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TRUST IN GOVERNMENT AND EFFECTIVE NUCLEAR SAFETY GOVERNANCE IN GREAT BRITAIN

| Jacqueline CK Lam | Victor OK Li | David M. Reiner | Yang Han | Shan Shan Wang |

11 April 2018

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Abstract

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applicable and can be transferred to other subject areas and to countries where public concerns over nuclear safety and energy security are significant.

1. Introduction

The UK relies on a diversified mix of generation technologies for energy security and has indicated its intent to develop new nuclear power technologies to satisfy the country's demands for electricity (Department of Energy and Climate Change, 2011b). Nuclear is a low-carbon and mature energy technology and currently represents 20% of total electricity generation in the UK, although almost all of the current fleet of nuclear power technologies is set to retire over the next decade. The UK government has outlined its vision for successfully delivering a planned 16 GW of domestic new build by 2030, which would comprise 12 reactors over five sites (Department of Energy and Climate Change, 2013). In 2016, after some delays, the UK government led by Theresa May decided to proceed with the Hinkley Point C project, which would be the first new nuclear power plant to be built in the UK since Sizewell B in 1987. China will take a one-third stake in the Hinkley C project – in the past few decades, China has developed ambitious nuclear programmes and recently began to produce its own nuclear plant designs. China aims to move up the export value chain and the recent agreement with the UK paves the way for the construction of Chinese designed nuclear reactors in the west (Gosden, 2016). The potential for a growing number of nuclear power technologies and the rising stake of China in the UK's nuclear plans may create public concern on nuclear safety and security in the UK.

1.1 Research Gaps

Public opinion studies show that fears of nuclear accidents can persist over long periods (Bromet *et al.*, 2011; Drottz-Sjöberg and Sjoberg, 1990; Visschers and Siegrist, 2013). Furthermore, perception and public acceptance can change following nuclear accidents (Huang *et al.*, 2013). In some parts of the world, such as the Czech Republic and the United States, though the public is generally in support of nuclear power, they are uncomfortable if nuclear power facilities are to be built in their neighbourhood (Rosa, 2005; Frantál *et al.*, 2016). Concerns regarding radioactivity are prevalent. In addition, they strongly believe that nuclear power facilities create wastes hazardous to human health, and damage the landscape (Kemp, 1990).

Public confidence in the safety of nuclear power technologies is critical for policymakers as the expansion of nuclear energy often triggers anti-nuclear sentiments, resulting in public resistance against the construction of nuclear power technologies and project delays (Glaser, 2012). Building public trust in nuclear safety emergency governance (NSEG) presents significant challenges for policymakers. First, the lack of transparency of the nuclear industry and nuclear accidents has negatively influenced the public's perceived trustworthiness of regulatory authorities (Greenberg and Truelove, 2010). Second, NSEG involves a complex mix of economic, social, environmental and governance concerns as well as a wide range of stakeholders, further complicating the building of public trust (OECD, 2010).

Studies on nuclear technology have focused on public acceptance of nuclear power (Ansolabehere and Konisky, 2009; Corner *et al.*, 2011; Diaz-Maurin and Kovacic, 2015; Gamson and Modigliani, 1989; Kasperson *et al.*, 1980; Pidgeon *et al.*, 2008; Rosa and Dunlap, 1994; Yuan *et al.*, 2017), public perception of nuclear risk (Huang *et al.*, 2013; Mah *et al.*, 2014a; Poortinga and Pidgeon, 2003; Teräväinen *et al.*, 2011), nuclear energy policy (Mu *et al.*, 2015; Qvist and Brook, 2015),

nuclear energy investment (Karaveli *et al.*, 2015), nuclear safety (Gotcheva *et al.*, 2016; Morrow *et al.*, 2014; Mu *et al.*, 2015), and public participation (He *et al.*, 2013), rather than on what affects and predicts government trustworthiness and its dimensionalities. Nevertheless, the topic of government trustworthiness in NSEG deserves greater attention following the Fukushima crisis due to increased public fear about nuclear safety and distrust of government's ability to tackle large-scale crises.

1.2 Methodological Innovation and Policy Significance

Our study aims to fill the current research gaps. Based on an ordinal logistic regression model, we aim to determine the variables that explain and predict overall government trustworthiness in NSEG in the UK. We have focussed on four different sets of independent variables, namely: (1) public risk perceptions towards old and new nuclear technologies; (2) knowledge about nuclear safety and power; (3) perceived level of public engagement in NSEG; and (4) demographics. Public perception of overall government trustworthiness in NSEG in the UK is taken as the dependent variable. In addition, we have also examined attitudes with regard to seven dimensions of government trustworthiness, and performed principal component analysis (PCA) to identify the relative weights of these seven dimensions.

Our study generates both methodological innovation and policy insightful results. First, our quantitative statistical study of perceived government trustworthiness in NSEG provides a systematic, quantifiable framework, to help readers understand how s, knowledge and perceived level of engagement, and demographics, will affect perceived government trustworthiness in NSEG, thus paving the way for the UK government to develop more meaningful and effective NSEG strategies that can build a trustful relationship between the UK government and its citizens. This is especially important during the time of Brexit, when the relationship between the public and the government is particularly politically sensitive and fragile.

Second, deviating from previous studies of public opinion regarding nuclear energy, which investigated whether public trust, and other factors, such as public acceptance, knowledge, and level of engagement, will affect public perceptions of the risks associated with nuclear energy, our study aims to uncover, in reverse order, whether government trustworthiness in a nuclear emergency/risk governance setting as perceived by the public can be affected/predicted by public risk perceptions and others, such as knowledge, level of engagement and demographics. This will allow us to inform the corresponding government on how future policy-making should take into account the various important factors to improve government trustworthiness in NSEG in the future.

Meanwhile, our trustworthiness model can be extended to other countries whenever effective nuclear emergency/risk governance that builds trust between citizens and its government, is needed. Our approach is particularly useful to countries which have deployed nuclear power technologies as well as those assessing the political feasibility of new deployment (Slovic, 1993), such as China, South Korea, India, Finland, Brazil etc. Besides, our logistic model of government trustworthiness can be extended to other projects with potential health and safety risk, where government trustworthiness are closely linked to public risk perceptions, the extent to which stakeholders are engaged, together with other key demographic factors such as gender, education, income, age and vote intention.

Third, we have differentiated between perceived risks towards old and new nuclear power technologies, and the inclusion of both as separate variables in our ordinal logistic model of perceived government trustworthiness in NSEG in the UK. The differentiation makes it possible to understand whether the public risk perceptions towards old and new nuclear technologies in the UK are different, and how different they are. Our results showing that the new reactor models appear to be slightly more threatening than the old reactors provide an important insight that replacing old reactors with

new ones would not reduce public fear towards nuclear, unlike the views hold by some physicists (Department for Business, Enterprise & Regulatory Reform, 2008).

Finally, the PCA of the relative weight of each dimension provides crucial insights into the most important influences on government trustworthiness. Knowledge of the importance of each dimension facilitates resources to be targeted economically for the purpose of enhancing government trustworthiness. The same PCA method above can also be used to evaluate risk perceptions towards nuclear power. Public risk perceptions can be deconstructed with the most important risk dimensions being identified and quantified.

2. Theoretical rationale

2.1 Trust and government trustworthiness

Trust can be defined as a bet on the future contingent actions of others, based on one sociological notion (Sztompka, 1999). Hetherington (2005); Hetherington and Globetti (2002); Hetherington and Husser (2012) and Easton (1965) argue that it is significant for the government to secure its trust from the citizens and subsequently obtain the legitimacy to govern, given that the opposite of trust, distrust, will undermine its authority to govern, subsequently creating unwanted chaotic consequences. Pidgeon *et al.* (2007) highlights specifically the importance of trust for crisis management, an aspect particularly relevant to nuclear energy. In order to gain trust from the public, a government must act anticipatively or, in other words, be trustworthy (Dasgupta, 2000; Good, 2000). According to Hardin (1996), certain characteristics of government trustworthiness, such as commitment and credibility, are important elements to induce trust. Hence, it is justifiable to measure public trust in government through the lens of government trustworthiness.

