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Risk Perception of Nuclear Energy After Fukushima: Stability and Change in Public Opinion in Switzerland

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Abstract

The accident at Fukushima Daiichi Nuclear Power Plant in 2011 greatly affected attitudes toward nuclear energy in many countries, including Switzerland. In this study, we analyzed the evolution of public opinion about nuclear energy in Switzerland from 2012 to 2014 to determine how different dimensions of attitudes toward nuclear energy changed in the years following the accident and which factors influenced general opinion about nuclear energy. The primary findings show that public opinion about nuclear energy became only slightly more positive as time passed and that the most important predictor of the general opinion about nuclear energy was the individual assessment of its benefits and risk.

Switzerland is one of the 30 countries that currently operate nuclear power plants. In fact, the five nuclear energy reactors in the four Swiss nuclear power plants account for 38% of Switzerland's domestic electricity generation (International Atomic Energy Agency, 2015). Although nuclear energy has several benefits, including generally low greenhouse gas output (Brook & Bradshaw, 2015; Vaillancourt, Labriet, Loulou, & Waaub, 2008), nuclear energy production also inevitably involves risks, as demonstrated by the accident at Japan's Fukushima Daiichi Nuclear Power Plant on March 11, 2011.

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After the plant was struck by a tsunami caused by a seaquake, four of its six reactors experienced a core meltdown (World Nuclear Association, 2015), thereby casting new light on the risk of nuclear energy production and causing public belief in the security of nuclear technology to falter (Holmberg, 2011; Newport, 2012; Prati & Zani, 2012; Turcanu, Perko, & Schröder, 2011; Visschers & Siegrist, 2013). In the wake of the accident, debates in many countries addressed whether the benefits of nuclear energy were worth the damage it could cause, and as a result, three countries—Belgium, Germany, and Switzerland—decided to phase out nuclear energy. However, in one or more popular referenda possible in the future, Swiss citizens could be involved in future decisions regarding the extent to which Switzerland eradicates nuclear power.

During 2003–2010, the general attitude of Swiss citizens toward nuclear energy was more or less stable. The so-called Angstbarometer, a yearly survey of roughly 700 Swiss citizens, indicates how much the Swiss public worries about radioactive contamination on a 10-point scale (1 = *Not worried*, 10 = *Highly worried*), and from 2003 to 2010, the mean response was 4.9–5.3 (GfS-Zürich, 2012). In 2008, a political debate over investments in new nuclear energy plants began when three nuclear energy plant operators—namely, Atel (currently Alpiq), BKW, and Axpo—applied for construction permits. In February 2011, a regional referendum in the canton of Berne showed that the small majority of the population there favored nuclear energy, as 51.2% voted for the construction of a new plant to replace the existing one.[1] Following the severe nuclear accident at Fukushima, however, that climate of opinion changed. The Angstbarometer showed a rise from 5.1 in 2010 to 5.7 in 2011 (GfS-Zürich, 2012), suggesting that the accident at Fukushima triggered the reconsideration of nuclear energy in general and discussions of whether its benefits truly justify its risks.

Of course, such reconsideration of nuclear energy and its risks attracted heavy coverage in media, both in Switzerland and around the world. As one study has shown, following the accident, two important Swiss quality national newspapers shifted from using a generally neutral to a rather negative tone in coverage that overwhelmingly focused more on the detriments of nuclear energy than their benefits (Kristiansen, forthcoming). Combined with a change in the valence of coverage, such heavy attention to nuclear energy created a context in which initial political decisions for a stepwise phasing out of nuclear energy in Switzerland made clear sense from the perspective of political actors involved. However, less than a year after the accident, media coverage entered into a reconsideration phase of the risks of nuclear power. As attention to nuclear energy's potential detriments remained high, coverage of

[1] Cantons are federal entities in Switzerland similar to U.S. states.

nuclear energy's benefits revived and even reached levels similar to those before the accident.

Today, the general change observed in the climate of opinion and in media coverage in Switzerland following the accident at Fukushima remains incompletely understood. Although Visschers and Siegrist (2013) have shown that trust greatly affected perceived risks and benefits of nuclear energy directly before and following the accident and, in turn, influenced public acceptance of nuclear power stations, that study addressed only short-term effects immediately after the accident. As such, an important gap in the research remains, for neither the dynamics of public opinion about nuclear energy nor factors that influence that opinion have been analyzed regarding the years after the accident at Fukushima. Consequently, though researchers have a fairly strong idea of what happened to public opinion about nuclear energy immediately after the accident, they know far less about what happened to it in the years following the event. This study addresses that gap.

Risk Perception and Public Opinion

Theoretical and empirical research that has addressed the perception of risks and formation of opinion regarding technologies such as nuclear energy (Siegrist, 2000), biotechnology (Bauer & Gaskell, 2002; Sjöberg, 2004), and nanotechnology (Cacciatore et al., 2011; Ho, Scheufele, & Corley, 2011) is plentiful. From a technical point of view, the definition of *risk* is straightforward: It is the product of the magnitude of potential damage and the probability of its occurrence. However, people rarely perceive and process the concept of risk in that way. In response, newer theoretical perspectives, including the social amplification of risk framework (Kasperson et al., 1988; Pidgeon, Kasperson, & Slovic, 2003; Renn, Burns, Kasperson, Kasperson, & Slovic, 1992; Slovic, 1987), conceptualize the perception and acceptance of risk as a complex process influenced not only by the objective nature of a risky technology such as nuclear energy or a risk event such as the nuclear disaster at Fukushima, but also by various underlying social and psychological factors of individuals in interaction with communication processes.

Sociodemographics

The perception and acceptance of technology-related risks vary according to underlying sociodemographic characteristics of a population or country (Eurobarometer, 2010). Men, younger people, and better-educated people perceive biotechnology and nuclear energy to be less risky than do women, older people, and less educated people. However, underlying psychological and social factors mediate and thus inform those differences. For example, education relates to and is a prerequisite of knowledge and information acquisition via media about science and technology.

