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The impact of gender on risk perception: Implications for EU member states' national risk assessment processes

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ABSTRACT

This study examined the influence of gender on individual risk perception. The analysis covered 17 involuntary risks and examined the effects of gender on three dimensions - likelihood, impact and overall risk rating. The results showed that while the magnitude and significance of the gender coefficients varied by risk, a general pattern was apparent: females judged involuntary risks as being more likely, having a greater impact, or having a higher overall risk rating than their male counterparts. The impact rating for Fire was the one significant exception to this pattern. These findings highlight how the composition of National Risk Assessment (NRA) focus groups may impact the outputs from Ireland's NRA process and the importance of EU Member States ensuring gender representation within NRA focus groups.

1. Introduction

Member States of the EU are required to submit national, or appropriate sub-national level, risk assessments (NRA), every three years. Guidelines on the content, methodology and structure of the NRAs were made available to support Member States [1], but under Article 6 (1313/2013/EU), each Member State was free to develop and refine the methodology underpinning the preparation of their NRA. This fluidity meant that "varying assessment methodologies and processes exist across Participating States" [2]; p.50). However, common elements were identified across many member states; with multi-stakeholder working groups often being used to rate the likelihood and impact of national-level risks [2].

While the EU guidelines offered no guidance on the composition of such multi-stakeholder working groups, ISO IEC 31010 [3]; on risk assessment techniques, emphasised the importance of considering human aspects such as socioeconomic position, ethnicity, culture and gender when conducting risk assessments. Similarly, research on individual risk perception revealed that variables such as "gender, age, and educational attainment are often (though not consistently) found to be mediating factors in risk perception" [4]; p.139). Notwithstanding this lack of consistency, many studies of risk perception have suggested that gender can play a significant role, and studies showed that females tended to rate risk higher than males [5–7]. The review by Chauvin highlighted that for a wide range of risks "from flood to earthquakes, from nuclear technology to environmental pollution, and from pesticides in food to cardiovascular disease" individual risk perception was impacted by gender [7]; p.41). These differing perceptions of risk can impact how risk information is interpreted and output from the process are used [3].

Considering this research, a lack of gender diversity within multi-stakeholder focus groups could have an adverse impact on the quality of output from a country's NRA process. This topic required further research as not all studies showed gender to be significant [4,8], and the results differed depending on the context, study and country, and risk type. For example, Lindell and Hwang [9] in the United States and Kellens et al. [10] in Belgium established that gender was a significant factor in flood risk perception. In contrast, the studies by Plapp [11] in Germany, and Burningham et al. [12] in England and Wales, found gender was not a significant factor in predicting flood risk perception. These contradictory findings raised the possibility that differences in research design, sampling, or additional less examined factors such as societal culture had an impact on the results. Therefore, in the context of NRAs, where multi-stakeholder focus groups were used to assess risk, it was unclear if a lack of gender diversity would influence the risk assessment process in each country. Although a vast body of literature on risk and gender existed, only a few studies examined the influence of gender systematically over a wide range of involuntary risks [5,13,14]. As a result, less is known about how the impact of gender varied by risk within one country and, more specifically, regarding risks drawn from

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NRAs. Studies involving NRAs across Europe [15–19] focused on the methodologies deployed but did not examine the influence of gender. This paper fills this gap by examining the impact of gender on the assessment of 17 involuntary NRA risks by the Irish public. The impact of gender on likelihood, impact and overall risk rating was examined. It identified the risks which females rated as being more likely, or more impactful than males and ascertained whether females rated specific risks more highly than males. We revealed the influence that gender-biased multi-stakeholder focus groups might have on Ireland's NRA by pinpointing these effects.

The remainder of this paper is structured as follows: Section 1.1 provides an overview of the Irish NRA. Section 1.2 presents a literature review on the influence of gender on risk perception, drawing attention to studies that examined a wide range of risks and differentiate between involuntary and voluntary risk. Section 2 introduces the methodology and defines the control variables. Section 3 provides the results of the analysis. Section 4 summarises the study and illustrates how these findings could impact the Irish NRA.

1.1. National Risk Assessments: policy and practice

"A number of high profile crises and disasters have driven the EU to increase cooperation among its member states in the area of civil protection and to enhance its capacity to conduct civil protection operations in Europe and around the world" [20]; p.1313). An important aspect of this enhancement of civil protection across member states is the completion of NRAs and the subsequent sharing of outputs from these assessments with international and national stakeholders. The completion of coordinated NRAs should strengthen emergency management practice and increases EU and national resilience [21]. "The ability to analyse different types of information from diverse stakeholders is among the core challenges that risk analysts in any domain may confront" [22]; p.2). Depending on a country's risk profile and data availability, several assessment methods may be leveraged, including focus groups and expert panels [22], i.e. multi-stakeholder working groups [2].

Many NRAs, such as those submitted by Belgium [23]; Denmark [24]; Finland [25]; Germany [26]; Ireland [27]; Lithuania [28]; Netherlands [29]; and Sweden [30]; referred to the contribution made by some form of multi-stakeholder working groups. For example, in Sweden [30]; workshops with relevant stakeholders from various state agencies and different levels of society were used to contribute to the final NRA. Notably, despite the influence which gender may have, the publicly available NRAs mentioned above provided no information on the characteristics of those participating in the multi-stakeholder working groups.