The increasing adoption of nuclear energy in the UK means that its citizens may be susceptible

to an increasingly uncertain and uncontrollable future due to the risks associated with the new and the existing nuclear power technologies. Assessing the trustworthiness in NSEG is vital for building public trust and enhancing cooperation, thus establishing a mutually beneficial relationship between the public and the government in NSEG.

2.2 The roles of risk perceptions, knowledge, stakeholder engagement and demographics

2.2.1 Perceived risk of nuclear power technologies

Nuclear risk perception is a subjective notion based on the characteristics and the severities of a nuclear accident (Slovic, 1987; Wildavsky and Dake, 1990). Heuristic and cognitive psychology hypothesizes that people use cognitive heuristics in processing information, which is the main cause of bias in assessing risks (Tversky and Kahneman, 1974; Yim and Vaganov, 2003). Based on this hypothesis, a psychometric paradigm has been constructed in such a way as to identify the determinants of risk perception (Fischhoff *et al.*, 1978). The psychometric method has been utilized for studying risk perception in a number of countries, such as Norway (Teigen *et al.*, 1988), Poland (Goszczynska *et al.*, 1991), Italy (Savadori *et al.*, 1998), France (Karpowicz-Lazreg and Mullet, 1993), and China (Lai and Tao, 2003). Even though crosscultural differences have been observed, the two-dimensional solution, consisting of both the threat dimension and the uncertainty dimension, was replicated in most studies. The psychometric paradigm can therefore be used to facilitate the assessment of public perception on nuclear risk in the UK.

Based on the psychometric paradigm, risks can be broadly categorized into two categories: threat and uncertainty (Fischhoff *et al.*, 1978). A threat risk generally elicits visceral feelings of terror, uncontrollability, catastrophe and inequality. An uncertainty risk is generally new and unknown to science. Research in psychometrics has proven that nuclear risk perception is highly dependent on intuition, imagination and experiential thinking (Langford, 2002). For example, factors which make nuclear accidents unusually memorable or imaginable, such as a recent disaster, heavy media

coverage, a sensational and dramatic story or a vivid film, could heighten risk perception (Besley, 2012). The recent Fukushima accident is a good case in point. Kim *et al.* (2013)'s survey across 42 countries shows a sharp decrease in public acceptance after the accident. It also verifies that such decrease was more prominent in countries with a higher density of nuclear reactors. In Hong Kong, with the Daya Bay nuclear power plant located nearby, Mah *et al.* (2012)'s survey conducted two months after the Fukushima accident shows a high level of public resistance towards nuclear energy. Huang *et al.* (2013)'s research also shows that there was a significant shift in the public perception of Chinese towards nuclear energy after the Fukushima accident. The perception towards social and personal risks of nuclear accident shifted from moderate to serious after the accident.

However, existing psychometric tests focusing on the risks of nuclear accidents do not differentiate between the risks of accidents from the old nuclear technologies and those from the new nuclear technologies. Given the introduction of new nuclear technologies with defence-in-depth mechanisms including the newly designed reactor models imported from China by the government and the nuclear industry in the UK, it is possible that the public may perceive these new technologies as relatively safer than the old counterparts. Replacing old nuclear technologies with new ones may help reduce public anxieties and risk perceptions towards nuclear energy, and therefore improve government trustworthiness.

Existing literature investigating the relationship between trustworthiness/trust and risk perception in different countries tends to predict perceived risks of nuclear energy based on trustworthiness of authorities, including the government. The surveys conducted by Mah *et al.* (2014a) on Hong Kong and Siegrist *et al.* (2014) on Switzerland suggest that trusts could reduce the perceived risks of nuclear technologies. However, these studies do not look at the reverse correlation, that is, how risk perception towards nuclear technologies can affect/predict government trustworthiness.

Given an increasing number of new reactor models are to be developed across different countries, including the UK, distinguishing public risk perception between old and new nuclear technologies and how these two are related to government trustworthiness are important. The use of psychometric tests to uncover public risk perceptions towards old and new nuclear technologies, and the study of how public risk perceptions between old and new technologies can affect/predict government trustworthiness, can thus help the UK government understand how risky these new reactor models are perceived by the public, and assist the formulation of relevant policy strategies to improve government trustworthiness in NSEG in the future.

2.2.2 Knowledge about nuclear and safety

The relationship between knowledge and trustworthiness is not straightforward. The possession of knowledge about a risky event can work in an opposite direction to trust. Siegrist and Cvetkovich (2000) ascertain that people with less knowledge on a complex issue will tend to rely on social trust, or experts who are trustworthy and whose opinions can be believed as being accurate, when making judgements. However, their study examines the role of knowledge in mediating social trust and perceived risk, instead of exploring directly the relationship between knowledge and social trust. In addition, previous literature covering knowledge and trust is usually mediated by perceived risks. There are studies investigating the relationship between knowledge and perceived risk (Kuklinski *et al.*, 1982; Nealey *et al.*, 1978), and between trust and perceived risk (Biel and Dahlstrand, 1995; Flynn *et al.*, 1992; Siegrist and Cvetkovich, 2000). However, very little research has directly examined the role of knowledge in predicting trust in government. It is thus important to directly determine whether knowledge is a predictor of trust in the UK government's NSEG.

2.2.3 Stakeholder engagement

Stakeholder engagement is the act of including stakeholders in the process of consideration, decision, and implementation of policy issues (Whitmarsh *et al.*, 2005). The process creates a sense of ownership and belonging. In addition, engagement with community stakeholders increases trust and fosters an effective operating environment, reducing resistance and facilitating successful implementation of policy decisions (Bloomfield *et al.*, 2001; Bradbury *et al.*, 1999; Mah et al., 2014b).

Arnstein (1969)'s ladder of participation, consisting of eight levels, is a well-established, reliable framework for evaluating the level of citizen engagement in government. Much of the literature examining the level of public engagement in the government's decision-making/planning process remains qualitative (Lane, 2005; Luyet *et al.*, 2012; Reed, 2008; Serrao-Neumann *et al.*, 2014; Späth and Scolobig, 2017), while some other works assessing the citizens' perceived level of engagement in government decision-making (Callahan, 2002; Tosun, 2005; Menzel *et al.*, 2013; Reilly *et al.*, 2016; Langer *et al.*, 2017) are more quantitative, and have partially adopted/elaborated on Arnstein's ladder of participation.

The evaluation of the level of citizen engagement is important, since citizen engagement has an important role to play in government trust-building. Paterson (2004) argues that stakeholders should be involved in all stages of the decision-making process, though the government is still responsible for making the final decision. An effective stakeholder engagement process helps the government implement risk management policies more effectively. Failure to represent stakeholders' viewpoints and build consensus could significantly weaken the legitimacy of risk management (Bradbury *et al.*, 1999). In order to effectively manage stakeholder engagement with NSEG in the UK, it is necessary to study how stakeholders perceive their engagement activities, and how government should engage with stakeholders in order to maximize government trustworthiness in NSEG.

2.2.4 Demographics

Demographic characteristics can influence stakeholder perception and acceptance of nuclear power. Stakeholders' attitudes, expectations and perception of nuclear risk may differ due to demographic variations (Rothman and Lichter, 1987). Demographics can affect one's perspective of trust in government (Cook and Wall, 1980; Mah *et al.*, 2014a; Meyer *et al.*, 2013; Reiner and Liang, 2011; Wilkes, 2015). Important factors include age, gender, income, education, voting intention (for a political party), work type, marital status, and religion status (Lang, 2013). Statistical analysis can be applied to determine the significant predictors of UK government's trustworthiness in NSEG.