Fundamental Values and Lifestyles

Values and lifestyle—for instance, postmaterialism and the appreciation of nature—usually correlate with higher risk perceptions and more negative attitudes toward biotechnology and nuclear energy, whereas an affinity for science and technology correlates with lower levels of risk perception and more positive attitudes (Whitfield, Rosa, Dan, & Dietz, 2009).

Preexisting Attitudes

Albeit mediated by trust in scientists and experts, attitudes for or against a specific technology or science and technology in general influence the risk perception and acceptance of specific technologies. As Brossard and Nisbet (2007, p. 24) have pointed out, "deference to scientific authority," especially among less informed publics, seems to be "a central value predisposition shaping support for agricultural biotechnology." Moreover, as Yeo et al. (2014) have concluded, ideological groups responded differently to the disaster at Fukushima and according to their party identifications. For instance, risk perceptions among conservatives decreased following the accident.

Benefits Versus Costs

From a perspective prioritizing rational choice, underlying values and preexisting attitudes regarding nuclear energy usually relate to the importance that an individual ascribes to, for example, low-priced, reliable, and clean energy sources. As a consequence, the perceived costs and benefits of nuclear energy act as mediating factors of risk perception and acceptance. People who associate low costs and high benefits with nuclear energy are more willing to accept the risks of nuclear energy. As Visschers and Siegrist (2013, p. 333) have posited, even a nuclear accident such as the one at Fukushima would not affect the basic relationship between perceived benefits and costs, for "the nuclear accident did not seem to have changed the relations between the determinants of acceptance." Accordingly, people would continue to consider the benefits of nuclear energy to be relevant and trust nuclear power stations, even after a severe event such as Fukushima.

Affect and Cognitive Shortcuts

Newer approaches to risk perception emphasize that risk processing and decision-making not only constitute a cognitive process, but also change owing to affect-inducing risk communication (Sjöberg, 2006b; Slovic, Finuncane, Peters, & McGregor, 2004; Visschers et al., 2012). Guided by a so-called media logic, media coverage of technology-related accidents and disasters increasingly emphasizes more personalized, dramatized, and emotionalized stories of events. Consequently, the emotional cues presented in media narratives evoke fear and elicit cognitive heuristics instead of rational decision-making (Petty, Briñol, & Priester, 2009; Scheufele, 2006).

Media Information and Communication

Media information (Sjöberg, 2006a) and interpersonal risk communication (Binder, Scheufele, Brossard, & Gunther, 2011) influence risk perception, and likewise, media coverage of new technologies usually varies in intensity and appraisal. For a long time, biotechnology was only a marginal issue in European media, and the framing of its media coverage was primarily positive and emphasized scientific progress and economic benefits (Bauer & Gaskell, 2002). However, incidents such as the cloning of the sheep Dolly and subsequent public protests by nongovernmental organizations intensified coverage and redirected its framing away from benefits and toward risks. Similarly, media discourse about nuclear energy shifted from frames highlighting positive progress to those emphasizing negative runaway and public accountability (Gamson & Modigliani, 1989).

In the case of nuclear energy, the accident at Three Mile Island in 1979 (Cunningham, 1986; Nimmo & Combs, 1982) and the catastrophes at Chernobyl in 1986 (Friedman, Gorney, & Egolf, 1987; Rubin, 1987) and Fukushima in 2011 dramatically increased media coverage of the risks of nuclear energy production (Desai, 2012; Friedman, 2011; Hoetzlein, 2012; Ionescu, 2012; Katchanovski, 2012; Kristiansen & Bonfadelli, 2014; Kubota, 2012; Perko, Turcanu, Geenen, Mamane, & van Rooy, 2011). Those major events have also triggered heated follow-up discussions in media and on social media platforms at the interpersonal level (Utz, Schultz, & Glocka, 2012), particularly regarding the safety and risks of nuclear energy. Assumably, the accident at Fukushima, its coverage, and public discussions about it precipitated a political debate that, in Germany and Switzerland, prompted decisions to abandon nuclear energy production in the future.

Societal, Political, and Cultural Context

The sociopolitical context of nuclear energy varies from country to country (Eurobarometer, 2010). Some countries depend heavily on nuclear energy, either for producing energy directly or in terms of their often export-oriented nuclear energy industries. Although any nuclear accident will influence risk perceptions and public attitudes toward nuclear power not only in the country of the accident, the effects might be weaker in countries that depend more heavily on nuclear energy (Kubota, 2012).

From Risk Perception to Opinion Formation

Assumed theoretically and demonstrated empirically, risk perception translates into both risk acceptance and attitudes for or against a technology such as nuclear energy. In times of low or stable media coverage, the perception of a risky technology usually correlates strongly with an attitude in favor or against the technology. However, in the case of nuclear energy, an accident or catastrophe in tandem with intensive media coverage will influence both the risk perception and preexisting attitudes. Accordingly, most surveys in the aftermath of the accident at Fukushima detected a sharp rise in the perceived risk and far lower positive attitudes toward nuclear energy than before (Holmberg, 2011; Newport, 2012; Turcanu, Perko, & Schröder, 2011; Visschers & Siegrist, 2013), which held true for Switzerland as well (GfS-Zürich, 2012).

After the catastrophe at Chernobyl, the influence of media coverage as risk communication was clear. As Renn (1990, p. 151) summarized it, the event's effect on public opinion was "the more dramatic and enduring, the more a country was affected by the fallout and the higher the percentage of indifferent positions toward nuclear power was prior to the accident." In the context of the accident at Fukushima, Siegrist and Visschers (2013, p. 114) have proposed the term *Fukushima effect*; for them, previous research has demonstrated highly stable positive attitudes toward nuclear energy since the 1980s, mostly owing to the rising price of oil, increased concerns about climate change, and a lack of convenient alternatives. Although nuclear accidents have usually increased public opposition toward nuclear power directly afterward, typically caused by the affect heuristic, public opinion also typically becomes more positive in the United States and Europe later on (Mazur, 1981).