In Ireland, the first NRA process completed in 2012 and those undertaken in 2017 and 2020 involved Government departments, state agencies, and each of the emergency management regions providing a list of risks that could trigger a national-level emergency. The NRA working group, comprising staff from the Office of Emergency Planning and academic experts, collated these risks into a consolidated list of risks. Once approved by the Government taskforce, in line with EU guidance on multi-stakeholder working groups, expert focus groups comprising of individuals with the appropriate combination of experience and knowledge came together to determine reasonable worse case scenarios and then assess the risk posed by each of the risks on the consolidated list of risks. The participants first assessed the likelihood of each risk occurring, followed by the potential impact. The focus groups were replicated to maximise the reliability and validity of the risk assessments. After completing several focus groups, the working group combined the results to form the Irish NRA. While the 2017 process was robust and in line with EU guidance, gender representation and diversity within each focus group was not reported. By examining the influence of gender on likelihood, impact and overall risk rating, this paper illustrates how a lack of gender representation and diversity within the NRA process could influence the outputs.

1.2. Risk perception and gender

Within the risk analysis literature, much attention has been paid to the inconsistency of findings from one study to the next. Differences between the impact of gender on risk perception have been attributed to pan-national variance: cultural, social, or gender equality differences between nations [13,31]. This socio-political hypothesis, originally posited by Flynn et al. [14]; is described by Chauvin [7] as the most plausible explanation for the varying impact of gender on risk perception. The hypothesis suggests that "white males see less risk in the world because they create, manage, control, and benefit from so much of it" [14]; p.1107). This is, in part, because of the inherently subjective nature of risk perception; where social, cultural and political values, along with psychological factors, can interact and influence an individual's assessment of risk [32].

Also, of central importance is whether the risk is voluntary or involuntary because having control over one's potential risk exposure may influence risk perception [33]. Individuals perceive they have less control over involuntary risks [33,34]; and are "willing to accept 'voluntary' risks roughly 1000 times greater than 'involuntary' risks" ([34]; p.1237). This distinction between voluntary and involuntary risks may also result in different criteria being applied when evaluating the level of risk posed [34].

Studies which focused on large numbers of risks tended to include both involuntary and voluntary risks and often merged some risks to form broader constructs [5,13,35]; and [14]. Flynn et al. [14]; for example, combined storms and floods, while Olofsson and Rashid [13] and Satterfield et al. [35] included 'natural disasters' as one risk. By exploring a wide range of risks, these studies were able to present risk perception patterns based on gender [5,13,35]; and [14]. The Finucane et al. [5] analysis of 19 health risks and eight food-related risks showed that for the entire range of risks white males generally perceived less risk than females and other races, which echoed the findings of Flynn et al. [14]. On the other hand, Olofsson and Rashid's [13] Swedish study of 17 risks, including smoking, alcohol, climate change and 'natural disasters', found no general differences based on gender. They suggested that in Sweden, this could be accounted for by the relative equality between genders. However, it should be noted that four risks: climate change, 'natural disasters', accidents related to leisure activities, and stress, were significantly impacted by gender. While no concrete conclusion can be drawn from the result, it highlighted that the impact of gender on risk perception might fluctuate depending on the type of risk measured within a country. In other words, among one sample, the relationship between gender and risk rating was not consistent. Further, the combining of a range of risks into one construct (e.g. 'natural disasters') made it difficult to assess the impact of gender for a specific risk such as flooding within the context of the broader risk construct.

Of the studies which included involuntary risks a sizeable portion showed a significant relationship between gender and risk perception [5,9,10,14,36–39]. For instance, in the early investigation of individuals' risk perceptions towards nuclear plants, Brody [36] found that females felt less safe and reported a higher degree of dissatisfaction with atomic power due to the associated health risks. However, some studies reported no significant findings between gender and risk perception [40–44].

While inconsistencies in empirical results existed, differences in research design, sampling and choice of control variables made it difficult to compare the published findings accurately. For instance, multiple forms of analysis were used, including structural equation modelling [42], logistic regression [39,43], and ordinary least squares (OLS) regression [45]. In other cases, there were notable differences between the selection of control/explanatory variables for each study. Although demographic factors such as income/economic condition or age were commonly included in such studies on risk [9,39,45,46], the inclusion of other factors like past experience [9,37], political orientation/voting behaviours [39,45], years in location [37], and climate-related variables [39,45] was not consistent across all studies. Finally, the involuntary risk constructs also presented a challenge for pattern analysis. Some used broad risk constructs: e.g. technological (which included risks such as radiation and pesticides) and, non-technological risks (which included risks such as extreme weather and crime) [47], or the risk of climate change using indicators like the impact on oneself; family; plants and animals [45], while other studies focused on a single specific involuntary risk such as volcanic risk perception [48] or earthquakes [38,49]. Even for the same risk, e.g. earthquakes, differences emerged regarding how risk perception was presented. In some instances, risk perception, as the dependent variable, was reported as one measure [38]. In other cases, multiple dependent variables were used; e.g. Kung and Chen [49]; p.1535) focused on the categories of personal impact and controllability (defined as "a sense of efficacy of self-protection in regard to earthquakes"). Knuth et al. [44]; p.597) suggested that an explanation for gender having no significant effect on risk perception could be connected to the dimension of risk measured. For example, they measured likelihood (perceived and objective) and found gender was not a determinant but did not test for a relationship with impact or overall risk rating.

