available district databases to ensure that both urban and rural districts were chosen. For the sampling method, we used the three-step sampling method which was similar to the procedure used in Indonesia.

Among the 1,000 sample, 50.3% were male and 49.7% were female, ranging from 21 to 70 years old (M = 38.04, SD = 13.41). Majority of the respondents were Bumiputera (63.9%), followed by Chinese (28.5%) and Indian (7.6%). The median education level was "Secondary Education" (SD = 1.14) and the median household income ranged from RM4,000 to RM4,999 (SD = 2.85). Our sample matched well with the Malaysia national census.

3.3. Singapore

We conducted the DTD survey between 18 July and 5 August 2018. Respondents who completed the survey were remunerated with a S$5 shopping voucher. A response rate of 38.36% was achieved by using the AAPOR Formula 3, with a margin of error of approximately ± 3% at the 95% confidence level.

We recruited the respondents using a stratified random sampling method and the Singapore Department of Statistics (DOS) Standard 2-Stage Design. First, we stratified Singapore into five regions – North, Northeast, East, West, and Central – as designated by the Urban Redevelopment Authority of Singapore [80]. Second, using the purchased residential address listing from the Singapore DOS, we randomly selected a residential address from each region. Upon each household visit, each respondent was chosen based on the next birthday rule. The rest of the procedures were similar to the procedures used in Indonesia.

Among the 1,000 sample, 51.3% were female and 48.7% were male, ranging from 21 to 88 years old (M = 44.48, SD = 15.47). Majority of the respondents were Chinese (73.8%), followed by Malay (13.3%), Indian (11.3%), and Eurasian (0.4%). The median education level was "Diploma & Professional Qualification" (SD = 2.27) and the median household income ranged from S$9,000 to S$9,999 (SD = 9.58).

3.4. Thailand

We conducted data collection from 22 June 2018 to 27 July 2018. Participants were remunerated with stationery items worth USD 2.50 upon completion of the questionnaire. The study attained a response rate of 31.97% with a margin of error of approximately ± 3% at the 95% confidence level, based on AAPOR Formula 3.

We used Thailand's national census [81] and Household Socio-economic Survey data [82] to generate a sample frame, and recruited the respondents using a three-step sampling method. First, we divided the country into six regions, excluding Bangkok, based on the scheme formalised by Thailand's National Geographical Committee. In each region, we selected one province based on its population size, cultural, and historical significance. Next, we selected both urban and rural districts from each province to ensure good coverage. For Bangkok, we included all the districts. In each district, household clusters were randomly selected. For the three-step sampling method, such as household selections, we followed the procedures used in Indonesia.

The breakdown of the sample's age, gender, and regional population closely reflected that of the national population. Of the 1,000 respondents, 50.0% were male and 50% were female. For ethnicity, all the participants were Thai. Participants' age ranged from 18 years to 70 years, and the median age was 42.0 years (M = 41.38, SD = 12.14). The median annual household income was between THB 35,000 –39,999 (approximately USD 1,080 –1,234) (SD = 2.71) and the median education level was the completion of senior vocational education, with most participants attaining a bachelor's degree or equivalent qualification) (SD = 1.86).

3.5. Vietnam

We collected the data in Vietnam between 28 June 2018 and 24 August 2018. Participants were remunerated with food items and snacks worth USD 1.70 upon completion of the questionnaire. The study attained a response rate of 31.24%, with a margin of error of approximately ± 3% at the 95% confidence level, based on AAPOR Formula 3.

We used the data from the Vietnam Census 2009 [83] and Household Living Standards Survey [84] to generate a sample frame. First, we choose the capital city of Vietnam, Hanoi and 7 administrative regions based on the geographical demarcation. Then, we selected one province from each region based on its population size, cultural influence and historical significance. Within each province, we selected districts to include both urban and rural areas. In each district, household clusters were randomly selected. After creating the sample frame, we recruited the participants using the three-step sampling method that was similar to the other four countries.

The breakdown of the sample's age, gender, and regional population closely reflected that of the national population. Of the 1,000 respondents, 52.3% were male and 47.7% were female. For ethnicity, 98.2% were Kinh and 1.8% were from other ethnic groups, including Muong (0.6%), Nung (0.5%), Khmer Krom (0.2%), Hoa (0.2%), Sán Dìu (0.2%), and Tay (0.1%). Participants' age ranged from 18 years to 89 years, and the median age was 35.0 years (M = 37.21, SD = 13.57). The median annual household income was between VND 10,000,000 – 19,999,999 (SD = 1.60) and the median education level was the completion of secondary education (SD = 1.32).