However, this general prediction differs according to both favorable versus unfavorable attitudes toward nuclear energy before the events and the strength of those attitudes (Eaton, Majka, & Visser, 2008). Whereas strong attitudes seem to be persistent over time as well as resistant to change, powerful key events such as nuclear catastrophes can prompt enduring attitudinal changes. For example, based on their empirical study in Italy, Prati and Zani (2012) have concluded that major nuclear accidents can influence values and pro-environmental beliefs in the long term as a basis of future public attitudes toward nuclear power.

Research Questions, Data, and Methods

In this study, we focused on opinion formation toward nuclear energy in Switzerland in the context following the accident at Fukushima and aimed to answer two research questions:

> *RQ1*: How did general opinion on nuclear energy and the risk perception of nuclear energy change in the years following the accident at Fukushima?
> *RQ2*: How strong was the influence of sociodemographics, risk perceptions, and media use on the general opinion about nuclear energy?

To answer those questions, we here present results from three surveys conducted in Switzerland in 2012, 2013 and 2014.

The main variable of interest in this study is the general attitude towards nuclear energy, assessed with answers on a 4-point scale (1 = *In favor*, 2 = *Mostly in favor*, 3 = *Mostly against*, 4 = Against). Furthermore, based on the literature review, we include a set of additional variables related to different dimensions of risk perception, sociodemographic characteristics, and media use. They included the following: (1) sociodemographic characteristics such as age, sex, and education; (2) language region (German or French speaking) and canton (i.e., whether a respondent lives in a canton where one or more nuclear power plants are in operation) as indicators of perceived proximity of hazard; (3) the use of media (i.e., frequency of newspaper, radio, television, and Internet use) on a 5-point scale (1 = *Daily*, 5 = *Never*); and (4) a personal assessment of the benefits versus the risks of nuclear energy, as assessed by answers to the question "Do you think that the benefits of nuclear energy justify the risks?" on a 5-point scale (1 = *Not at all*, 5 = *Very much*), opinions on the safety of nuclear power plants in Switzerland, as assessed by answers to the question "How safe do you perceive Swiss nuclear power plants to be?" on a 5-point scale (1 = *Not safe at all*, 5 = *Very safe*), and perceptions of the possibility of a nuclear accident in Switzerland, as assessed by answers to the question "Do you worry about the possibility of a nuclear accident in Switzerland?" on a 5-point scale (1 = *Not at all*, 5 = *Very much*).

In the three surveys conducted in Switzerland in 2012, 2013, and 2014, we assessed Swiss citizens' general opinion about nuclear energy and the three dimensions of risk perception regarding it.[2] All three surveys were computer-assisted telephone interviews administered by Demoscope and GfS-Zürich.

The first survey conducted in 2012, a year after the accident at Fukushima, during March 6–24 in all three language regions of Switzerland

[2]Our study is representative of German- and French-speaking parts of Switzerland. For pragmatic reasons, not all surveys included all language regions, and we therefore omitted some regions from the study (i.e., the Italian-speaking part), while the Romansh-speaking region, owing to its bilingual nature, arguably finds a voice in the German-speaking sample.

(i.e., the German-, French-, and Italian-speaking part). However, we have excluded results from the Italian-speaking part, which accounts for roughly 4% of Switzerland's population, because the surveys conducted in 2013 and 2014 excluded it. The sample size for the 2012 survey was 657 participants. The second survey conducted in 2013, at approximately the second anniversary of the Fukushima accident, during March 4–22, with 1,013 participants, whereas the third survey took place during May 19–June 10, 2014 and encompassed exactly 1,000 participants. The number of survey items varied by year. Table 1 summarizes variables available for each survey.

As Table 2 shows, the sample of respondents for all three surveys had a nearly equal distribution of sexes, an age average of about 50 years, and a more or less similar educational distribution. As such, the three surveys are comparable.

We performed data analysis in two steps. In this article, we present the descriptive results of the three surveys, which address RQ1, and discuss changes that occurred over time. In the process, we compare changes in variables directly related to attitudes on nuclear energy.

Second, in response to RQ2, we estimated linear regression models for each survey year. Our general analytical model appears in Figure 1. The response variable for each model is the general opinion on nuclear energy, whereas the set of predictor variables varies for each year, as Table 1 shows. In our modeling approach, we primarily focus not on whether the predictor variables exert a statistically significant influence on the response variable, but which possible model combination is most likely to correspond to reality in terms of model fit given the data. During model selection, however, instead of manually including or excluding predictor variables according to their statistical significance to choose the best model, we resorted to selection according to the Bayesian Information Criterion (BIC) per Schwarz (1978). Although model selection via information-theoretic criteria is a nonstandard procedure in the social sciences, the advantages of the approach over more conventional selection methods are clear (Burnham & Anderson, 2002). We opted for the BIC instead of other information criteria, including the Akaike Information Criterion (Akaike, 1974), because the BIC puts greater emphasis on the parsimony of models insofar as it penalizes the introduction of additional parameters (Burnham & Anderson, 2004). Such parsimony translates into higher consistency in the model selection process (Kuha, 2004).

We performed model selection within the *R* statistical environment with the "leaps" package (Lumley & Miller, 2009) by comparing all model subsets (i.e., all combinations of predictor variables). Given the varying number of available predictor variables per year, there were 32,768 models for 2012, 128 models for 2013, and 16,384 models for 2014.