In summary, differences in methods of analysis, control variables, and broad or narrow risk constructs made it difficult to determine whether a pattern exists across involuntary risks. Evidence suggested that gender differences in risk perception can vary by risk, but this required further analysis [31,50]. As a result, the literature provided limited insights into the influence that gender-biased multi-stakeholder focus groups might have on the Irish NRA. To examine changes in the impact of gender by risk, a wide range of risks were studied, the effect of gender on likelihood, impact and overall risk ratings was identified, and only single or standalone involuntary risks were examined.

2. Methods

A questionnaire designed to examine the influence of gender on individuals' rating of involuntary risks was administered online (using Qualtrics software) and in paper format. Participants were members of the general public who could opt-in voluntarily once they had read the plain language statement. To reduce evaluation apprehension participants' anonymity was guaranteed. Twitter and Facebook were used to promote the questionnaire online, and it was also promoted on social media by government and public agencies, such as the Met Éireann (the national meteorological service), County Councils, the Office of Emergency Planning, and Dublin Fire Brigade. Each questionnaire took approximately 20 min to complete, and all data was collected within 2016.

The analysis included data from 1977 respondents, of whom 59.1% identified as female, and was carried out using the statistical software package STATA (StataCorp; Release 14.2/SE). The sociodemographic characteristics of those surveyed matched the Irish census data closely. The Central Statistics Office, Ireland [51] data shows, for adults (aged 20 years and over), there are slightly more females than males in Ireland (4.9%), giving a 4.2% point (pp) difference between our data and the national census data. Household income (66.8% earn less than €70,000) and homeownership (77.8%) were also reasonably representative with the national data (67.6% homeownership; income: 62.6% had a gross income of less than €60,000) [52,53]. However, there was under-representation (19.9% points) from respondents in the 55 or over age range [54]. Finally, as the latest CSO [55] data shows that the ethnicity of Ireland is predominately white (92.4%) this factor was not measured.

The cross-sectional questionnaire was developed for an Irish context and was informed by both government and academic questionnaires [56–58]. To help ensure accuracy and validity, the questionnaire was pilot tested on specialists in emergency management and members of the general public.

As preliminary tests for association between females and each of the likelihood, impact and risk rating variables Goodman and Kruskal's Gamma statistic were computed. The outputs are provided in Supplementary Table 1 in the Appendix. Polychoric correlations for likelihood and impact measures are provided in Supplementary Table 2 in the Appendix.

Ordered probit analysis with marginal effect calculations and OLS regression were used to estimate the impact of gender on the three distinct components of 17 involuntary risks (likelihood, impact and risk rating). These 17 risks were drawn from the 29 risks assessed as part of the 2017 Irish NRA process (see Ref. [59]). Including natural, technological and civil risks allowed us to explore differences in perception for risks from the same category, for example, floods and storms. It should be noted that although the term "natural" is used in the NRA, we prefer the term socio-natural is preferred as it allows for the intersection between natural hazards and human activity; risk and emergencies are rarely, if ever, totally natural events. The 12 excluded risks were less relevant to household settings and covered five transportation risks (Aviation, Maritime, Road, Rail, Transport Hubs), Crowd and Public Safety, Industrial and Hazmat Incidents, Tsunami, Space Weather and Volcanic Ash. Using 17 risks drawn from the NRA allowed us to assess the most credible risks for an Irish context, and compare the findings with the output from the NRA.

To isolate the effect of gender on respondents' perception of risk, control variables (discussed below) were selected and used consistently throughout all 51 regressions. This resulted in the following general form for each of the preparedness variables:

$$\textit{dependent variable} = f[\textit{gender}, \ \textit{socio–demographics}, \ \textit{risk exposures}, \ \textit{household preparedness}, \textit{non} - \textit{protective responses}]$$

Before beginning the analysis, variance inflation factor (VIF) values were used to check for multicollinearity. A VIF score of five or above indicates multicollinearity. The results show VIF scores within acceptable limits [60] having a maximum VIF of 2.27 and a mean VIF of 1.39.

Only the regression coefficients and marginal effects of the independent variable gender (female) are reported. See supplementary Tables 3-5 in the Appendix for three examples of the complete regression outputs, along with the regression outputs in table format. Marginal effects provided an additional illustration of the impact of gender on risk, quantifying the effect in probability terms. For each risk, we outlined the difference in probability of particular responses for females compared to males. These were computed with all other explanatory variables (see Table 1) set to their mean scores. By showing the extent to which the impact of gender was dispersed across each point on the scale (likelihood and impact) for the 17 risks, our research expanded and deepened the work of Kung and Chen [49] and others while allowing us to determine the importance of gender representation in the NRA assessment process.

2.1. Variable definitions - dependent variables

While there are many definitions of risk, most incorporate three common facets: the source of the risk, the likelihood (uncertainty), and the impact (consequence). The ISO [61] definition states: 'Risk is usually expressed in terms of risk sources, potential events, their consequences and their likelihood'. As outlined by Brown et al. [62] risk rating, likelihood and impact should be analysed individually to allow for a more nuanced understanding of the dimensions which are influenced by gender. In this study, we asked respondents to assess the likelihood of the risks affecting them or their home and, should an emergency be triggered, the level of impact they would experience. Likelihood was measured using a five-point scale with one for 'extremely unlikely' to five for 'very likely'. Impact was also measured on a five-point scale with one representing 'very low impact' up to five for 'very high impact'. To measure an individual's overall risk rating for each of the 17 risks, we multiplied the likelihood and impact ratings together, in line with

Table 1
Independent control variables used in regressions and marginal effect calculations.