3.6. Measures

We included the demographics variables – gender, age, marital status, education, and monthly household income – as control variables. All

items were measured using 5-point Likert scales and were averaged to create a composite index unless otherwise stated. Tables S1 and S2 (see supplemental material) shows the exact item wordings and descriptive statistics of all the variables.

Support for nuclear energy was measured using three items, ranging from 1 (Strongly disagree) to 5 (Strongly agree). These items were summed and averaged to form a composite index, with higher scores indicating higher support for nuclear energy.

Religious guidance was measured using a single item, ranging from 1 (No guidance at all) to 5 (A lot of guidance). A higher score indicates higher religious guidance.

Trust in university scientists, business leaders, government, and international institutions were each measured using two items, ranging from 1 (No trust at all) to 5 (A great deal of trust). The two items were summed and averaged to form a composite index, with higher scores indicating higher trust in university scientists, business leaders, government, and international institutions.

Nuclear knowledge was measured using 13 dichotomous items. Respondents were required to indicate "true", "false", or "I don't know" for the 13 statements. For each item, the correct answer was recoded into "1", while the incorrect answer was recoded into "0". Responses that fell into the "I don't know" category were recoded as "0". All the items were summed to create a composite variable, with higher scores indicating higher nuclear knowledge.

Attention to nuclear related news were measured using four items, ranging from 1 (No attention at all) to 5 (A lot of attention). These items were summed and averaged to form a composite index, with higher scores indicating higher attention to nuclear related news.

Attention to nuclear related information were measured using eight items, ranging from 1 (No attention at all) to 5 (A lot of attention). These items were summed and averaged to form a composite index, with higher scores indicating higher attention to nuclear related information.

Benefit perceptions and *risk perceptions* were each measured using six items, ranging from 1 (Strongly disagree) to 5 (Strongly agree). Each of the six items were summed and averaged to form a composite index, with higher scores indicating higher benefit and risk perceptions.

3.7. Analytical approach

We conducted five ordinary least squares hierarchical regression analyses using *SPSS software version 25*. The variables were entered into the regression model based on their assumed causal order [85]. We entered the variables based on the presumed or actual time precedence, the logic, and also by referring to past studies [85]. For example, studies have shown that people are cognitive misers who reply on heuristic when forming perceptions and attitudes [11,12] Hence, it is assumed that value predispositions variables should be entered into the model before media attention and nuclear knowledge. Likewise, individuals' benefit and risk perception could be affected by value predisposition, media attention, and knowledge [62]. Therefore, benefit and risk perception should be entered in the last block.

All the control variables were entered in the first block, followed by value predisposition variables in the second block. Media attention variables were entered in the third block. The knowledge variable was entered into the fourth block, while perception variables were entered into the fifth block. In this study, we entered the seven interaction terms in the last block. The interaction terms were created by multiplying the standardized values of the main effect variables. These interaction terms include: (a) the interaction between religious guidance and nuclear knowledge, (b) the interaction between trust variables and nuclear knowledge, and (c) the interaction between perception variables and nuclear knowledge.

4. Results

4.1. National differences in public support for nuclear energy

Fig. 1 shows the levels of public support for nuclear energy development in Indonesia, Malaysia, Singapore, Thailand, and Vietnam. We conducted a one-way ANOVA test to compare if there are significant differences in public support for nuclear energy development across the five SEA countries. The result (see Table 1) shows that there was a significant difference in public support for nuclear energy development among the five countries (F (4, 4994) = 249.20, p = .000).

The Post Hoc comparisons test (see Table 2) indicated that the mean score of public support for nuclear energy development in Indonesia (M = 2.87) was significantly higher than Malaysia (M = 2.32, p < .001), Singapore (M = 2.29, p < .001), Thailand (M = 1.52, p < .001), and Vietnam (M = 2.25, p < .001). The Post Hoc comparison results also showed that the mean score of public support for nuclear energy development in Malaysia (M = 2.32) was significantly higher than Thailand (M = 1.52, p < .001). The results also showed that Singapore (M = 2.29) has higher public support for nuclear energy development as compared to Thailand (M = 1.52, p < .001), while Vietnam (M = 2.25) has higher public support of nuclear energy development for nuclear development as compared to Thailand (M = 1.52, p < .001).

4.2. Factors predicting support for nuclear energy development

We conducted five ordinary least squares hierarchical regression analyses to examine factors influencing public support for nuclear energy development in Indonesia, Malaysia, Singapore, Thailand, and Vietnam. Table 3 presents the final models[1] of the factors predicting public support for nuclear energy development in each country.