Table 1
Overview of the Variables Available Per Survey Year

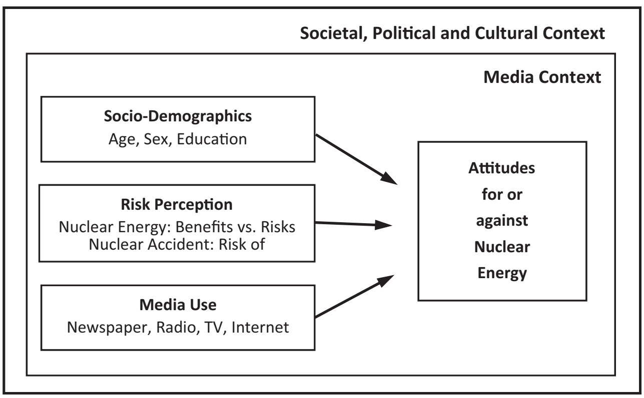
2012	2013	2014
General opinion on nuclear energy	General opinion on nuclear energy	General opinion on nuclear energy
Risk perception benefit vs. risk	Risk perception benefit vs. risk	Risk perception benefit vs. risk
Risk perception accident in CH	–	Risk perception accident in CH
Risk perception safety CH	Risk perception safety CH	–
Age	Age	Age
Sex	Sex	Sex
Education level	Education level	Education level
Operator canton	Operator canton	Operator canton
Language region	Language region	Language region
Public service TV	–	Public service TV
Public service radio	–	Public service radio
Newspaper	–	Newspaper
Local TV	–	Local TV
Local radio	–	Local radio
Internet	–	Internet
Foreign TV	–	Foreign TV

Table 2
Structure of the Samples

Sample descriptive variables Variable		2012 $n = 657$	2013 $n = 1013$	2014 $n = 1000$
Female		327 (49.8%)	512 (50.5%)	520 (52%)
Age		$M = 48.9$ ($SD = 17.4$)	$M = 49.1$ ($SD = 17.5$)	$M = 47.7$ ($SD = 19.1$)
Education[a]	1	49 (8%)	119 (12%)	186 (19%)
	2	300 (46%)	437 (43%)	370 (37%)
	3	116 (18%)	190 (19%)	151 (15%)
	4	92 (14%)	93 (9%)	157 (16%)
	5	98 (15%)	172 (17%)	134 (13%)

Note. [a]Which education did you complete most recent? 1 = *No finished education or only obligatory school education etc.*; 2 = *Vocational training and obligatory school to vocation training*; 3 = *College education (gymnasium) higher vocational education*; 4 = *Applied university education*; 5 = *University*.

Figure 1
Analytical model



Descriptive Results: How Opinions and Risk Perceptions Changed

Table 3 displays the general attitude toward nuclear energy and the three dimensions of risk perception in the 2012, 2013, and 2014 surveys.

The general opinion on nuclear energy in Switzerland during these years suggests that Swiss citizens are typically against nuclear energy. In 2012 and 2013, the mean was 2.9 on a 4-point scale (1 = *In favor of nuclear energy*, 4 = *Against nuclear energy*), while in 2014, the mean changed to 2.8, which constituted a significant change ($p = .016$) compared with the mean in 2013.[3]

[3]We calculated and compared mean values with one-way analysis of variance (ANOVA) and Tukey's post hoc test.

This result indicates that the Swiss were less critical of nuclear energy in 2014 than in 2013.

The other three variables reported in Table 3 measured the three dimensions of risk perception. The first gauged whether people consider that the benefits of nuclear energy justify the risks. As Table 3 shows, the Swiss population disagreed with that statement in all years surveyed, but only slightly. The only significant (p = .001) difference occurred between the means of 2013 (M = 2.6) and 2014 (M = 2.8); in 2014, more people responded that the benefits of nuclear energy could justify the risks. That result could indicate that, as time passed, the impact of the accident at Fukushima on risk perception faded, an interpretation supported by the other two dimensions of risk perception. In 2014, respondents worried less about an accident at a Swiss nuclear power plant (M = 2.6) than they did in 2012 (M = 2.7). Furthermore, respondents considered the safety of Swiss nuclear power plants to be greater in 2013 (M = 3.4) than in 2012 (M = 3.3). However, those differences were not statistically significant.

Although not all differences among years are sizeable enough to be statistically significant, a picture of the development of attitudes toward nuclear energy is clear: as time passed after the accident at Fukushima, the more favorably the Swiss viewed nuclear energy. However, that change in attitude was modest.

Estimation Results: Explaining the General Opinion About Nuclear Energy Model Selection Results for the 2012 Survey

Table 4 shows parameter estimates for the best-fitting model for 2012 survey data with the general opinion about nuclear energy as the response variable.

The linear model in Table 4 explains 39.9% of variance (adjusted R^2 = 0.399) in the general public opinion about nuclear energy. Of all initial predictor variables, only three remained in the best model: respondents' assessment of the benefits versus the risks of nuclear energy, the perception of the safety of Swiss nuclear power plants, and the use of local television channels. Those three variables significantly influenced respondents' opinions.

Estimates show that respondents more likely to deem the benefits of nuclear energy to not justify its risks were more likely to also be against nuclear energy ($B = -0.277$, SE = 0 .025, $p < .001$). In a similar vein, respondents who worried about the safety of Swiss nuclear power plants were also more likely to be against nuclear energy ($B = -0.200$, SE = 0.033, $p < .001$), although that effect was more than a quarter weaker than the effect of the risks-versus-benefits assessment.

The fact that two of the three parameters in the best model for 2012 pertained to risk perception raises the question of collinearity. However, with variance inflation factors of 1.23 for the benefits-versus-risks variable

Table 3
Public Opinion and Risk Perception Variables for 2012, 2013, and 2014

Risk perception and public opinion on nuclear energy Variable	2012 $n = 657$	2013 $n = 1{,}013$	2014 $n = 1{,}000$
Opinion on nuclear energy[a]	2.9 (0.9, −0.364, 2.366)	2.9 (0.9, −0.461, 2.341)	2.8 (0.9, −0.309, 2.349)
Risk perception benefit vs. risk[b]	2.7 (1.3, 0.193, 1.994)	2.6 (1.3, 0.256, 1.963)	2.8 (1.3, 0.201, 1.991)
Risk perception accident in CH[c]	2.7 (1.2, 0.215, 2.161)	–	2.6 (1.3, 0.312, 2.027)
Risk perception safety CH[d]	3.3 (1.0, −0.321, 2.580)	3.4 (1.1, −0.456, 2.470)	–

Note. The reported numbers have the following meaning: mean (standard deviation, skewness, kurtosis).
– This question was not asked in that survey.
[a]What is your opinion on nuclear energy? 1 = *In favor*, 2 = *Mostly in favor*, 3 = *Mostly against*, 4 = *Against*.
[b]Do you think the benefits of nuclear energy justify the risk? 1 = *Not at all*, 5 = *Yes, very much so*.
[c]Do you worry about the possibility of a nuclear accident in Switzerland? 1 = *Not at all*, 5 = *Very much*.
[d]How safe do you perceive Swiss nuclear power plants to be? 1 = *Not safe at all*, 5 = *Very safe*.