3. Data and methods

3.1 Sampling and survey methods

In order to determine the factors that predict UK government trustworthiness in NSEG, we conduct a survey covering four key dimensions: 1) perceived risk of nuclear power technologies, 2) knowledge about nuclear technology and safety, 3) stakeholder engagement and 4) demographics. A questionnaire was developed and an online survey was conducted in late April 2015 through YouGov, a leading opinion poll research company based in the UK. Respondents were selected from a pool of 360,000 UK residents aged 18 or above, by representative sampling. A pilot online survey was distributed to 200 respondents in early April 2015, followed by the full online survey with 1,007 respondents in mid-April 2015. The questionnaire covers five parts:

A. Perceptions of the UK government's trustworthiness in NSEG

B. Perceptions of risks of death/harm associated with nuclear radioactivity

C. Levels of engagement in the UK government's NSEG

D. Knowledge about nuclear technology and safety

E.   Demographics and attitudinal questions regarding phasing out or retaining nuclear power in the UK

Part A – Stakeholder perceptions of the UK government trustworthiness in NSEG

In the UK, responsibility for nuclear safety and emergency planning in the event of a nuclear accident is shared among the industry, local and national governmental agencies. In order to understand the level of public trust towards the UK government in NSEG, we sought their views on seven key dimensions of trust in the UK government's past record of trustworthiness on public health, food, water and road safety governance. The seven key dimensions are:

1.   Openness – Does the government provide all relevant unclassified information to the public?

2.   Reliability – Does the government endeavour to keep its promises and commitments?

3.   Integrity – Does the government take actions consistent with its words?

4.   Credibility – Are governmental actions valid?

5.   Fairness – Is the government committed to impartial decision-making?

6.   Caring – Does the government listen to concerns raised by the public?

7.   Competence – Does the government have the necessary skills and expertise to carry out its duties?

Part B – Public perception of risks of death/harm associated with nuclear power technologies

We included a total of twelve questions in our survey to uncover the respondents' risk perception with regards to nuclear power technologies. To create a sense of greater proximity, we invited our respondents to provide their risk perception responses based on the assumption that a new nuclear power plant is located at a distance of 5 miles away from their residence (although in reality very few British residents live within 100 miles of a nuclear power plant). Nine risk perception questions are modified from the psychometric paradigm, which aims to uncover the perception of technological

risks including nuclear accidents (Fischhoff *et al.*, 1978). Six questions relating to the threat dimension and three to the uncertainty dimension of the nuclear risk have been developed to uncover respondents' risk perceptions towards both new and the old nuclear technologies:

1. Voluntariness (Threat) – Do people enter the risky situation voluntarily?

2. Immediacy of effect (Threat) – To what extent is the risk of death immediate?

3. Control over risk (Threat) – To what extent can you avoid death while engaging in the activity, if you are exposed to the risk of each activity or technology?

4. Chronic-catastrophic (Threat) – Is this the chronic risk that kills people one at a time or a catastrophic risk that kills large number of people all at once?

5. Common-dread (Threat) – Is this the risk that people have learnt to live with and can think about reasonably calmly, or is it one that people have great dread instinctively?

6. Severity of consequences (Threat) – How likely is it that the consequence will be fatal, if the risk from the activity is identified in the form of a mishap or illness?

7. Knowledge about risk (Uncertainty) – To what extent is the risk known precisely by the people who are exposed to those risks?

8. Knowledge about risk (Uncertainty) – To what extent is the risk known to science?

9. Newness (Uncertainty) – Are these risks new and unfamiliar ones, or old and familiar ones?

Part C – Existing levels of stakeholder engagement in the UK government's NSEG

Stakeholder engagement plays an important role on NSEG decision-making. It can boost stakeholder trust in NSEG (Mah *et al.*, 2014a), or ameliorate stakeholder distrust, particularly when the risk of a nuclear accident is distributed unevenly (Löfstedt, 2005). To determine existing levels of engagement in the UK government's NSEG, we deploy the ladder of engagement for measurement, which can be categorized into eight levels of stakeholder participation/empowerment, from the lowest level of

engagement Level 1 (Manipulation), to the highest level of engagement, Level 8 (Citizen Control) (Arnstein, 1969):

1. Level 1, Manipulation – Stakeholders are not being engaged at all. The government and industry are solely responsible for the emergency plan

2. Level 2, Therapy – Stakeholders are invited to sit in the emergency planning meetings but not allowed to share their personal views

3. Level 3, Informing – Stakeholders are informed of the emergency plan only

4. Level 4, Consultation – Stakeholders are able to sit in the emergency planning meetings and express their views but not have a right to vote on the final plan

5. Level 5, Concession – Stakeholders are allowed to help develop emergency plans, but government officials reserve the right to veto their plans

6. Level 6, Partnership – Stakeholders are being consulted and are invited to select from a few limited options

7. Level 7, Delegated power – Stakeholders are given some of the power to plan for the emergency, alongside industry and government

8. Level 8, Citizen control – Stakeholders are given the full power to plan for the emergency

Part D – Knowledge of nuclear technology and safety

Sound knowledge about nuclear technology and safety can help the public understand better the risks associated with nuclear power and prepare for emergencies. A government that provides adequate and relevant nuclear/risk information may reduce risk perceptions and boost public confidence/trust in the government's NSEG (Mah *et al.*, 2014b; Renn and Levine, 1991; Rogers *et al.*, 2007; Siegrist *et al.*, 2005). However, the relationship between knowledge and public trust in the authorities may not always be as straightforward as it seems. In some cases, in the absence of knowledge, perceived

risks could be an important determinant of trust in nuclear experts by the public (Siegrist and Cvetkovich, 2000). To understand the level of knowledge of our respondents and how this will affect public trust in the government's NSEG, we asked our respondents whether they are familiar with the specific knowledge of nuclear safety issues and the general knowledge of nuclear power.

Part E – Demographics

Similar to other social studies, where demographics can be influencing variables, our study will include demographic variables in our logistic regression model to determine if they could also be used to predict government trustworthiness in NSEG. Variables such as age, gender, education, income, voting intention, marital status, work type, and religion status, which might influence overall government trustworthiness on NSEG are treated as independent variables in our ordinal logistic regression model (refer to Table 1 for detailed definitions of individual demographic variables).

3.2 Statistical models

3.2.1 Principal component analysis (PCA)

To understand what dimensions are affecting government trustworthiness, PCA is applied. The analytical approach utilizes a variance and covariance matrix of the dimensions to extract latent factors, calculate loadings and construct a weight vector to estimate the respondents' perception on overall government trustworthiness (Nardo *et al.*, 2005). We follow the procedures below to derive the weights of the different dimensions (Nardo *et al.*, 2005):

1. Latent factors representing seven key dimensions of overall government trustworthiness are identified. Each latent factor depends on a set of loadings and each loading measures the correlation between the individual dimension and the factor. The latent factors that preserve a significant amount of cumulative variance of the original data are retained to form an un-rotated factor matrix. In this study, factors that have eigenvalues larger than one are retained.

2. The un-rotated factor matrix is transformed into a rotated factor matrix by varimax rotation to obtain a simpler structure:

$$\text{Rotated factor matrix} = \begin{bmatrix} FL_{1,1} & \cdots & FL_{1,n} \\ \vdots & \ddots & \vdots \\ FL_{m,1} & \cdots & FL_{m,n} \end{bmatrix} \qquad (1)$$

where

$FL_{i,j}$ is the factor loading of dimension i on factor j,

m is the total number of dimensions, and n is the total number of factors.

3. A vector equal to the proportion of the explained variance is extracted from the rotated factor matrix:

$$\text{Proportion vector} = [P_1 \quad \cdots \quad P_n] \qquad (2)$$

$$P_j = \frac{\sum_{k=1}^{m}(FL_{k,j})^2}{\sum_{l=1}^{n}\sum_{k=1}^{m}(FL_{k,l})^2} \qquad (3)$$

where P_j is the proportion of the explained variance, and j is the column number.

4. Intermediate weights of seven dimensions are calculated from the rotated factor matrix corresponding to the factor loadings. An intermediate weight matrix can be formed:

$$\text{Intermediate weight matrix} = \begin{bmatrix} IW_{1,1} & \cdots & IW_{1,n} \\ \vdots & \ddots & \vdots \\ IW_{m,1} & \cdots & IW_{m,n} \end{bmatrix} \qquad (4)$$

$$IW_{ij} = \frac{(FL_{i,j})^2}{\sum_{k=1}^{m}(FL_{k,j})^2} \qquad (5)$$

where IW_{ij} is the intermediate weight, i is the row number, and j is the column number.