After taking into consideration the control variables (demographics), the results showed that among the value predispositions variables, religious guidance was negatively associated with support for nuclear energy development in Indonesia (β = -0.07, p < .05) and Thailand (β = -0.09, p < .001), but positively associated with support for nuclear energy development in Vietnam (β = 0.07, p < .01). Trust in university scientists was positively associated with support for nuclear energy development in Singapore (β = 0.12, p < .01), Thailand (β = 0.09, p < .05), and Vietnam (β = 0.13, p < .01). On the other hand, trust in business leaders was positively associated with support for nuclear

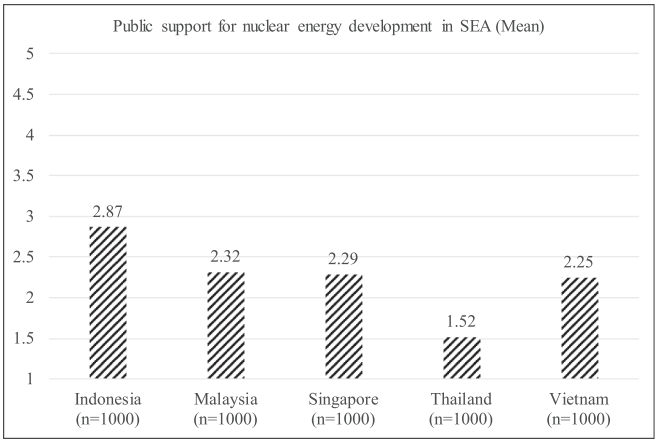

Fig. 1. Descriptive statistic for public support for nuclear energy development.

[1] Five separate ordinary least squares hierarchical regression models for each country are available in the supplemental material.

Table 1
One-way ANOVA for support for nuclear energy development.

Test of Between-Subject Effects					
Dependent variable: Support for nuclear energy development					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	927.634	4	231.908	249.198	0.000
Within Groups	4648.450	4995	0.931		
Total	5576.084	4999			

Table 2
Post Hoc test for support for nuclear energy development.

Multiple Comparisons						
Dependent variable: Support for nuclear energy development						
Tukey HSD						
(I) Country	(J) Country	Mean Difference (I-J)	Standard Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Indonesia	Singapore	0.58***	0.04	0.00	0.46	0.70
	Malaysia	0.56***	0.04	0.00	0.44	0.67
	Vietnam	0.62***	0.04	0.00	0.51	0.74
	Thailand	1.35***	0.04	0.00	1.24	1.47
Malaysia	Singapore	0.03	0.04	0.97	−0.09	0.14
	Vietnam	0.07	0.04	0.50	−0.05	0.19
	Indonesia	−0.56***	0.04	0.00	−0.67	−0.44
	Thailand	0.80***	0.04	0.00	0.68	0.92
Singapore	Malaysia	−0.03	0.04	0.97	−0.14	0.09
	Vietnam	0.04	0.04	0.87	−0.08	0.16
	Indonesia	−0.58*	0.04	0.00	−0.70	−0.46
	Thailand	0.77*	0.04	0.00	0.65	0.89
Thailand	Singapore	−0.77***	0.04	0.00	−0.89	−0.65
	Malaysia	−0.80***	0.04	0.00	−0.92	−0.68
	Vietnam	−0.73***	0.04	0.00	−0.85	−0.61
	Indonesia	−1.35***	0.04	0.00	−1.47	−1.24
Vietnam	Singapore	−0.04	0.04	0.87	−0.16	0.08
	Malaysia	−0.07	0.04	0.50	−0.19	0.05
	Indonesia	−0.62***	0.04	0.00	−0.74	−0.51
	Thailand	0.73***	0.04	0.00	0.61	0.85

Note: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

energy development in Indonesia (β = 0.16, $p < .001$), Malaysia (β = 0.13, $p < .001$), and Singapore (β = 0.10, $p < .01$). Trust in the government was positively associated with support for nuclear energy development in Indonesia (β = 0.12, $p < .001$). This block accounted for a much greater amount of variance in support for nuclear energy development in Indonesia (17.60%), Malaysia (23.70%), Singapore (12.60%), and Vietnam (17.40%), but lesser for Thailand (5.90%).

For the media attention block, attention to nuclear related news was positively associated with support for nuclear energy development in Indonesia (β = 0.14, $p < .001$), Malaysia (β = 0.14, $p < .001$), Thailand (β = 0.13, p < .001), and Vietnam (β = 0.09, $p < .01$), but not in Singapore. Attention to nuclear related information was positively associated with support for nuclear energy development in Indonesia (β = 0.08, $p < .05$), Singapore (β = 0.11, $p < .01$), Thailand (β = 0.16, $p < .001$), and Vietnam (β = 0.16, $p < .001$), but not in Malaysia. This block explained 4.50% (Indonesia), 4.10% (Malaysia), 1.20% (Singapore), 15.60% (Thailand), and 5.70% (Vietnam) of variance in support for nuclear energy development.