Table 4
Model Selection Result for the 2012 Survey

Predictor	Estimate	*SE*	*p*	Partial eta-squared	Cohen's f-squared
Age					
Sex					
Education					
Nuclear canton					
Language region					
Risk perception benefit vs. risk[a]	−0.277	0.025	.000	0.205	0.258
Risk perception safety CH[b]	−0.200	0.033	.000	0.096	0.106
Risk perception accident CH					
Public service TV CH					
Public service radio CH					
Internet					
Foreign TV					
Newspaper					
Local TV CH[c]	−0.046	0.021	.027	0.020	0.020
Local radio CH					

Note. Only those parameters where numbers are reported are part of the best fitting model selected by the BIC. Partial eta-squared and Cohen's f-squared (Cohen, 1988) indicate the individual effect size of the given parameter.
Response variable: Nuclear opinion pro/contra; R^2 = 0.415; Adjusted R^2 = 0.399.
Response variable: What is your opinion on nuclear energy? 1 = *In favor*, 2 = *Mostly in favor*, 3 = *Mostly against*, 4 = *Against*.
[a]Do you think the benefits of nuclear energy justify the risk? 1 = *Not at all*, 5 = *Yes, very much so*.
[b]How safe do you perceive Swiss nuclear power plants to be? 1 = *Not safe at all*, 5 = *Very safe*.
[c]How often do you use Swiss local TV? 1 = *Daily*, 2 = *Several times*, 3 = *Once a week*, 4 = *Rarely*, 5 = *Never*.

and of 1.21 for the safety perception of Swiss nuclear power plants, collinearity probably posed no dilemma. An additional analysis of the condition indices (Belsley, Kuh, & Welsch, 2005) performed with the "perturb" *R* package (Hendrickx, 2012) corroborated that finding; the highest condition index was 9.82, which is below the threshold of 30, which would suggest collinearity. However, though the highest condition index was fairly low, the variance decomposition proportions for the two variables were >0.5. If the corresponding condition index was not 9.82 but some value >30 instead, that would suggest probable collinearity.

The third model parameter with an impact was local television use. In short, the more often respondents reported watching local television stations, the more likely they were to be against nuclear energy ($B = -0.046$, $SE = 0.021$, $p = .027$). Albeit small, the effect is notable, for it was the only media use variable that remained in the best model for the 2012 survey.

Interestingly, the level of worry about an accident at a Swiss nuclear power plant did not contribute to the best model for 2012. Furthermore, classic sociodemographic variables such as age, sex, and education did not contribute enough to justify inclusion in the best model for 2012. Geographical variables also fell by the wayside during model selection. That is, living in a canton with a nuclear power plant in operation did not contribute to a meaningful model, nor did the differentiation between the German- and French-speaking parts of Switzerland.

Model Selection Result for the 2013 Survey

The 2013 survey did not ask any media use questions and excluded the question of whether respondents worried about an accident at a Swiss nuclear plant. Table 5 reports parameter estimates for the best-fitting model for the 2013 data with the general opinion on nuclear energy as the response variable.

The linear model in Table 5 explained 44.6% of the variance (adjusted $R^2 = 0.446$). For the 2013 survey, significant predictor variables were respondents' age, perception of benefits versus risks, and safety perception of Swiss nuclear energy plants. As for the 2012 model, the presence of two risk perception variables in the best-fitting model raises concerns regarding collinearity. However, with variance inflation factors of 1.30 for the risks-versus-benefits variable and 1.30 for the perception of safety of Swiss nuclear power plants, collinearity again likely posed no dilemma. The highest condition index for the variables in the 2013 model was 9.79, which supports the notion that collinearity was not an issue.

Table 5
Model Selection Result for the 2013 Survey

Predictor	Estimate	*SE*	*p*	Partial eta-squared	Cohen's f-squared
Age	0.004	0.001	.001	0.012	0.012
Sex					
Education					
Nuclear canton					
Language region					
Risk perception benefit vs. risk[a]	−0.359	0.020	.000	0.270	0.370
Risk perception safety CH[b]	−0.195	0.022	.000	0.079	0.086

Note. Only those parameters where numbers are reported are part of the best fitting model selected by the BIC. Partial eta-squared and Cohen's f-squared (Cohen, 1988) indicate the individual effect size of the given parameter.

Response variable: Nuclear opinion pro/contra; $R^2 = 0.451$; Adjusted $R^2 = 0.446$.

Response variable: What is your opinion on nuclear energy? 1 = *In favor*, 2 = *Mostly in favor*, 3 = *Mostly against*, 4 = *Against*.

[a]Do you think the benefits of nuclear energy justify the risk? 1 = *Not at all*, 5 = *Yes, very much so*.

[b]How safe do you perceive Swiss nuclear power plants to be? 1 = *Not safe at all*, 5 = *Very safe*.

The estimate for age means that the older a respondent was, the more likely he or she was to favor nuclear energy ($B = 0.004$, $SE = 0.001$, $p = .001$). Respondents more likely to not think that the benefits of nuclear energy justify its risks were more likely to be against nuclear energy ($B = -0.359$, $SE = 0.020$, $p < .001$), as in the 2012 survey. However, compared with the best-fitting model for 2012, in the best model for 2013, the effect of the benefits-versus-risks parameter was much stronger. Another similarity with the 2012 survey was the safety perception of Swiss nuclear power plants; the more someone worried about the safety of those plants ($B = -0.195$, $SE = 0.022$, $p < .001$), the more likely he or she was against nuclear energy in general. The effect was highly similar in size to the effect for the 2012 model. In contrast to the best model for the 2012 survey, age had significant impact in the 2013 model. However, it was the sole sociodemographic variable to have an impact because sex and education, along with the two geographical variables, did not contribute to the best-fitting model.