Characteristic	Value	Description
Household (1977n)		
Child in the home	44.4% (872n)	1 for child in the home, 0 otherwise
Owns the home	77.8% (1536n)	1 for homeownership, 0 otherwise
Age (1977n)		
34 or under	38.4% (760n)	1 if aged 34 or under, 0 otherwise
35-54	49.3% (975n)	1 if aged 35–44, 0 otherwise
55 or older	12.2% (242n)	1 if aged 45 or older, 0 otherwise
Lives in (1977n)		
A city	17.3% (342n)	1 for city, 0 otherwise
The suburbs or outskirts of a city	10.1% (199n)	1 for Suburbs, 0 otherwise
A town	19.7% (389n)	1 for town, 0 otherwise
A village	26% (515n)	1 for village, 0 otherwise
A rural area	26.9% (532n)	1 for rural area, 0 otherwise
Years living at current address (1970n)		
Mean (SD)	12.56 (10.45)	
Mode	10	
Median (min, max)	10 (<1, 100)	
Household Income (1603n)		
Below 30,000	19.5% (321n)	1 for income below 30,000, 0 otherwise
30,000–70,000	47.3% (759n)	1 for income 30,000–70,000, 0 otherwise
Over 70,000	33.2% (532n)	1 for income over 70,000, 0 otherwise
Higher Education (1968n)		
Has a Degree or above	71.8% (1413n)	1 for degree or above, 0 otherwise
Household Preparedness Score (Z-Score) (1935n)		
Mode	1.031	
Median (min, max)	0.043 (−2.256, 1.841)	
Non-protective responses (1850n)		
Mean (SD)	3.35 (3.55)	
Mode	0	
Median (min, max)	2 (0, 19)	
Risk Exposure (1974n)		
Mean (SD)	5.20 (2.99)	
Mode	4	
Median (min, max)	5 (0, 17)	

international practice. To control for priming effects and the possible impact of reduced cognitive effort, questions on likelihood and impact ratings were frontloaded and demographic data collected towards the end of the questionnaire. Each point on the Likert scale was assigned a descriptive label, and the endpoint labels did not contain absolute terms, such as "impossible", which respondents may be less willing to choose.

The perceived likelihood, perceived impact, and the overall risk rating for each of the 17 risks were used as the dependent variables in the regression models. These risks were selected from three categories of the National Risk Assessment for Ireland: natural, technological and civil. The six natural risks considered were: Flooding, Drought, Snow, Storm, High Temperatures and Low Temperatures. The five technological risks were: Fire, Disruption to Energy Supply, Nuclear Incident Abroad, Radiation (Domestic) and Cyber Incident. The six civil risks were: Loss of Critical Infrastructure (e.g. Water), an Infectious Disease Affecting Humans, an Infectious Disease Affecting Animals, Waterborne Disease Outbreak, Foodborne Disease Outbreak and Terrorism.

Since the dependent variables for likelihood and impact were ordered categorical variables, an ordered probit model was used for each. To interpret the estimated parameter coefficients of the ordered probit, the marginal probability effects were calculated and presented separately. The overall risk rating was treated as a continuous variable and analysed using a standard OLS regression model.

2.2. Variable definitions - independent variables

The choice of independent variables was informed by protection motivation theory which shows experience and socioeconomic characteristics influence risk perception [63,64]. Kellens et al. [65]; p.44) suggest the "most important characteristics seem to be age, gender, education, income, and home ownership". Tobin and Montz (1997 cited in Ref. [66] also suggest that the presence of a child in the household should be measured.

Gender was the key independent variable of interest in our study. It was coded as a dummy with '1' assigned if the respondent declared as female and '0' if they identified as male. The remainder of the socioeconomic factors were used as independent control variables and are listed in Table 1.

Respondents' direct exposure to each of the 17 risks was measured using a self-reported check (dummy: yes/no measure) for each risk. These 17 dummy variables were summed to produce a construct: risk exposure, which measured the range of prior exposures to varying risks. This experience was not limited to their household setting to capture respondents with broader experience such as those working in emergency response roles.

Lechowska's [66] review of the risk perception literature on floods emphasised that while there remains an unclear relationship between risk perception and preparedness, it was likely a respondent could present with a lower risk perception score if they had already undertaken some preparedness activities. For this reason, our analysis also controlled for preparedness using two constructs: respondents' emergency preparedness based on a Household Preparedness Score and non-protective responses.

The first construct, Household Preparedness Score, drew from a list of 24 emergency items and actions which were used to measure household preparedness. In line with prior research, the list of items was split into three categories: evidence of planning; protective actions; and emergency resources [62]. The scores for planning, action and resources were z-transformed separately, then summed and averaged to generate the Household Preparedness Score. This approach was followed to achieve equal weighting for each category within the construct. The Household Preparedness Score was checked for reliability using Cronbach's alpha, which was calculated using the three scores from the individual preparedness categories (Cronbach's $\alpha = 0.70$).