For the knowledge block, nuclear knowledge was associated with support for nuclear energy development in Thailand (β = 0.10, $p < .01$) and Vietnam (β = 0.11, $p < .001$). The knowledge block accounted for a negligible amount of variance across the countries – Indonesia (0.20%), Malaysia (0%), Singapore (0.20%), Thailand (2.90%), and Vietnam (3.60%).

For the perception block – benefit perception was positively associated with support for nuclear energy development across all the countries – Indonesia (β = 0.40, $p < .001$), Malaysia (β = 0.45, $p < .001$), Singapore (β = 0.36, $p < .001$), Thailand (β = 0.37, $p < .001$), and Vietnam (β = 0.39, $p < .001$). Risk perception was negatively associated with support for nuclear energy development in Indonesia (β = -0.07, $p < .05$), Malaysia (β = -0.22, $p < .001$), Singapore (β = -0.36, $p < .001$), and Thailand (β = -0.24, $p < .001$), but not in Vietnam. This block accounted for a large amount of variance in support for nuclear energy development in Indonesia (12.40%), Malaysia (11.90%), Singapore (18.90%), and Thailand (12.60%), but lesser in Vietnam (10.00%).

For the interactions block, we found that there were no significant moderation effects of religiosity on the relationship between nuclear knowledge and support for nuclear energy across the five countries. Therefore, H1 was not supported. To answer RQ1-RQ3, we found that trust in university scientists significantly moderated the relationship between nuclear knowledge and support for nuclear energy in Thailand (β = 0.06, $p < .05$). Fig. 2 depicts that among Thais with high level of nuclear knowledge, those with high trust in university scientists had higher support for nuclear energy development as compared to those with low trust in university scientists. However, this difference was not observed among Thais with low level of nuclear knowledge. We also found a significant interaction between benefit perception and nuclear knowledge in predicting support for nuclear energy in Vietnam (β = 0.05, $p < .05$). Fig. 3 shows that among Vietnamese with high level of nuclear knowledge, those with higher benefit perception had higher support for nuclear energy as compared to those with low benefit perception. In addition, we found that risk perception significantly moderated the relationship between nuclear knowledge and support for nuclear energy in Malaysia (β = -0.06, $p < .05$). Fig. 4 shows that risk perception had stronger impact on Malaysians with high level of nuclear knowledge, in which people with low level of risk perception had higher support for nuclear energy development as compared to those with high level of risk perception. This block explained 0.30% (Indonesia), 1.30% (Malaysia), 0.20% (Singapore), 0.40% (Thailand), and 0.60% (Vietnam) of variance in support for nuclear energy.

Overall, all the factors explained 36.70% (Indonesia), 44.30% (Malaysia), 34.30% (Singapore), 44.90% (Thailand), and 41.70% (Vietnam) of variance in support for nuclear energy development in all the countries.

5. Discussion

This study compared public support for nuclear energy development in five SEA countries – Indonesia, Malaysia, Singapore, Thailand, and Vietnam. Overall, we found that the levels of public support for nuclear energy differed across the five SEA countries. More importantly, we examined factors predicting public support for nuclear energy across the five SEA countries. Consistent with previous studies [10], we found that the public rely on value predispositions (i.e. trust in various stakeholders) and media frames as cognitive shortcuts to form nuclear energy related decisions. More importantly, we established that value predisposition such as trust in university scientists, risk and benefit perceptions are interpretive tools – perceptual filters – that people use to make sense of nuclear knowledge and nuclear energy.

Our analysis generated several important findings. Conducted almost a decade after the 2011 Fukushima nuclear accident, our study shows that majority of the public across the five Southeast Asian countries are against nuclear energy development in their respective countries, with their mean scores ranging from 1.52 (Thailand) to 2.87 (Indonesia), all below the mid-point of 3.00 (1 = Strongly Disagree, 5 = Strongly Agree). Although there have been no deaths or cases of radiation sickness from the Fukushima nuclear accident, 100,000 people were evacuated from their homes as a preventative measure [86]. In addition to the approximately 19,500 people who were killed by the earthquake or tsunami, there were 2313 disaster-related deaths among evacuees from the Fukushima prefecture [86]. Considering the severity of the incident, coupled with the close geographical proximity of Japan to Southeast

Table 3
Factors predicting public support for nuclear energy development in Indonesia, Malaysia, Singapore, Thailand, and Vietnam.