5. By multiplying the proportion vector (2) by the transpose of the intermediate weight matrix (4), a weight vector to estimate the UK respondents' perception on overall government trustworthiness can be constructed:

$$\text{Weight vector} = [P_1 \quad \dots \quad P_n] \begin{bmatrix} IW_{1,1} & \dots & IW_{1,n} \\ \vdots & \ddots & \vdots \\ IW_{m,1} & \dots & IW_{m,n} \end{bmatrix}^T = [W_1 \quad \dots \quad W_m] \qquad (6)$$

where W_m is the weight of key dimension m.

In general, the larger the weight W_m, the greater the contribution of dimension m $(m = 1\ to\ 7)$ to the respondents' perception on overall government trustworthiness. By identifying the weight of each dimension, one can predict how the same increase in the respondents' agreement on such dimension will affect their perception on overall government trustworthiness.

The PCA model capturing the relative weights of the seven dimensions used to estimate perception of overall government trustworthiness in NSEG for all respondents is:

$$\text{Overall government trustworthiness} = \begin{bmatrix} W_1 \\ \vdots \\ W_7 \end{bmatrix}^T \begin{bmatrix} \text{Integrity} \\ \text{Reliability} \\ \text{Openness} \\ \text{Fairness} \\ \text{Competence} \\ \text{Credibility} \\ \text{Caring} \end{bmatrix} \qquad (7)$$

Similarly, a PCA can also be applied to analyse the nine risk dimensions of old or new nuclear power technologies and how these nine key risk dimensions are related to each other. The larger the weight of dimension m $(m = 1\ to\ 9)$, the greater the dimension's contribution to the respondents' perception on overall risk of old and new nuclear power technologies. By identifying the relative weight of each of the nine dimensions, one can predict how the same increase in the respondents' agreement on each dimension will affect their overall risk perceptions towards new or old nuclear technologies. The PCA model capturing the relative weights of the nine dimensions used to estimate overall risk perceptions of the new or the old nuclear power technologies in the UK for all respondents is:

$$\text{Risk perceptions of new nuclear power technologies} = \begin{bmatrix} W_1 \\ \vdots \\ W_9 \end{bmatrix}^T \begin{bmatrix} \text{Voluntariness} \\ \text{Immediacy of effect} \\ \text{Control over risk} \\ \text{Chronic} - \text{catastrophic} \\ \text{Common} - \text{dreaded} \\ \text{Severity of consequences} \\ \text{Known} - \text{unknown to yourself} \\ \text{Known} - \text{unknown to scientist} \\ \text{Newness} \end{bmatrix} \quad (8)$$

$$\text{Risk perceptions of old nuclear power technologies} = \begin{bmatrix} W_1 \\ \vdots \\ W_9 \end{bmatrix}^T \begin{bmatrix} \text{Voluntariness} \\ \text{Immediacy of effect} \\ \text{Control over risk} \\ \text{Chronic} - \text{catastrophic} \\ \text{Common} - \text{dreaded} \\ \text{Severity of consequences} \\ \text{Known} - \text{unknown to yourself} \\ \text{Known} - \text{unknown to scientist} \\ \text{Newness} \end{bmatrix} \quad (9)$$

By multiplying the weight vector with the average score of nine risk dimensions, a risk score vector to estimate the UK respondents' risk perceptions can be constructed as:

$$\text{Risk score vector} = [W_1 P_1 \quad \dots \quad W_9 P_9] \quad (10)$$

where $W = [W_1 \quad \dots \quad W_9]$ is the weight vector, and P_i is the average value of the risk dimension i for all respondents ($i = 1 \dots 9$).

Threat and uncertainty factor scores of new and old nuclear technologies can be calculated as the sum of corresponding risk scores.

3.2.2 Ordinal logistic regression

We conduct a regression analysis to further assess the influence of four key sets of factors: i) risk perceptions of nuclear power technologies; ii) knowledge of nuclear technology and safety; iii) stakeholder engagement; and iv) demographics. Since the values presented by each respondent are categorical and ordered, an ordinal logistic regression model is chosen for statistical analysis (Lam *et al.*, 2013). Mathematically, the ordinal logistic regression model can be represented as:

$$\ln\left[\frac{P_{jk}}{1 - P_{jk}}\right] = \alpha_j - \beta_1 X_1 - \cdots - \beta_n X_n + \varepsilon \qquad (11)$$

where

$P_{jk} = \text{Prob}(Y_k <= j), j = 1 \text{ or } 2;$

Y_k = response by respondent k; $Y_k = 1$ ("high trustworthiness"), or 2 ("undecided");

α_j is the y-intercept for $j = 1$ ("high trustworthiness"), or $j = 2$ ("undecided");

β_i is the slope of the selected variable X_i (refer to Table 1 for variable specification);

ε is the random error with zero mean and finite variance.

P_{1k} is the probability of respondent k taking the view that the UK government is highly trustworthy in NSEG. P_{2k} is the probability of respondent k taking the view that the UK government is highly trustworthy in NSEG or undecided as to whether the UK government is trustworthy or not in NSEG. We use $Y_k = 3$ ("low trustworthiness") as the reference category.

From Equation (11),

$$P_{jk} = \exp(A_{jk})/[1 + \exp(A_{jk})] \qquad (12)$$

where $A_{jk} = \alpha_j - \beta_1 X_1 - \cdots - \beta_n X_n + \varepsilon$

Hence the probability of respondent k taking the view that the UK government is highly trustworthy in NSEG is:

$$P_{1k} = \exp(A_{1k})/[1 + \exp(A_{1k})] \qquad (13)$$

where $A_{1k} = \alpha_1 - \beta_1 X_1 - \cdots - \beta_n X_n + \varepsilon$

Factors that increase A_{1k} also increase P_{1k}. Hence the interpretation of P_{1k} is as follows:

If $\beta_i > 0$, an increase in variable X_i will decrease A_{1k}, and P_{1k}, the probability of respondent k taking the view that the UK government is highly trustworthy.

If $\beta_i < 0$, an increase in variable X_i will increase A_{1k}, and P_{1k}, the probability of respondent k taking the view that the UK government is highly trustworthy.

The ordinal logistic regression model is constructed to reveal the relative importance of each of the four key sets of factors and to predict the likelihood of the UK government trustworthiness in NSEG based on a respondent k's opinions and characteristics. Model selection is conducted in three stages. First, univariate analysis is undertaken to assess the potential strength of each independent variable (see Table 2). Next, we run a multivariate ordinal logistic regression model with the selected variables (representing the four key sets of factors) that carry a p-value less than 0.1 (see Table 3). Finally, we repeated the analysis by including only the statistically significant variables that carry a p-value less than 0.05 (see Table 4).

4. Results and discussions

We conducted a PCA with varimax rotation to determine the relative contribution of each dimension in predicting government trustworthiness (See Section 4.1) and the overall risk perceptions of new and old nuclear technologies (See Section 4.2). We then conducted an ordinal logistic regression analysis to study the key factors that affected and predicted government trustworthiness in NSEG in the UK based on four different sets of factors: 1) risk perceptions of old and new nuclear technologies, 2) knowledge of nuclear technology and safety, 3) stakeholder engagement and 4) demographics (See Section 4.3).

4.1 Government trustworthiness on NSEG

When asked whether the members of the public would consider the UK government as trustworthy in NSEG based on its past record of trustworthiness in public health, food, water and road safety governance, 24% agreed and 42% disagreed while 34% neither agreed nor disagreed (see Figure 1). Our results also indicated that more than half of respondents did not trust the UK government to

effectively plan for the mitigation of a nuclear catastrophe. Over half (52%) of respondents indicated mistrust and only 28% indicated trust.