Model Selection Result for the 2014 Survey

For model selection for the 2014 survey, we once again included variables on media use, as we did for 2012 data. However, the 2014 survey omitted the question of whether respondents felt that Swiss nuclear reactors were safe. Model selection for 2014 data thus occurred with one less variable than for 2012 data. Table 6 reports parameter estimates for the best-fitting model for 2014 data with the general opinion on nuclear energy as the response variable.

The linear model in Table 6 explained 40.8% of the variance (adjusted $R^2 = 0.408$). In the 2014 survey, significant predictor variables were respondents' assessment of the benefits versus the risks of nuclear energy ($B = -0.268$, $SE = 0.019$, $p < .001$), their level of worry about an accident at a Swiss nuclear power plant ($B = 0.243$, $SE = 0.019$, $p < .001$), and, once again, the use of local television channels ($B = -0.066$, $SE = 0.017$, $p < .001$). In a pattern similar to the results for the 2012 and 2013 surveys, two of the three predictor variables in the best model for the 2014 survey pertained to risk perception. As with the 2012 and 2013 models, collinearity was likely not an issue. Variance inflation factors for the assessment of risks versus benefits and for worry about an accident at a Swiss nuclear power plant were both 1.08. Additionally, the highest condition index was 12.64, which was slightly greater than for the 2012 and 2013 models, yet still low enough to suggest that collinearity likely posed no problem.

One sociodemographic variable that was part of the best model for the 2014 survey was not present in the 2012 and 2013 models: sex. In short, women were slightly more likely to be against nuclear energy than men in the 2014 survey.

The estimate of the assessment of risks versus benefits of nuclear energy once again showed that respondents were more likely to be against nuclear

Table 6
Model Selection Result for the 2014 Survey

Predictor	Estimate	*SE*	*p*	Partial eta-squared	Cohen's f-squared
Age					
Sex	0.16	0.05	.000	0.014	0.014
Education					
Nuclear canton					
Language region					
Risk perception benefit vs. risk[a]	−0.271	0.018	.000	0.204	0.257
Risk perception accident CH[b]	0.247	0.019	.000	0.171	0.206
Public service TV CH					
Public service radio CH					
Internet					
Foreign TV					
Newspaper					
Local TV CH[c]	−0.066	0.017	.000	0.021	0.022
Local radio CH					

Note. Only those parameters where numbers are reported are part of the best fitting model selected by the BIC. Partial eta-squared and Cohen's f-squared (Cohen, 1988) indicate the individual effect size of the given parameter.
Response variable: Nuclear opinion pro/contra; $R^2 = 0.411$; Adjusted $R^2 = 0.408$.
Response variable: What is your opinion on nuclear energy? 1 = *In favor*, 2 = *Mostly in favor*, 3 = *Mostly against*, 4 = *Against*.
[a]Do you think the benefits of nuclear energy justify the risk? 1 = *Not at all*, 5 = *Yes, very much so*.
[b]Do you worry about the possibility of a nuclear accident in Switzerland? 1 = *Not at all*, 5 = *Very much*.
[c]How often do you use Swiss local TV? 1 = *Daily*, 2 = *Several times a week*, 3 = *Once a week*, 4 = *Rarely*, 5 = *Never*.

energy the less that they thought that the risks justified the benefits. Furthermore, the more the respondents reported worrying about an accident at a Swiss nuclear power plant, the more they were against nuclear energy in general. For the 2012 model selection, the additional variable not present in the 2014 survey was the perception of safety of Swiss nuclear power plants. For the best model for 2012 data, safety perception was a significant model parameter, whereas worry about an accident was not. The presence of worry about accidents in the best model for 2014 thus requires cautious interpretation. Had the question of safety perception been present in the 2014 survey, then it is possible that the variable would have been part of the best 2014 model and not worry about accidents, which could simply be a function of the safety perception of Swiss nuclear power plants.

An effect observed in the 2012 model reappeared in the 2014 model: the more the respondents reported watching local television channels, the less likely they were to favor nuclear energy in general. The effect size was of a similar scale; though the effect was small, it is nevertheless noteworthy, for it was the sole media use variable that contributed to the best model for 2014 survey data.

Analysis of Missing Data

We estimated all three models presented in the previous sections as complete case analyses. If a respondent did not give a specific answer to one or several of the survey items, then we excluded that respondent from data analysis, which prompted a loss of data for each sample year, as Figure 2 illustrates.

Though the loss of data initially seems tolerable—86–89% of the total data were complete cases—additional analysis of missing data is necessary. Testing whether those data are missing completely at random (MCAR; Heitjan & Basu, 1996), as proposed by Jamshidian and Jalal (2010), revealed that only missing data for the 2012 survey satisfied the condition. To clarify whether missing data for other years were missing at random or not, we performed an additional analysis with imputed data using the "mice" *R* package (van Buuren & Groothuis–Oudshoorn, 2011), which operates with predictive mean matching and logistic regression—the latter for factors only—as imputation techniques. Although there were no fixed criteria for the number of imputations to perform, we erred on the side of caution and performed 100 imputations for each variable, as Graham, Olchowski, and Gilreath (2007) suggested. With the imputed data sets, we re-estimated the models for all years, though because missing data for 2012 were likely MCAR, we calculated the imputations for 2012 as well.

The results of the multiple imputations reported in Table 7 strongly suggest that the missing data posed no major problem and did not introduce any considerable bias. The parameter estimates as well as the *p*-values changed little compared with those in the original models.

Summary

All predictor variables in the three models with best model fit (Tables 4–6) were statistically significant. However, as statistical significance alone is not necessarily a meaningful indicator of the real-world relevance of a parameter, we also analyzed the confidence intervals (CI) of parameter estimates (Cohen, 1994; Gardner & Altman, 1986; Jones, 1955; Nakagawa & Cuthill, 2007; Poole, 2001). Figure 3 depicts the 95% CI of the parameter estimates for the three models reported in Tables 4–6.