	Indonesia			Malaysia			Singapore			Thailand			Vietnam		
	B	*SE*	β	*B*	*SE*	β	*B*	*SE*	β	*B*	*SE*	β	*B*	*SE*	β
Block 1: Demographics															
Gender (1 = Male; 2 = Female)	−0.12	0.05	−0.06*	−0.06	0.05	−0.03	−0.07	0.06	−0.03	−0.01	0.03	−0.01	−0.08	0.05	−0.04
Age	0.00	0.00	0.05	0.00	0.00	−0.04	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.07*
Marital status (0 = Others; 1 = Married)	−0.04	0.07	−0.02	−0.08	0.07	−0.04	−0.09	0.07	−0.04	0.00	0.04	0.00	−0.17	0.06	−0.08**
Education level	0.02	0.03	0.02	−0.06	0.03	−0.06*	−0.01	0.02	−0.02	−0.03	0.01	−0.10**	0.02	0.02	0.02
Monthly household income	0.01	0.02	0.02	0.03	0.01	0.07**	0.00	0.00	−0.01	0.04	0.01	0.20***	−0.04	0.02	−0.06*
Incremental R^2 (%)			1.80**			3.30***			1.10*			7.40***			4.40***
Block 2: Value predispositions															
Religious guidance	−0.08	0.03	−0.07*	0.00	0.03	0.00	0.02	0.02	0.02	−0.05	0.01	−0.09***	0.05	0.02	0.07**
Trust in university scientists	0.02	0.04	0.02	0.05	0.04	0.05	0.12	0.04	0.12**	0.05	0.02	0.09*	0.12	0.04	0.13**
Trust in business leaders	0.16	0.03	0.16***	0.14	0.04	0.13***	0.09	0.03	0.10**	0.01	0.02	0.01	−0.03	0.04	−0.03
Trust in the government	0.12	0.03	0.12***	0.04	0.04	0.04	0.04	0.04	0.04	−0.02	0.02	−0.04	−0.03	0.03	−0.03
Trust in international institutions	−0.05	0.04	−0.04	0.01	0.04	0.01	−0.01	0.04	−0.01	−0.01	0.02	−0.01	0.04	0.03	0.05
Incremental R^2 (%)			17.60***			23.70***			12.60***			5.90***			17.40***
Block 3: Media attention															
Attention to nuclear news	0.13	0.04	0.14***	0.16	0.04	0.14***	−0.07	0.04	−0.06	0.12	0.03	0.13**	0.11	0.04	0.09**
Attention to nuclear information	0.09	0.04	0.08*	0.07	0.04	0.06	0.16	0.05	0.11**	0.15	0.04	0.16***	0.21	0.05	0.16***
Incremental R^2 (%)			4.50***			4.10***			1.20**			15.60***			5.70***
Block 4: Knowledge															
Nuclear knowledge	−0.07	0.12	−0.02	−0.08	0.12	−0.02	0.20	0.16	0.04	0.28	0.08	0.10**	0.46	0.11	0.11***
Incremental R^2 (%)			0.20			0.00			0.20			2.90***			3.60***
Block 5: Perceptions															
Benefit perception	0.47	0.03	0.40***	0.48	0.04	0.45***	0.46	0.04	0.36***	0.28	0.02	0.37***	0.35	0.03	0.39***
Risk perception	−0.07	0.03	−0.07*	−0.22	0.03	−0.22***	−0.46	0.03	−0.36***	−0.14	0.01	−0.24***	0.02	0.03	0.02
Incremental R^2 (%)			12.40***			11.90***			18.90***			12.60***			10.00***
Block 6: Interactions[a]						−0.03									
Trust in university scientists * Nuclear knowledge	−0.03	0.03	−0.03	−0.04	0.03	0.04	−0.03	0.03	−0.03	0.03	0.02	0.06*	0.02	0.02	0.02
Benefit perception * Nuclear knowledge	−0.01	0.03	−0.01	0.00	0.03	0.00	0.00	0.03	0.00	0.01	0.02	0.02	0.05	0.02	0.05*
Risk perception * Nuclear knowledge	−0.01	0.03	−0.01	−0.06	0.03	−0.06*	0.01	0.03	0.01	−0.01	0.02	−0.03	0.03	0.02	0.03
Incremental R^2 (%)			0.30			1.30**			0.20			0.40			0.60***
Total R^2 (%)			36.70***			44.30***			34.30***			44.90***			41.70***

Note:
***$p < 0.001$, **$p < 0.01$, $p < 0.05$
[a] Another 4 non-significant interaction terms across the five countries (Religious guidance * Nuclear knowledge, Trust in business leaders * Nuclear knowledge, Trust in government * Nuclear knowledge, Trust in international institutions * Nuclear knowledge) are included in the model and not shown in the table.