The second preparedness construct, non-protective responses, controls for denial, wishful thinking or fatalism among respondents [57]. This construct was drawn from two lines of questioning:

(1) Respondents who said they did not want to think about preparedness, or respondents who said they would not prepare because the 'emergency services will help me' were coded as a dummy with '1' applied, '0' otherwise.
(2) For each of the 17 risks, respondents were asked if there was anything they could do to prepare. These responses were also coded as dummy measures, where '1' applied if the respondent said 'no'.

These responses were subsequently summed to form the 'non-protective response' scale ranging from 0 to 19 (19 indicating a high level of non-protective responses). Non-protective responses had a Cronbach's $\alpha = 0.89$.

3. Results

The 17 modal scores by gender were plotted on a radar chart together with the outputs from the NRA (2017), see Fig. 1. The figure showed the modal score for 10 of the 17 risks were the same for both male and female respondents. For these, a comparison with the NRA (2017) data revealed there was agreement between males, females and the NRA for only two risks, Nuclear and High Temperatures. Food Borne Disease and

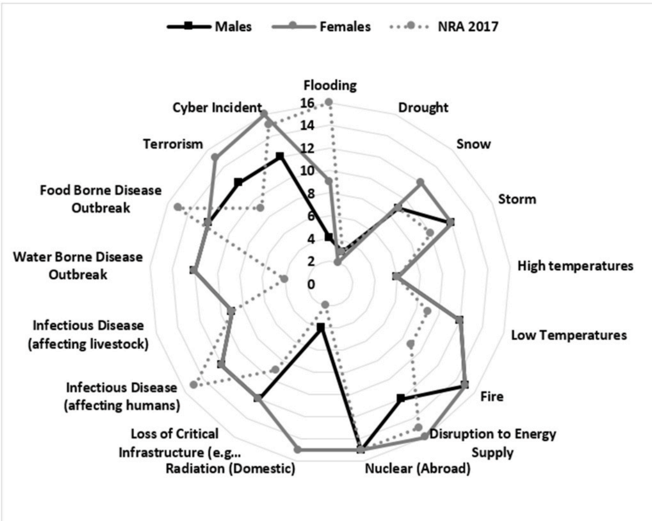

Fig. 1. Overall risk rating (modal) for females, males, and the NRA (2017).

Infectious Disease (Human) received a higher rating in the NRA, while Storm, Low Temperatures, Fire, Loss of Critical Infrastructure, Infectious Disease (Livestock), Water Borne Disease were rated as posing a lower level of risk.

For the seven risks where there was a difference between the females and males scores, the risks were judged higher in all but one case by females. Drought was the only risk which was rated higher by males (a modal score of 3 for males and 2 for females). The most substantial gender difference in risk rating was for Radiation (domestic), which had a modal score of 4 for males and 15 for females. For this set of risks, the NRA scores were closer to those of females for Flooding, Disruption to Energy Supply and Cyber Incident and closer to those of males for Drought, Snow, Radiation (Domestic) and Terrorism.

The descriptive analyses presented in Fig. 1 helped to visualise the differences in the impact of gender on each of the 17 risks in Ireland, and though the findings suggested seven risk ratings might be influenced by gender, a more comprehensive analysis was required. To investigate further the relationship between gender and risk, when controlling for risk exposure, non-protective responses, preparedness and socioeconomic factors (see Table 1), regression analytical tests were required. Fig. 2 visualises the results of these regressions and are representations of the data provided in Supplementary Table 6 in the Appendix.

Fig. 2 was used to illustrate the influence of gender on the assessment of overall risk, likelihood and impact ratings. The results for each risk were plotted in ranked order on a candlestick stock chart with gender coefficients as the centre point and the low and high shadow lines representing the upper and lower 95% confidence interval limits. Fig. 2 provides a helpful illustration of the extent to which the impact of gender varied by risk when controlling for the factors listed in Table 1.

The likelihood and impact coefficients for gender were calculated using an ordered probit model. Fig. 2 showed the gender coefficients from the ordered probit models of risk likelihood and risk impact rating results (by order of magnitude). For risk likelihood, chi-squared values and log likelihoods ranged between $\chi2(16) = 54.12$, $p < 0.001$ (Fire, Log-Likelihood $= -1753.07$) and $\chi2(16) = 169.84$, $p < 0.001$ (Terrorism, Log-Likelihood $= -2032.69$). Gender (females) was shown to be significant and positive in 15 of 17 likelihood regressions. This suggested that when we controlled for the other factors (Table 1), females consistently judged the likelihood of these risks triggering an emergency as higher than males. The risk impact chi-squared values and log likelihoods ranged between $\chi2(16) = 36.21$, $p = 0.003$ (Fire, Log-Likelihood $= -1672.34$) and $\chi2(16) = 112.18$, $p < 0.001$ (Low Temperatures, Log-Likelihood $= -1896.49$).