To obtain additional insights, a series of questions were designed to evaluate government trustworthiness along nine dimensions. According to our results, Component 1 had an eigenvalue exceeding one (3.99) and explained 56.94% of the total variance, and all seven key dimensions of trustworthiness were clustered on the same component (See Table 5 for the dimensions of government trustworthiness). This component was most heavily loaded for integrity, reliability and openness, which indicated that these three dimensions were relatively more important predictors of UK government's trustworthiness in NSEG. On the other hand, fairness, competence, credibility and caring were relatively less important predictors (see Table 5). With the use of PCA and varimax rotation, a weight vector was constructed to estimate the overall trustworthiness (see Section 3.2.1).

$$\text{Overall government trustworthiness} = \begin{bmatrix} 0.180 \\ 0.168 \\ 0.158 \\ 0.132 \\ 0.130 \\ 0.121 \\ 0.111 \end{bmatrix}^T \begin{bmatrix} \text{Integrity} \\ \text{Reliability} \\ \text{Openness} \\ \text{Fairness} \\ \text{Competence} \\ \text{Credibility} \\ \text{Caring} \end{bmatrix} \qquad (14)$$

Based on the weights of the seven dimensions shown in Equation (14), the UK government can identify ways to increase its overall trustworthiness in NSEG by paying specific attention to the dimensions of higher weights, for instance, addressing the dimension of integrity, reliability and openness, which have accounted for 50% of the overall weight. If the costs and resources necessary to improve each dimension are similar, prioritizing the higher weighted dimensions can be more cost-effective. However, it does not mean that other dimensions should be taken lightly. The difference in weights between the dimensions is significant though no single dimension is dominant and even the lowest dimension has a weight of greater than 10%. It is therefore worthwhile for the government to

attend to all seven dimensions to improve trustworthiness, especially if there are diminishing returns to (or higher costs associated with) focusing on a particular dimension.

4.2 Risk perceptions regarding old and new nuclear power technologies in the UK

PCA was also applied to analyse the nine key risk perception dimensions of new and old nuclear technologies, as shown in Tables 6 and 7, respectively (see Table 6 for the risk component of new nuclear technologies and Table 7 for the risk component of old nuclear technologies). To provide a general picture of risk perceptions, PCA was performed and weighted vectors were constructed to estimate the loading of each risk characteristic for new and old nuclear technologies:

$$
\text{Risk perceptions of new nuclear technologies} = \begin{bmatrix} 0.117 \\ 0.111 \\ 0.121 \\ 0.125 \\ 0.124 \\ 0.110 \\ 0.104 \\ 0.076 \\ 0.113 \end{bmatrix}^T \begin{bmatrix} \text{Voluntariness} \\ \text{Immediacy of effect} \\ \text{Control over risk} \\ \text{Chronic} - \text{catastrophic} \\ \text{Common} - \text{dreaded} \\ \text{Severity of consequences} \\ \text{Known} - \text{unknown to yourself} \\ \text{Known} - \text{unknown to scientist} \\ \text{Newness} \end{bmatrix} \quad (15)
$$

$$
\text{Risk perceptions of old nuclear technologies} = \begin{bmatrix} 0.077 \\ 0.115 \\ 0.119 \\ 0.117 \\ 0.118 \\ 0.123 \\ 0.109 \\ 0.094 \\ 0.129 \end{bmatrix}^T \begin{bmatrix} \text{Voluntariness} \\ \text{Immediacy of effect} \\ \text{Control over risk} \\ \text{Chronic} - \text{catastrophic} \\ \text{Common} - \text{dreaded} \\ \text{Severity of consequences} \\ \text{Known} - \text{unknown to yourself} \\ \text{Known} - \text{unknown to scientist} \\ \text{Newness} \end{bmatrix} \quad (16)
$$

The values of the weighted vectors of risk perceptions for new and old nuclear technologies (Equations (15) and (16)) showed that none of the risk dimensions were dominant. The weight for each dimension ranged from 0.076 to 0.125 for new nuclear technologies, and from 0.077 to 0.129 for old nuclear technologies. The difference in weights was less than 0.060 in both cases, indicating that the public generally viewed these risk dimensions as being of similar importance and that there

was relatively little difference in their view of old and new nuclear technologies.

We further analysed the perceived risk across the nine risk dimensions for both old and new nuclear technologies (see Figure 2). Comparing the two types of nuclear technologies, respondents perceived new nuclear technologies to be relatively more uncertain but less threatening compared to old nuclear technologies. However, the difference in perceived threat and perceived uncertainty appeared to be very small for these two types of nuclear technologies (see Table 8). Our result confirmed that replacing old with new nuclear technologies will not reduce public fear significantly. Any attempt to build public trust based on engineering measures alone will not suffice.

4.3 Factors explaining the UK government's trustworthiness in NSEG

We studied the key factors that may affect and predict government trustworthiness in NSEG based on four different sets of variables: 1) risk perception towards nuclear technologies, 2) knowledge of nuclear energy and safety, 3) existing level of stakeholder engagement and 4) demographics, using an ordinal logistic regression model (see Section 3.2.2).

The results of our main ordinal logistic regression models were tabulated in Tables 2 - 4. Overall, our analysis, presented in descending order of the value of β, showed that being male, intention to vote for the Conservative party, overall risk perceptions towards the new nuclear technologies, and existing engagement level were significant predictors (which constitute the main independent variables) of overall government trustworthiness in NSEG (the dependent variable). Definitions for dependent and independent variables of the logistic regression were listed in Table 1. In terms of the odds ratio which measures the strength of the association between the independent variable and the dependent variable, the value of the highest impact factor (voting intention for the Conservative Party) and the lowest impact factor (overall risk perceptions towards new nuclear technologies) could be up to a factor of 10 (see Table 4). In fact, the odds of being high trustworthiness

in NSEG in groups with the intentions to vote for the Conservative Party is about 7 times higher than that of the intentions to vote for the Labour Party, while for one unit increase in overall risk perceptions towards the new nuclear technologies, the odds of being high trustworthiness in NSEG will decrease by 33% on average.

4.3.1 Demographics factors: gender and voting intention

During the survey, demographic information including gender, age, income, education, voting intention, marital status, work type and religion status were gathered. Our regression analysis showed that among all demographic factors, being male and intention to vote Conservative were associated with increase in overall government trustworthiness, with the latter having the most significant influence.

4.3.2 Risk perceptions towards new and old nuclear power technologies

British respondents held different risk perceptions towards new and old nuclear technologies. When the respondents were asked how they would assess the risk of death/harm associated with nuclear radiation released from new nuclear technologies, 40% perceived a high risk and 40% perceived a low risk, whereas for old nuclear technologies, the ratio of high risk to low risk was 56% to 24%, while 20% were undecided for both categories.

Overall risk perception was a significant predictor of overall government trustworthiness in NSEG only for new nuclear technologies. Based on the direction and magnitude of parameter estimates, increase in risk perception would decrease overall government trustworthiness in NSEG. Moreover, the magnitude of parameter estimate for new nuclear technologies was much larger than old nuclear technologies. From our results, it could be concluded that the public's overall perceived risks of new and old nuclear technologies were generally correlated negatively with the UK government's trustworthiness in NSEG, and the impacts of perceived risks towards the new nuclear

technologies are more significant. The results were consistent with previous findings in the literature that risk perception was generally linked negatively to trustworthiness (Mah *et al.*, 2014a; Schmidt, 2004).

4.3.3 Existing level of engagement

Our respondents were asked to assess: 1) their existing level of engagement in NSEG based on their general conception of how they are currently being engaged in the UK government's environmental planning; 2) their levels of satisfaction at their rated level of engagement, based on their perception of the UK government's previous record on public health, food, water and road safety emergency planning (Table 9). We divided stakeholder engagement into eight levels, ranging from manipulation to citizen control, which were structured along the ladder of public participation (Arnstein, 1969). The higher the level, the more intensive the participation and power influence in decision-making (see Section 3.1 for details). The majority (57%) of respondents believed that the current level of stakeholder engagement was Level 2 (Therapy), and only 11% of such respondents were satisfied with this level of engagement. About 12% of respondents believed that they would want to be engaged at Level 6 (Partnership), and only 30% were satisfied with being engaged at this level. The results suggested that the existing engagement level was perceived to be low. One reason could be that most of the respondents did not live in the vicinity of the sites of nuclear power technologies and existing engagement was generally targeted at emergency planning areas around such sites. Nonetheless, except for Levels 1 (Manipulation) and 5 (Concession), the results showed a general trend that the higher the engagement level, the higher the satisfaction level. Citizens may find Level 5 less satisfactory, given that the veto right of the government could negate their time and efforts.