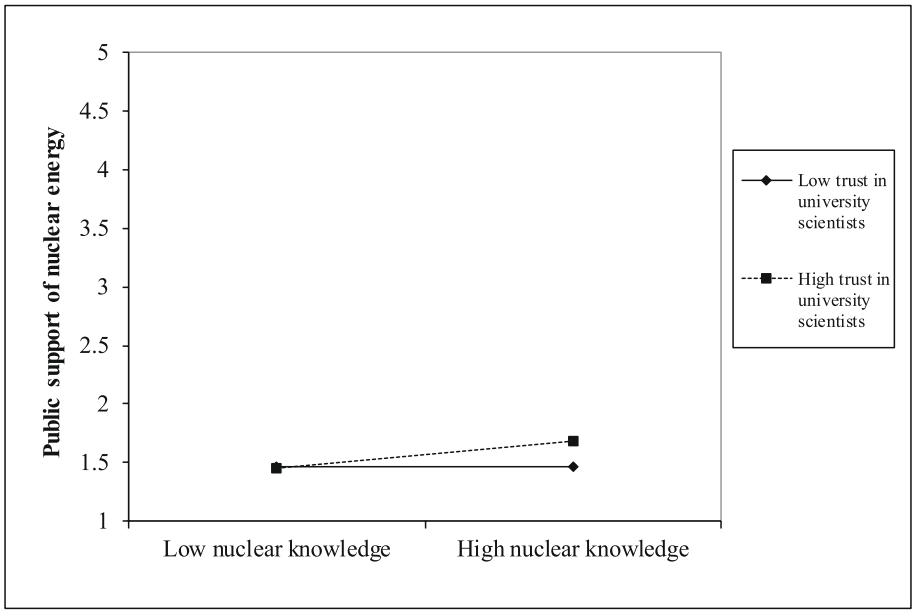

Fig. 2. Interaction effects of trust in university scientists and nuclear knowledge on public support for nuclear energy in Thailand.

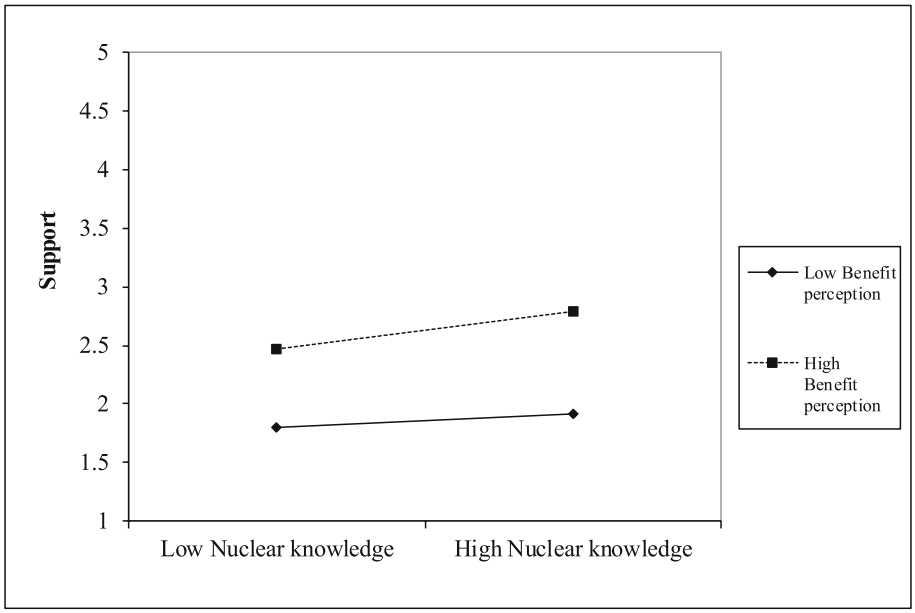

Fig. 3. Interaction effects of benefit perception and nuclear knowledge on public support for nuclear energy in Vietnam.

Asia, this probably explained the generally low levels of public support for nuclear energy development in the five SEA countries.

In terms of variations across countries, we found that the highest level of public support for nuclear energy development is observed among Indonesians, while the Thais show the lowest level of support for nuclear energy as compared to their neighbouring countries. These findings could possibly be explained by the stages of nuclear energy development in these countries. Indonesia appears to be the one with the most concrete plan for nuclear energy development among the five SEA countries [16]. Hence, with the well-developed communication strategies and outreach programs on nuclear energy [16], it is expected that Indonesians would have higher public support for nuclear energy as compared to the other four countries. On one hand, although Thailand has plans for nuclear energy development [87], many Thais felt that they do not possess sufficient nuclear related knowledge and is not yet ready for nuclear energy [18], thus showing the lowest level of support for nuclear energy development among the five countries.