Fig. 2, coefficients on gender (female) from ordered probit analysis of

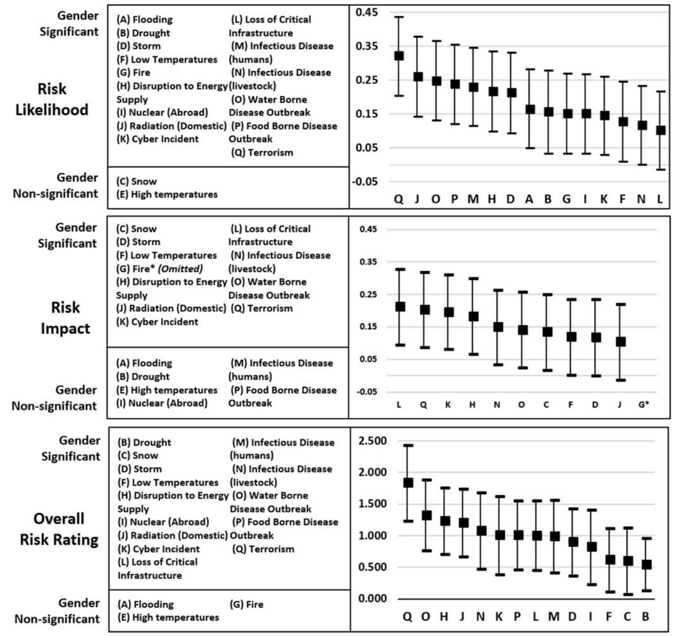

Fig. 2. Coefficients on Gender (Female) from Ordered Probit Analysis. Note: Gender coefficients values are provided on the vertical axis; coefficient significance is reported in Supplementary Table 6 and ranges between $p < 0.1$ & $p < 0.01$. "Fire G*" is omitted from "Risk Impact" due to the negative coefficient ($\beta = -0.115$).

risk impact ratings showed the relationship between females and the risk likelihood rating was positive and significant for 15 of the 17 risks. Only the likelihood ratings for snow and high temperatures presented as having a non-significant effect with gender. The gender coefficient was significant in fewer of the risk impact ratings, although significant differences remained for 11 of the 17 risks. In 10 of the 11 risks (excluding Fire – risk impact rating), the results showed the relationship between being female and assessment of risk impact was positive and significant. From these results, the conclusion can be drawn that gender has a significant effect on likelihood and impact ratings in Ireland and that the strength of the association varied by risk component.

An OLS regression was run for each of the 17 risks to examine the effect of gender on overall risk rating (i.e. likelihood multiplied by impact), and the results are also reported in Fig. 2 (overall risk rating). The gender (female) coefficient was positive and significant in 14 OLS regressions, showing that, when controlling for risk exposure, non-protective responses, household preparedness and sociodemographic factors (see Table 1) being female had a significantly positive influence on the respondents' overall risk ratings. The OLS gender (female) coefficients ranged between $\beta = 0.563$ (Drought) and $\beta = 1.856$ (Terrorism), with the largest gender differences observed for Terrorism, Disruption to Energy Supply, Waterborne Disease Outbreak, and Radiation (Domestic). The lowest significant gender differences were evident for Drought, Snow, and Low Temperatures with values of $\beta = 0.563$, $\beta = 0.618$, and $\beta = 0.636$, respectively. Furthermore, for this Irish sample, the Risk Ratings for Flooding, High Temperatures and Fire were found not to be significantly impacted by gender. The conclusion drawn from these results suggested the impact of gender on overall risk ratings fluctuates by risk highlighting the gender impact was not consistent when Table 1 factors are controlled.

Having established a variation in the impact of gender on risk ratings (overall risk, likelihood and impact), the subsequent analyses explored more deeply the components of risk: likelihood and impact ratings, using the marginal effect calculated from the ordered probit analysis in Supplementary Table 6 in the Appendix and Fig. 2.

Table 2 (part A and B) sets out the marginal effects of gender on perceived likelihood and impact of a risk, based on the ordered probit analysis. This table (part A and B) report the difference in the probability of a female as opposed to a male stating each response (on the risk likelihood or impact scale), having controlled for all other explanatory variables (Table 1) and evaluated at the mean values of these explanatory variables. The marginal effect calculations helped to quantify the gender differences in likelihood and impact assessments for each risk. In addition, the point estimates of the marginal effects showed, for each risk component, how the impact of gender varied by risk rating.

In line with the positive coefficient on 'female' reported in the ordered probit regressions, the associated marginal effects reflect a redistribution of probabilities away from stating lower levels of likelihood towards higher categories. Overall, the marginal effects in Table 2 (part A) show that for the statistically significant risks being female decreases the probability that the individual will state the risk likelihood rating is 'Extremely Unlikely'. For example, females were 10% points less likely than males to say Terrorism was 'Extremely Unlikely'; 8.4% points less likely to say Radiation (Domestic) was 'Extremely Unlikely'; and 5.6% points less likely to say Flooding was 'Extremely Unlikely'. Overall, Snow and High Temperature both resulted in non-significant estimates, suggesting no impact from gender when all other explanatory variables equal their mean score in the model. Of the statistically significant estimates, the risk likelihood rating for Loss of Critical Infrastructure was least affected by gender, with Terrorism presenting as being one of the risks most affected by gender.

Table 2 (part B) reported the difference in the predicted probability of each response for a female compared to a male, controlling for all other explanatory variables. In line with the results on 'female' reported in the ordered probit regressions, the results in Table 2 (part B) show considerable variation for the significance of gender on each of the 17 risk impact ratings. A total of six risk impact ratings were found not to be significantly affected by gender, which was the largest grouping of non-significant gender results in any of our analysis. This suggested the effect of gender on risk not only varied by risk, but also for each risk, there was a different effect on likelihood and impact ratings.