4.3.4 Variables not affecting and predicting government trustworthiness

Contrary to existing literature and the general belief that more knowledge about nuclear technology

could reduce public fears and increase confidence, our study found that knowledge was an insignificant predictor of public trust in NSEG ($p > 0.05$, see Table 3). This implied that there is no straightforward 'deficit' model operating (Sturgis and Allum, 2004), and strategies that spoon-feed the public with information would not increase government trustworthiness in NSEG in the UK. Our ordinal logistic analyses also found that age, education, marital status, work type and religion status ($p > 0.1$, see Table 2), and income ($p > 0.05$, see Table 3), were insignificant factors and predictors of overall government trustworthiness.

4.3.5 Significant Factors for Predicting Government Trustworthiness in NSEG

Based on the selected ordinal logistic regression model with only significant variables (see Section 3.2.2), the formula for predicting the probability of high government trustworthiness of NSEG in the UK was as follows:

$$P(\text{High Trustworthiness}) = \exp(A)/[1 + \exp(A)] \qquad (17)$$

where

$A = -2.264 - 0.262 \times$ Overall Risk Perceptions towards New Nuclear Technologies $+$ $0.183 \times$ Existing Engagement Level $+ 0.536 \times$ Gender (Male) $+ 2.082 \times$ Voting Intention (Conservative Party).

5. Conclusions and policy implications

We have investigated the factors that affect and predict overall government trustworthiness in NSEG in the UK, by examining risk perceptions towards old and new nuclear technologies, knowledge about nuclear safety, stakeholder engagement and demographics. We have developed an econometric model to study the relationships and ascertain the probability of government trustworthiness for given levels of risk perception, knowledge about nuclear safety, stakeholder engagement as well as

demographic factors.

To achieve the UK Climate Change Act target of reducing greenhouse gas emissions by 80% compared with 1990 levels in an economically efficient manner, the UK government has recognized the importance of having "nuclear, renewables and carbon capture and storage technologies competing with each other to deliver energy at the lowest possible cost" (Department of Energy and Climate Change, 2011a). The number of new nuclear power technologies is projected to increase. With the approval of Hinkley Point C project in which Chinese influence is prominent, public concerns about nuclear NSEG may rise, particularly if several other sites are also developed. Our study has revealed that the risk perceptions towards new nuclear technologies would negatively impact the trustworthiness of the government in nuclear emergency governance. Such risk perception could be further reinforced as China is expected to take a greater role in nuclear development in the UK, with China's determination to export more nuclear technologies to the world (World Nuclear Association, 2018).

Among the seven key dimensions of trustworthiness, our analysis has shown that integrity, reliability and openness are particularly relevant to the UK government's overall trustworthiness in NSEG. Hence, the UK government should devote resources towards upholding the integrity, reliability and transparency of the process to improve public trust in NSEG. One way to address these aspects may be through better and greater stakeholder engagement.

Mapping the dimensions of integrity, reliability and openness onto the various levels of stakeholder engagement, we see that except for the lowest level (Manipulation), all other levels would require the government to exhibit qualities of integrity, reliability and openness. Beyond the half of the respondents who are satisfied with the Manipulation level, we have found that, in general, the higher the perceived level of engagement, the higher the satisfaction with the UK government. An

interesting exception happens at the level of Concession, where stakeholders are allowed to develop plans that can be vetoed by the government. Such a veto mechanism will lead to public suspicion of the government's integrity and reliability, and therefore reduce overall public satisfaction and perceived trustworthiness of the government.

Devoting more effort into stakeholder engagement may not have significant impacts on the administrative costs of the government. The comparison between the satisfaction expressed over the Therapy and Consultation levels revealed that if the public are invited to emergency planning meetings, simply allowing them the opportunity to speak would significantly increase the number of satisfied participants, even when they do not have any voting rights on the final emergency plan. Since more than half of the respondents believe they have been given the opportunity to attend planning meetings, acknowledging their participation and giving them the opportunity to speak can be easily achieved without much additional cost.

An important insight gained from our survey is that while overall risk perceptions is an important predictor of overall government trustworthiness on NSEG, it is statistically significant only for new nuclear technologies. The higher the public's overall perceived risk associated with new nuclear technologies, the lower the overall perception of government trustworthiness on NSEG. Contrary to some nuclear experts who assert that newer nuclear models with 'defence-in-depth' mechanisms would provide greater safety assurance to the public (Department for Business, Enterprise & Regulatory Reform, 2008), our results confirm that such a "newer means safer" mentality is not held by the British public. Uncertainties and threats associated with new nuclear models clearly have instilled some degree of public fear and distrust. As such, any future approval plans for new nuclear technologies by the UK government or any other plans to build new models by industry may provoke public fears and greater scrutiny. In order to reduce this, it is critical for the

UK government to portray an image of an integral, reliable and open government while explaining to the public how NSEG and other safety procedures and considerations regarding the construction, operation and decommissioning of new nuclear reactors in the UK, will be attended to carefully, to avoid any potential serious nuclear accidents associated with the new reactor models from occurring in the UK in future.

Our study has also shown that males intending to vote for the Conservative Party are more likely to perceive the government as trustworthy. Future studies may wish to explore the psychological theories behind such correlation and tailor strategies specifically towards female and/or non-Conservative Party voters to improve the effectiveness of current measures. Of course, at the time of our survey in 2015, the Conservatives were leading the government, so it could well be that if there were to be a future Labour government, then Labour voters might then be more trusting in government on NSEG (and other issues). Our study also confirms that knowledge is an insignificant predictor of public trust in NSEG. This implies that strategies that spoon-feed the public with more information would not increase government trust on NSEG.

Our analytical approach is applicable both to countries that already have extensive nuclear power technologies as well as those contemplating significant new deployments, such as China. The survey questions can be easily modified to suit the conditions of a particular country. Our logistic regression model of government trustworthiness can also be extended to other projects with potential health and safety risks such as other large energy or infrastructure projects, where government trustworthiness is closely linked to public risk perceptions, stakeholder engagement, and other key demographic factors such as gender and voting intention.