The parameter with the greatest CI range was the sex estimate for the 2014 model. Though the estimate was significant at the $p < .001$ level, the impact of the standard error was sizeable. That finding is important, for given that sex is a dichotomous variable, assumably its relevance is specific, though in reality, it is broad. As such, in 2014, sex probably mattered as a predictor of

Figure 2
Visual summary of the missing data for each model

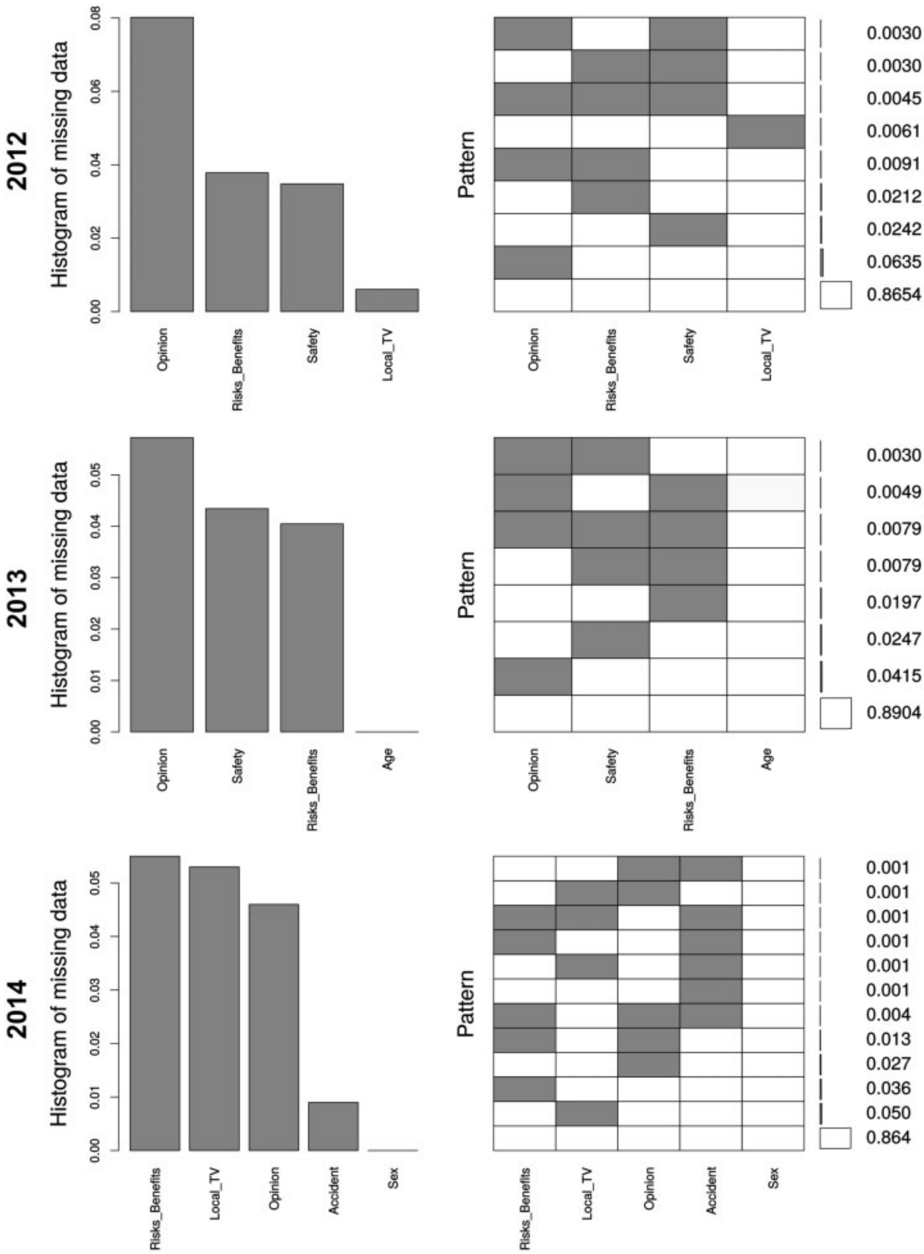
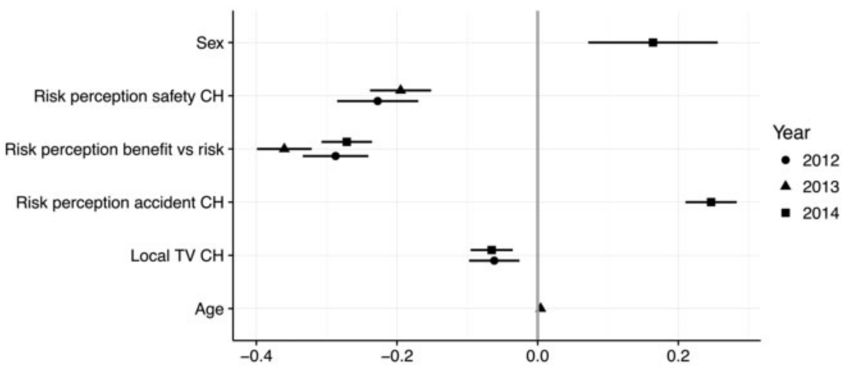


Table 7
Model Estimations With the Imputed Data Sets

Year	Predictor	Estimate	*SE*	*p*	n missing	Fmi
2012	Risk perception benefit vs. risk	−0.283	0.023	0.000	25	0.091
	Risk perception safety CH	−0.237	0.028	0.000	23	0.072
	Local TV CH	0.053	0.018	0.003	4	0.073
2013	Risk perception benefit vs. risk	−0.358	0.020	0.000	41	0.097
	Safety	−0.192	0.022	0.000	44	0.097
	Age	0.005	0.001	0.000	0	0.093
2014	Risk perception benefit vs. risk	−0.262	0.018	0.000	55	0.089
	Sex	0.168	0.046	0.000	0	0.064
	Accident	0.241	0.018	0.000	9	0.060
	Local TV CH	0.059	0.016	0.000	53	0.188

Note. "Fmi" denotes the fraction of missing information (Wagner, 2010).