Overall, Table 2 (part B) showed that for all significant risks but one (Fire), the predicted probability of a female classifying the impact of a risk as 'High' and 'Very High' was larger than for a male respondent. In Table 2 (part B), the greatest gender differences were evident for Loss of Critical Infrastructure and Terrorism, where the probability of females perceiving these two risks as 'Very high' was 7 and 6.5% points more than for males. But, in the case of the risk impact rating for Fire, the pattern changed. For Fire, the marginal effect of being female was negative for 'Very high Impact' as opposed to positive. This was the only risk where this significant gender shift occurred and is in line with the significant negative coefficient on 'female' reported in the ordered probit regression for the impact rating of Fire. This suggested that males had a higher probability of rating the impact of Fire higher than females.

4. Discussion and conclusion

Against the backdrop of Article 6 of the European Union Civil Protection Mechanism [67], NRA guidelines provided vital direction on the risk assessment process for the Member States [1,2,21]. There was no reference, however, to ensuring gender representation within the NRA. The significance of this omission was difficult to determine at the outset of this study as less was known about how the impact of gender varied by risk within one country and, most specifically, regarding involuntary risks drawn from an NRA. Therefore, using 17 involuntary risks taken from the Irish NRA, this study tested the influence of gender on likelihood, impact and overall risk rating using a sample of 1977 respondents. Appropriate risk selection was vital to achieving our goal, especially as some previous studies had combined risk constructs, e.g. Flynn et al. [14] joined storms and floods. This methodology allowed us to reveal that gender had a broad and varied influence on risk rating and that the risk components, likelihood and impact, were affected differently across a variety of involuntary risks.

The first stage of the analysis compared the modal risk ratings for both genders with the 17 risks reported in the NRA ([27]). Knuth et al. [44] examined the alignment of perceived risk (likelihood) and

Table 2
Ordered probit analysis: Marginal effect of gender on likelihood (part A) and impact (part B).

		Extremely Unlikely	Very Unlikely	Unlikely	Likely	Very Likely
Gender: Likelihood (Part A)						
Natural Risks	Flooding	−5.6%***	−1%***	2.8%***	2.8%***	1%***
	Drought	−6.2%**	0.7%**	3.5%**	1.4%**	0.5%**
	Storm	−1.6%***	−2.3%***	−4.1%***	3.7%***	4.3%***
	Low Temperatures	−1.2%**	−1.7%**	−2.2%**	3.2%**	1.9%**
Technological Risks	Fire	−1.3%**	−2.3%**	−1.8%**	4%**	1.4%**
	Disruption to Energy Supply	−1.1%***	−2.6%***	−4.9%***	4.6%***	4%***
	Nuclear (Abroad)	−4.8%**	−1.3%**	2.5%**	2.8%**	0.8%**
	Radiation (Domestic)	−8.4%***	−2.0%***	6.0%***	3.5%***	0.9%***
	Cyber Incident	−2.6%**	−2.1%**	−1%**	3.6%**	2.1%**
Civil Risks	Loss of Critical Infrastructure	−1%*	−2%*	−0.7%*	2.7%*	1%*
	Infectious Disease (humans)	−4%***	−3.8%***	−0.3%	6%***	2.1%***
	Infectious Disease (livestock)	−3.1%**	−1.4%**	0.3%	3.1%**	0.9%**
	Water Borne Disease Outbreak	−4.7%***	−4.3%***	1.7%***	5.7%***	1.6%***
	Food Borne Disease Outbreak	−3.8%***	−4.5%***	1.1%***	6%***	1.2%***
	Terrorism	−10.0%***	−2.7%***	4.6%***	6.2%***	2.0%***
Gender: Impact (Part B)						
		Very low Impact	Low Impact	Moderate Impact	High Impact	Very high Impact
Natural Risks	Snow	−1.3%**	−2.9%**	−0.8%**	3.4%**	1.6%**
	Storm	−0.6%*	−2.4%**	−1.7%**	3.1%**	1.6%**
	Low Temperatures	−1.5%**	−3.1%**	1%*	2.9%**	0.7%**
Technological Risks	Fire	0.4*	0.9*	1.5*	1.8*	−4.6*
	Disruption to Energy Supply	−1.1%***	−3.4%***	−3%***	3.5%***	4%***
	Radiation (Domestic)	−1.6%*	−1.7%*	−0.9%*	0.7%*	3.6%*
	Cyber Incident	−2.9%***	−3.6%***	−1.3%***	3.5%***	4.3%***
Civil Risks	Loss of Critical Infrastructure	−1.5%***	−2.5%***	−3.8%***	0.8%**	7%***
	Infectious Disease (livestock)	−3.4%***	−2.3%***	−0.1%	2.5%***	3.3%***
	Water Borne Disease Outbreak	−1.5%**	−2%**	−2%**	1.1%**	4.5%**
	Terrorism	−3.7%***	−2.9%***	−1.6%***	1.7***	6.5%***

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Non-significant variables removed.

objective risk (likelihood) for five involuntary risks (terrorism, traffic accidents, flood, domestic fire, public fire) among members of the general population, some of whom had experiences of an emergency. The results of their study indicated "an impact of gender as well as emergency experience on the accuracy of risk perception" [44]; p.592). They found that "although men and women with no emergency experiences underestimated their specific objective risks for fire and traffic accidents, women were much closer to their objective risks than were men … This trend was also found in the general-s [group of general survivors] sample. Men underestimated both risks whereas women estimated both risks correctly." [44]; p.592). Although the methodologies between the two studies are not directly comparable, the NRA outputs can be viewed as an expert opinion against which the risk ratings by females and males can be compared. The results in Fig. 1 confirm the Knuth et al. ([44], p.596) finding that "it should not be assumed that men and women will always perceive their risk differently to either objective estimations of the risk or to each other".