Second, our findings revealed that religious guidance was a negative determinant of public support for nuclear energy development in Indonesia and Thailand, but a positive predictor for public support for nuclear energy development in Vietnam. This suggests that the more Indonesians and Thais perceive religion to provide guidance to their daily life, the less likely they would support nuclear energy development. In contrast, the more Vietnamese perceive religion to provide guidance to their life, the more likely they would support nuclear energy development. Future studies should have a more in-depth exploration on the types of religion in each country, and how these different religions affect public support for nuclear energy differently.

Third, we found that trust in university scientists only predicted public support for nuclear energy in Singapore, Thailand, and Vietnam,

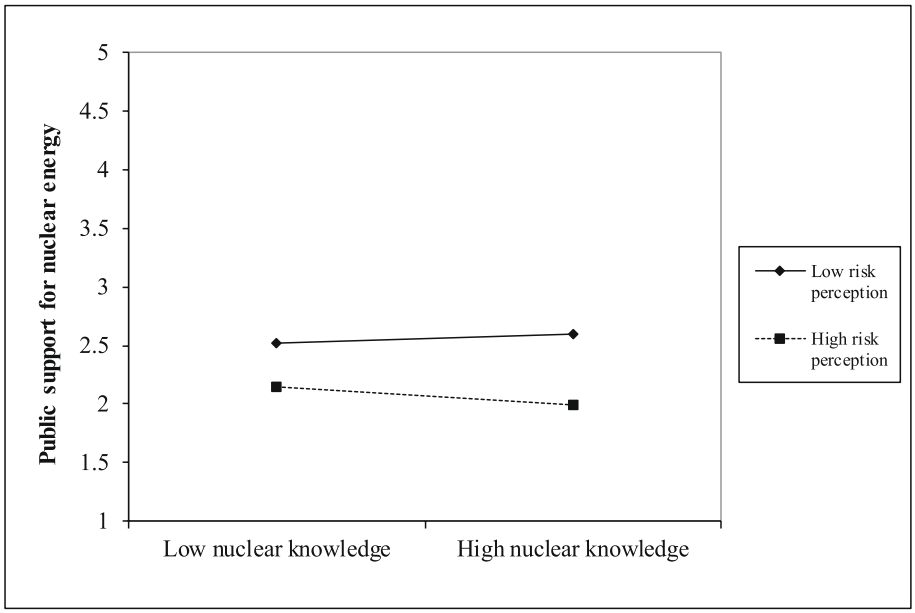

Fig. 4. Interaction effects of risk perception and nuclear knowledge on public support for nuclear energy in Malaysia.

while trust in business leaders predicted public support for nuclear energy in Indonesia, Malaysia, and Singapore. This suggests that Indonesians and Malaysians rely on their trust in business leaders as cognitive shortcut in decision making, while Thais and Vietnamese leverage on their trust on university scientists to form decision. Meanwhile, Singaporeans rely on both trust in university scientists and business leaders as their heuristic cue to make decision. Interestingly, trust in the government is only positively associated with support for nuclear energy development in Indonesia, but not in the other four countries. This could be attributed to the greater experience and the more established nuclear energy infrastructure in Indonesia as compared to the other four countries [19], as well as the successful public outreach programs which enhance public's confidence in the government [2]. However, we found that trust in international institution is not significantly associated with support for nuclear energy development in any countries. This finding can possibly be explained by the relatively low involvements of international institutions given that these five countries currently do not have an operating nuclear power plant. Overall, these findings are consistent with past studies which argued that trust in relevant authorities would enhance public acceptance of nuclear energy [48,49,51,62,88].

Fourth, we found that attention to nuclear news was a positive predictor of public support for nuclear energy across the four countries, except for Singapore. One possible explanation is because Singapore currently do not have any concrete plan for nuclear energy development, thus the news coverage of nuclear energy in Singapore might be lower as compared to the other four countries. In contrast, attention to nuclear information was found to predict public support for nuclear energy in all countries, except for Malaysia. This indicates that Malaysians rely on nuclear related news, rather than nuclear information, to form decision on nuclear energy development. These findings were consistent with existing studies [10,56,57], positing that media attention serves as a heuristic cue in forming attitudes toward science and technology.