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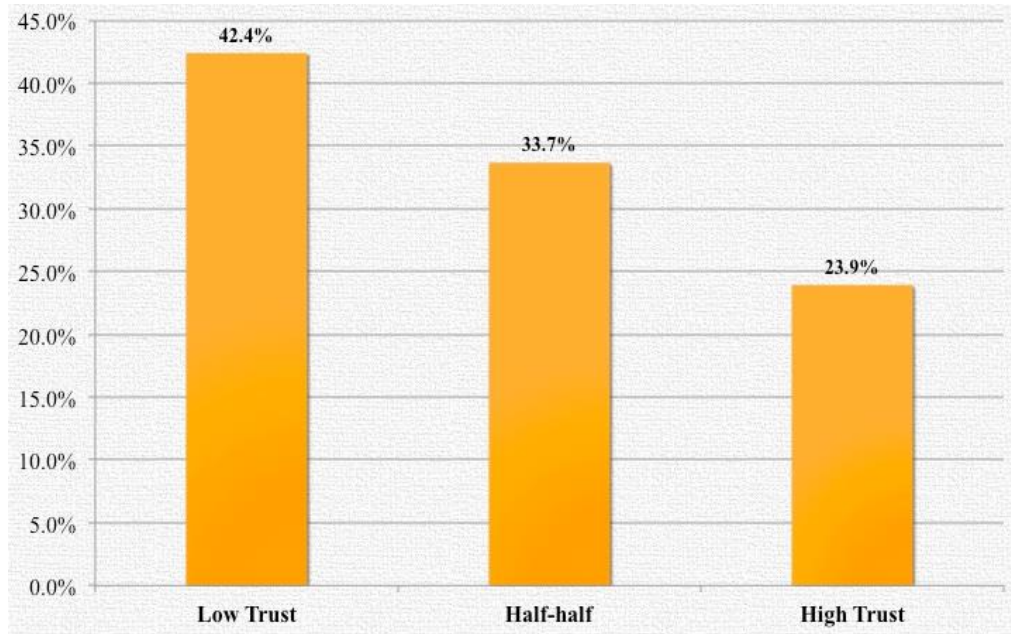
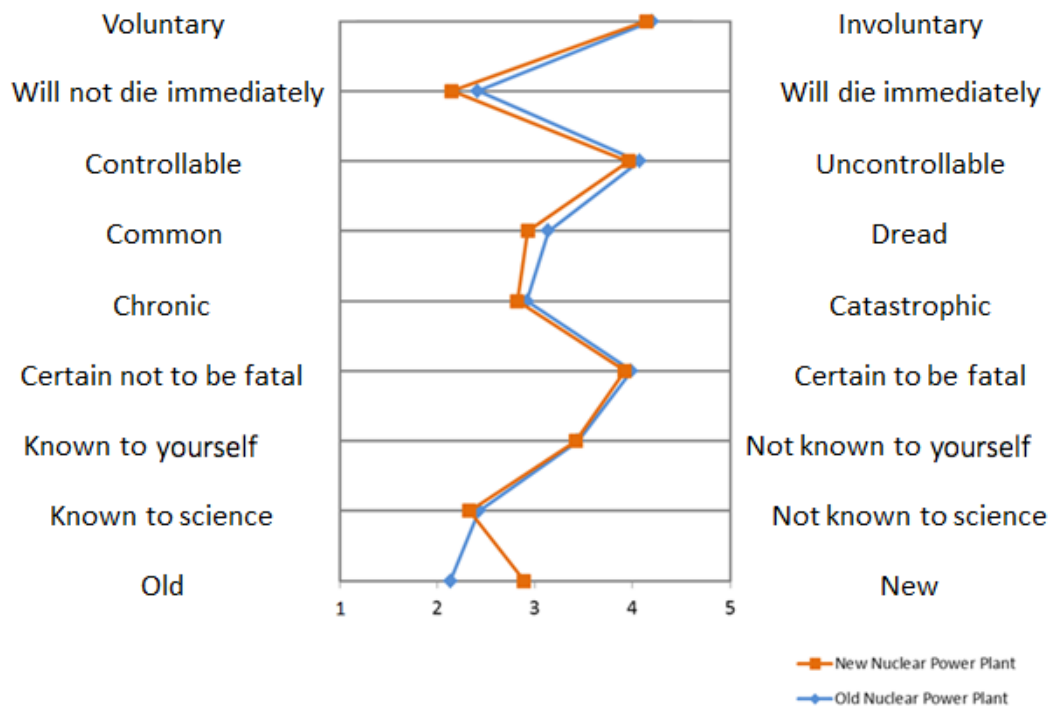**Figure 1.** Perception of overall government trustworthiness in NSEG in the UK

Figure 2. Characteristics of public risk perceptions towards new and old nuclear technologies in the UK

Table 1. Definition of dependent and independent variables used in the ordinal logistic regression model

Dependent Variable	Definition
Trustworthiness	Respondent's view on the UK government's trustworthiness in NSEG; on the scale of 1 if "high trustworthiness" to 3 if "low trustworthiness"

Independent Variables	Definition
Overall risk perceptions (New nuclear power technologies)	Overall nuclear radiation risk perceptions of respondents towards new nuclear power technologies; on the scale of 1 ("low risk") to 5 ("high risk")
Overall risk perceptions (Old nuclear power technologies)	Overall nuclear radiation risk perceptions of respondents towards old nuclear power technologies; on the scale of 1 ("low risk") to 5 ("high risk")
Knowledge of nuclear power/safety	Total scores of specific knowledge of nuclear power/safety; on the scale of 0 ("score 0") to 4 ("score 4")
Existing engagement level	Existing engagement level of nuclear power/safety; on the scale of 1 if "Level 1" to 8 if "Level 8"
Gender	Gender of respondent; 1 if "male" and 0 if "female"
Age	Age of respondent; on the scale of "<20" to ">60"
Income	Yearly income of respondent; on the scale of "<£5,000" to ">£100,000"
Education	Education level of respondent; 0 if "non-degree or below" and 1 if "degree or above"
Voting intention	Voting intention of respondent; on the category of 1 if "Conservative Party", 2 if "Labour Party", 3 if "Liberal Democrats", 4 if "Other parties", 5 if "Don't know"
Marital status	Marital status of respondent; on the category of 1 if "Married", 2 if "Living as married", 3 if "Separated", 4 if "Divorced", 5 if "Widowed", 6 if "Never married", 7 if "Civil partnership"
Work type	Work type of respondent; on the category of 1 if "Professional or higher technical work", 2 if "Manager or Senior Administrator", 3 if "Clerical", 4 if "Sales or Services", 5 if "Foreman or Supervisor of Other Workers", 6 if "Skilled Manual Work", 7 if "Semi-Skilled or Unskilled Manual Work", 8 if "Other", 9 if "Have never worked"
Religion status	Religion status of respondent; on the category of 1 if "Yes", 2 if "No", 3 if "Don't know", 4 if "Prefer not to say"

Table 2. Univariate ordinal logistic regression that explains/predicts the UK government

trustworthiness in NSEG[1]

Independent Variables	β-value	p-value
Overall risk perception (New nuclear power technologies)	0.327	0.000
Overall risk perception (Old nuclear power technologies)	0.354	0.000
Knowledge of nuclear power/safety	-0.108	0.064
Existing engagement level	-0.214	0.000
Gender [male][2]	-0.440	0.000
Age	-0.048	0.267
Income	-0.271	0.000
Education [non-degree or below][3]	0.043	0.720
Voting intention [Conservative Party][4]	-2.082	0.000
Voting intention [Liberal Democrats][4]	-0.614	0.027
Voting intention [Other parties][4]	0.374	0.048
Voting intention [Don't know][4]	-0.304	0.129
Marital status [Married][5]	-0.458	0.498
Marital status [Living as married][5]	-0.235	0.736
Marital status [Separated][5]	-0.369	0.645
Marital status [Divorced][5]	0.046	0.947
Marital status [Widowed][5]	-0.574	0.436
Marital status [Never married][5]	-0.220	0.748
Work type [Professional or higher technical work][6]	-0.214	0.658
Work type [Manager or Senior Administrator][6]	-0.751	0.126
Work type [Clerical][6]	-0.140	0.773
Work type [Sales or Services][6]	0.308	0.548
Work type [Foreman or Supervisor of Other Workers][6]	-0.414	0.495
Work type [Skilled Manual Work][6]	0.311	0.554
Work type [Semi-Skilled or Unskilled Manual Work][6]	-0.097	0.847
Work type [Other][6]	-0.177	0.724
Religion status [Yes][7]	-0.156	0.813
Religion status [No][7]	0.199	0.763
Religion status [Prefer not to say][7]	0.164	0.859

Remarks:
1. Reference category for dependent variable: "low trustworthiness"
2. Reference category for gender: "female"
3. Reference category for education: "degree or above"
4. Reference category for voting intention: "Labour Party"
5. Reference category for marital status: "Civil partnership"
6. Reference category for work type: "Have never worked"
7. Reference category for religion status: "Don't know"

Table 3. Ordinal logistic regression that explains/predicts the UK government trustworthiness in NSEG[5]

Variables (Coefficients)	
Total number of opinions	385
Number of 1 ("high trustworthiness") opinions	102
Number of 2 ("undecided trustworthiness") opinions	105
Number of 3 ("low trustworthiness") opinions	178

McFadden pseudo R^2	0.174
Intercept for response = 1 ("high trustworthiness"): α_1	-2.347***
Intercept for response = 1 ("high trustworthiness") or response = 2 ("undecided trustworthiness"): α_2	-0.730
X_1 Overall risk perceptions on old nuclear technologies: β_1	0.035
X_2 Overall risk perceptions on new nuclear technologies: β_2	0.246*
X_3 Existing engagement level: β_3	-0.209***
X_4 Knowledge: β_4	0.051
X_5 Income: β_5	-0.089
X_6 = 1 if Gender = "male" else 0: β_6	-0.598*
X_7 = 1 if Voting intention = "Conservative Party" else 0: β_7	-2.019***
X_8 = 1 if Voting intention = "Liberal Democrats" else 0: β_8	-0.317
X_9 = 1 if Voting intention = "Other parties" else 0: β_9	0.171