For clarity, the regression results from stage two of the analysis are summarised in a Venn diagram (Fig. 3) showing the significance of gender on likelihood, impact and overall risk rating.

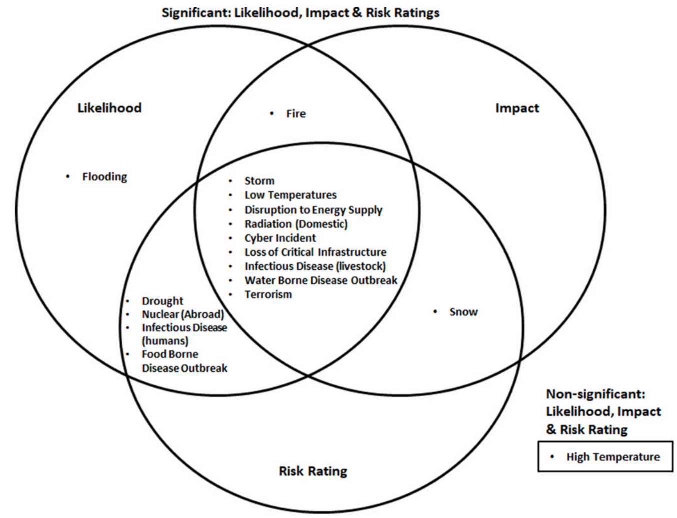

Fig. 3. Venn diagram outlining the significance of gender on each component of risk.

In summary, the results of the regressions indicated that gender was significant across many of the 17 involuntary risks, with the coefficient on gender significant in a total of 40 of the 51 regressions (which controlled for the other factors in Table 1). More specifically, the analysis showed that gender was significant for 15 likelihood risk ratings; 10 impact risk ratings; and 14 overall risk ratings. These results indicated higher risk ratings for females rather than males. All other results were insignificant apart from the fire impact rating, which males rated higher than females. Generally, these results supported previous studies that had included involuntary risks within the analysis (see Refs. [5,9,10,14,36–39]). These results also contradicted studies that had shown no significant relationship between gender and risk rating (see Refs. [40–43]). Most importantly, as previously discussed, these prior studies were typically unsuitable for comparison due to small differences in research design, variations in control variables included, and the coding of some involuntary risks (e.g. combining involuntary risks into one construct, such as 'natural disasters'). Hence, selecting natural, technological and civil risks from the Irish NRA allowed us to explore subtle differences in the risk ratings across the Irish sample.

These findings supported the earlier premise that gender had a varying influence on likelihood and impact ratings for the set of involuntary risks. For example, the results showed the likelihood rating for Infectious Disease (affecting humans) was impacted by gender; yet the impact rating was not. Where significant differences were found, the predicted probabilities of a female, compared to a male, classifying the risk likelihood as 'Likely' and 'Very Likely' ranged from 1.9% points higher for Drought to 8.2% points higher for Terrorism. Similarly, the probabilities that females would rank risks as having 'High Impact' and Very High Impact' ranged from 3.6% points higher for Low Temperatures, to 8.2% points higher for Terrorism, compared to males.

In Ireland, participants of the focus groups first assessed likelihood and then impact for each risk. By examining the marginal effects for both the likelihood and the impact ratings, this study showed that Terrorism, Cyber Incident, Water Borne Disease Outbreak, Storm, Disruption to Energy Supply, and Loss of Critical Infrastructure had the greatest potential exposure to different outputs in the absence of gender representation. These empirical findings suggested that a failure to ensure gender representation within the NRA focus groups has the potential to impact the assessment of certain risks more negatively than others.

Emergencies have also been shown to affect females and males differently [68], and this difference could affect risk rating; further justification for gender representation within the NRA focus groups. Focus groups collect rich data from participants' discussions and interactions [69,70]. In a risk assessment context, diversity, including gender representation, should help ensure a platform where different viewpoints on risk can be discussed. Gender diversity should lessen the chances of under or overestimation of risk. We recommend countries use diverse multi-stakeholder focus groups. To ensure gender representation, stakeholders should be encouraged to send both male and female experts, and data on the composition of the focus groups should be reported within the NRA documents. In line with the EU Joint Research Centre recommendation [21], an input from the general public is also proposed as it presents an opportunity to include a more diverse range of opinions within the NRA. This recommendation has been adopted by the Irish Government, and public risk assessments form part of the NRA [71] methodology.

Future research could test the impact of diverse focus groups on the output from NRAs. Due to pan-national variance, this study cannot be used to identify the risks impacted by gender outside of Ireland (see Refs. [13,31]). The methods of this study are, however, repeatable, and it would be instructive to replicate the study in other countries to build a complete picture across member states and to inform EU guidance on the completion of NRAs.

This study extends previous NRA studies by examining the impact of gender on the rating of involuntary risks, as well as the fluctuation of this impact across risks. The findings demonstrate that while the general idea that risk is judged as higher by women than by men is sound, there is variation within these 17 involuntary risks. The findings underline the importance of gaining a more nuanced view of the impact of gender on risk rating at a national level and the need to consider how gender-biased multi-stakeholder focus groups could impact the reliability of NRA outputs.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2021.102452.

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