Next, in response to the call to assess the role of nuclear-specific knowledge [62], our study took the first step in examining the effects of nuclear-specific knowledge on public support of nuclear energy. Although the findings revealed that nuclear knowledge exerted limited influence on public support for nuclear energy in Indonesia, Malaysia, and Singapore, we found that nuclear knowledge was significantly associated with public support for nuclear energy in Thailand and Vietnam. This indicates that Thailand and Vietnam may have effective campaigns, information dissemination, and education system in enhancing nuclear energy knowledge among the public. Future studies should further examine how communication strategies in these countries contributes to public support for nuclear energy. In addition, these findings suggest that the role of nuclear knowledge should not be totally dismiss as it exerts differing effects across different contexts. Future studies could further examine and compare the role of nuclear knowledge on public opinion of nuclear energy across countries with differing stages of nuclear energy development.

Besides, we found that benefit perception towards nuclear energy serve as key heuristic shortcuts in shaping public support for nuclear energy in across the five countries. Risk perception was also used as a cognitive shortcut across all countries, except for Vietnam. In line with previous studies, our results showed that people with higher benefit perception are more likely to support nuclear energy development [71], while people with higher risk perception were less likely to support nuclear energy development [69,70]. However, in Vietnam, we found that risk perception is not significantly associated with support for nuclear energy development. One possible explanation is that Vietnam recently has indefinitely postpone their nuclear energy plan. Therefore, perceived risk does not exert any influence on Vietnamese support for nuclear energy development.

In addition, one of the major contributions of our study is the role of value predisposition (i.e. trust in university scientists) and perceptions (i.e. risk and benefit perceptions) as perceptual filters for the knowledge-support relationship. Our results indicated that trust in university scientists moderated the effect of nuclear knowledge on support for nuclear energy development. In other words, individuals who trusted university scientist in nuclear energy related matters would use their dispositional lens to override the potential positive effects of nuclear knowledge on public support for nuclear energy [10]. Our results also indicate that benefit and risk perceptions moderated the effects of nuclear knowledge on support for nuclear energy. We found that nuclear knowledge has weaker effects on support for nuclear energy development among individuals with low level of benefit perception as well as those with high level of risk perception.

However, such interaction effects were not observed between value predisposition variables, such as religious guidance, trust in business leaders, trust in government, trust in international institutions, and nuclear knowledge. These non-significant results suggest that nuclear knowledge affects public support for nuclear energy independently of

these value predispositions. Moreover, as there is currently no commercial nuclear power plant in SEA, the public might not be familiar with nuclear energy. Hence, religious guidance, trust in business leaders, trust in government, trust in international institutions might not serve as compelling perceptual filters to influence the knowledge-support relationship.

In sum, this study concludes that value predispositions (i.e., trust in university scientists) and risk and benefit perceptions are key perceptual filters in shaping public support for nuclear energy development in SEA countries.

6. Limitations and implications

Similar with other studies, this study has some limitations and implications. First, the surveys collected were cross-sectional data and therefore, our findings might not be sufficient to infer causality [89]. Second, as this study was conducted in the context of SEA countries where nuclear energy development is still on-going and there is no operating nuclear power plant in the region, we are researching an emergent public opinion process [90]. Hence, the results may not be generalizable to other contexts that already have a well-established nuclear energy plan or with operating nuclear power plant. Future studies should further examine and compare the effects of perceptual filters on public support for nuclear energy in countries that are at different stages of nuclear energy development.

Theoretically, this study attested to the concept of perceptual filters by showing that knowledge about nuclear energy may be interpreted by different segments of the audience, depending on their trust in value predispositions and perceptions toward nuclear energy. This study is also one of the few studies that examines the effects of domain-specific knowledge – nuclear knowledge – on public support for nuclear energy. Moreover, as past studies tend to focus on public support for nuclear energy development in countries with operating nuclear power plants [16], this study serves as a pioneer piece in examining public support for nuclear energy development in countries at nascent stages of development.

Practically, our findings inform the policymakers and relevant authorities of the current level of public support for nuclear energy in the region given that public support is one of the key determinants of successful nuclear energy developments. Future studies should include more SEA countries that past studies have overlooked to depict a fuller picture of public support for nuclear energy in the region [62], and assess how other national-level factors in the areas of energy, economic, and human wellbeing could influence public support for nuclear energy in the region. Policymakers and communication practitioners of the respective countries are suggested to leverage on public's trust in relevant authorities, such as university scientists and business leaders, to convey information about nuclear energy development in the country to the public.

In sum, this study highlights that the concept of perceptual filters is applicable in the context of public attitudes toward nuclear energy development and provides evidence that the general public in SEA countries uses different cognitive shortcuts to form decision about nuclear energy development.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2021.102155.

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