Remarks:

1. Reference category for dependent variable: "low trustworthiness"

2. Reference category for gender: "female"

3. Reference category for voting intention: "Labour Party"

4. *p-value < 0.05, **p-value < 0.01, ***p-value < 0.001

5. All dependent variables that predict overall government trustworthiness via univariate analysis with p-value < 0.1 (See Table 2)

Table 4. Ordinal logistic regression that explains/predicts the UK government trustworthiness in NSEG[5]

Variables (Coefficients)	
Total number of opinions	475
Number of 1 ("high trustworthiness") opinions	116
Number of 2 ("undecided trustworthiness") opinions	137
Number of 3 ("low trustworthiness") opinions	222
McFadden pseudo R^2	0.171
Intercept for response = 1 ("high trustworthiness"): α_1	-2.264***
Intercept for response = 1 ("high trustworthiness") or response = 2 ("undecided trustworthiness"): α_2	-0.531
X_1 Overall risk perceptions on new nuclear technologies: β_1	0.262***

X_2 Existing engagement level: β_2			-0.183***
X_3 = 1 if Gender = "male" else 0: β_3			-0.536**
X_4 = 1 if Voting intention = "Conservative Party" else 0: β_4			-2.082***

Remarks:

1. Reference category for dependent variable: "low trustworthiness"

2. Reference category for Gender: "female"

3. Reference category for Voting intention: "Labour Party"

4. *p-value < 0.05, **p-value < 0.01, ***p-value < 0.001

5. All dependent variables that predict overall government trustworthiness via multivariate ordinal logistic regression with p-value < 0.05 (See Table 3)

Table 5. Principal component analysis of seven dimensions of the UK government trustworthiness in NSEG

Key Dimensions	Survey Questions	Mean	Component 1
Integrity	Does the government take actions consistent with its words?	2.53	0.847
Reliability	Does the government try hard to keep its promises?	2.76	0.819
Openness	Does the government tell the whole truth about important activities?	2.27	0.794
Fairness	Is the government committed to impartial process of decision making?	2.62	0.726
Competence	Does the government have the necessary skills and competence to carry out its duties? Is the government staffed by first class scientists and engineers?	2.75	0.719
Credibility	Does the government ignore the views of scientists who disagree with it? Does the government not distort facts to make its case?	2.56	0.693
Caring	Does the government listen to the concerns raised by people like you?	2.41	0.665
Total variance explained			
Initial eigenvalue			3.986
Percentage of variance			56.938%
Cumulative percentage			56.938%
Kaiser-Meyer-Olkin KMO and Bartlett's Test			
KMO Measure of Sampling Adequacy: 0.878			
Approximate Chi-Square: 3215.256			
Bartlett's Test of Sphericity, significance: 0.000			

Table 6. Principal component analysis of nine dimensions of nuclear radiation risks from new nuclear technologies

Key Dimensions	Survey Questions	Component 1 (Threat)	Component 2 (Threat)	Component 3 (Uncertainty)
Chronic-catastrophic	Do you think that the risk will kill/harm a small number of people gradually over time or a large number of people all at once? (1=chronic, 5=catastrophic)	*0.736*	0.095	0.278
Immediacy of effect	Whether you think the risk of death/harm would be immediate or would it happen over a long period of time? (1=delayed, 5=immediate)	*0.728*	-0.092	-0.137
Common-dread	Is the risk associated a common one that you do not worry about much or one that you dread? (1=common, 5=dread)	*0.691*	0.308	0.221
Voluntariness	Whether you think the risk has been imposed on you or whether you think you have had any say over the risk? (1=voluntary, 5=involuntary)	-0.007	*0.768*	0.013
Control over risk	Do you think you would be able to avoid the risk of death/harm through your own skills or expertise? (1=controllable, 5=uncontrollable)	0.014	*0.698*	0.351
Severity of consequences	Do you think it would end up being fatal or it would end up not being fatal if someone was exposed to the risk? (1=certain not to be fatal, 5=certain to be fatal)	0.416	*0.615*	-0.013
Newness	Do you think it to be a new risk to you or a risk that has each been around for a long time? (1=old, 5=new)	-0.010	-0.058	*0.750*
Knowledge about risk (Personal)	How would you rate your knowledge of the risk? (1=known precisely, 5=not known precisely)	0.070	0.272	*0.666*
Knowledge about risk (Scientist)	How would you rate scientists' knowledge of the risk? (1=known precisely, 5=not known precisely)	0.146	0.085	*0.593*

Total variance explained

Initial eigenvalue		2.634 (≥1)	1.318 (≥1)	1.076 (≥1)
Percentage of variance		19.437%	18.354%	18.065%
Cumulative percentage		19.437%	37.791%	55.856%

Kaiser-Meyer-Olkin KMO and Bartlett's Test
KMO Measure of Sampling Adequacy: 0.734
Approximate Chi-Square: 393.307
Bartlett's Test of Sphericity, significance: 0.000

Table 7. Principal component analysis of nine dimensions of nuclear radiation risks from 50-year old nuclear technologies

Key Dimensions	Survey Questions	Component 1 (Threat)	Component 2 (Threat)	Component 3 (Uncertainty)
Control over risk	Do you think you would be able to avoid the risk of death/harm through your own skills or expertise? (1=controllable, 5=uncontrollable)	*0.730*	0.021	0.226
Severity of consequences	Do you think it would end up being fatal or it would end up not being fatal if someone was exposed to the risk? (1=certain not to be fatal, 5=certain to be fatal)	*0.670*	0.392	-0.033
Voluntariness	Whether you think the risk has been imposed on you or whether you think you have had any say over the risk? (1=voluntary, 5=involuntary)	*0.616*	-0.001	-0.041
Immediacy of effect	Whether you think the risk of death/harm would be immediate or would it happen over a long period of time? (1=delayed, 5=immediate)	-0.169	*0.727*	-0.097
Chronic-catastrophic	Do you think that the risk will kill/harm a small number of people gradually over time or a large number of people all at once? (1=chronic, 5=catastrophic)	0.187	*0.706*	0.203
Common-dread	Is the risk associated a common one that you do not worry about much or one that you dread? (1=common, 5=dread)	0.345	*0.650*	0.200
Newness	Do you think it to be a new risk to you or a risk that has each been around for a long time? (1=old, 5=new)	-0.289	0.221	*0.708*
Knowledge about risk (Scientist)	How would you rate scientists' knowledge of the risk? (1=known precisely, 5=not known precisely)	0.089	0.148	*0.658*
Knowledge about risk (Personal)	How would you rate your knowledge of the risk? (1=known precisely, 5=not known precisely)	0.294	-0.171	*0.648*

Total variance explained

	Component 1	Component 2	Component 3
Initial eigenvalue	2.350 (≥1)	1.327 (≥1)	1.247 (≥1)
Percentage of variance	19.138%	18.919%	16.649%
Cumulative percentage	19.138%	38.057%	54.706%

Kaiser-Meyer-Olkin KMO and Bartlett's Test

KMO Measure of Sampling Adequacy: 0.692
Approximate Chi-Square: 325.428
Bartlett's Test of Sphericity, significance: 0.000

Table 8. Risk perceptions (threat and uncertainty factors) towards new and old nuclear technologies

Score	Mean (new nuclear technologies)	Mean (old nuclear technologies)	Mean (paired difference)
Threat Factor	2.33	2.39	-0.06
Uncertainty Factor	0.90	0.89	0.01

Table 9. Existing levels of stakeholder engagement and corresponding levels of satisfaction

Perceived Level of Engagement	Percentage of Respondents Perceived to be at this Level	Percentage of Respondents Satisfied at this Level
Level 1, Manipulation	0.75%	50%
Level 2, Therapy	57.09%	11%
Level 3, Informing	9.51%	27%
Level 4, Consultation	2.80%	27%
Level 5, Concession	7.65%	16%
Level 6, Partnership	11.94%	30%
Level 7, Delegated power	6.34%	32%
Level 8, Citizen control	3.92%	38%