Figure 3
Parameter point estimates (dots) and 95% confidence intervals for the parameter point estimates (error bars)



the general attitude toward nuclear energy, but how much it mattered varied to a relatively high degree. The narrowest CI in Figure 3 was for the age estimate in 2013. Although the effect was weak—the variable measures annual increments—it was specific, with an age estimate of 0.004 and CI ranges of 0.002–0.007.

The other three parameter estimates all had similar CI ranges. CIs for the 2012 estimates were slightly broader than the same CIs for other years, likely owing to the smaller sample size of the 2012 survey.

Three parameters depicted in Figure 3 appeared for at least 2 years. In those cases, an overlap of CIs for different years suggests that the real-world effect was the same for those years. Likewise, CIs that did not overlap suggest that the real-world effect differed for those years. There is one such case of nonoverlapping CIs for different years: the negative effect of the benefits-versus-risks assessment by respondents was probably stronger in 2013 than in 2014.

Discussion

The descriptive results indicate that the general opinion on nuclear energy in Switzerland is slightly negative. Opinion stabilized in the two years following the accident at Fukushima, and given the results of the Angstbarometer (GfS-Zürich, 2012), Fukushima strongly affected people's perception of nuclear energy. Our results nevertheless show that public opinion after the accident remained relatively stable. Although one might have expected 2012 to be a dramatically different year and opinion to look different in 2013 as the accident fades in the public memory, the actual shift in opinions was modest. Significant changes are observable only for some variables and for some years. From 2013 to 2014, the general opinion on nuclear energy became slightly less negative, yet remained rather negative. With a significant change from 2013 to 2014, the trend toward a slightly more positive assessment of nuclear energy is also observable regarding answers to the question of whether the benefits of nuclear energy justify its risks. These findings concur with those of similar studies that have also found the Fukushima effect to weaken over time (Siegrist & Visschers, 2013).

The explanatory results for all three surveys show a clear influence of risk perception on opinions about nuclear energy. People who do not think that the benefits justify the risks are more likely to be against nuclear energy in general.

In 2012 and 2013, the surveys asked respondents whether they worried about the safety of Swiss nuclear power plants, and in both years, the variable exerted significant influence: the more an individual reported worrying about the safety of Swiss nuclear power plants, the more likely he or she was to be against nuclear energy in general.

Interestingly, the question of whether respondents worried about an accident at a Swiss nuclear power plant did not influence their general opinion on nuclear energy in 2012, the year closest to the Fukushima accident. In 2013, the survey omitted the question, but in 2014, worry about an accident at a Swiss nuclear power plant was a significant predictor of respondents' opinions on nuclear energy in general. That is, the more they reported worrying about an accident, the more likely they were to be against nuclear energy.

Sociodemographic variables are only partly relevant in explaining opinions about nuclear energy. The age of respondents had an impact in 2013 only, and respondents' sex mattered only in 2014. The education of respondents was not a relevant predictor in any year surveyed. As such, a nuclear accident together with strong media coverage might have weakened or even closed preexisting gaps between sociodemographic groups. This can be thought of as one of the ways in which the Fukushima effect on public opinion manifests. The fact that sex has a substantial effect in 2014 could indicate that the Fukushima effect, strong though it might be, is not permanent but has something akin to a half-life. As the Fukushima effect begins to wear off, the "usual suspects" of sociodemographic variables seem to matter once again. For the 2012 and 2014 surveys, a set of variables measured how often respondents used different news media outlets. The sole relevant finding regarded the use of local television, both in 2012 and 2014; the more often respondents reported watching local television, the more likely they were to be against nuclear energy. Local television stations in Switzerland are private businesses, and there is evidence that they rely on more emotional, sensationalist reporting styles in general and probably even more when covering controversial issues such as nuclear energy. Consequently, local television in Switzerland could exert a negative affective effect on audiences. In that light, risk perception seems to be the strongest predictor of someone's opinion.

Conclusion

Our study yielded two primary results. First, the general opinion of nuclear energy and the different dimensions of risk perceptions have changed since the accident at Fukushima. Simply put, Swiss citizens have become more accepting of nuclear energy. This finding suggests that the accident at Fukushima triggered a change in opinion, and as time passed, public opinion on nuclear energy shifted back to its preaccident levels. That trend, however, was slow, given that the changes in attitude were relatively small. It remains unclear from our results alone whether and how long that trend will continue into the future.

Second, the most consistent and strongest predictor of the general opinion about nuclear energy was the answer to the question of whether the benefits of nuclear energy justify its risks. The more an individual considers that the benefits are worth the risks, the more he or she has a positive opinion about nuclear energy in general. This finding strongly suggests that the opinion on nuclear energy results from a rational process, not an affective one, at least in situations with strong media coverage. In that sense, thinking about the benefits and the risks of nuclear energy and deciding what one values to be more relevant is a complex cognitive task. Of course, it is possible that an individual weighing benefits and risks is not fully rational, but influenced by confirmation bias.

The limitations of the study are aspects that researchers should analyze more thoroughly in future studies. Though not crucial, the first limitation needs attention in future research: We omitted the Italian-speaking part of Switzerland from our data, which resulted in the exclusion of roughly 4% of the Swiss population from our samples. For the sake of best possible representativeness, future research should therefore include the Italian-speaking part of Switzerland.

Moreover, we asked respondents only whether they considered the benefits of nuclear energy to justify the risks. What exactly respondents considered to be benefits and risks, however, remains uncertain. Future research should address that aspect, not least because it would help to clarify the potential for confirmation bias. For example, if a person named several risks, but could not name any benefit, then that could indicate confirmation bias more than rational decision-making. That dimension merits further exploration, for the question taps directly into the nature of human cognition, as explained by the dual mode of thinking (Frankish, 2010). In short, is risk perception the result of deliberate, rational analysis (i.e., rational choice) or of irrational heuristics (i.e., behavioral economics)?

Another finding that merits attention in the future is the role of news media. The only relevant effect that we found was a relationship between the general opinion on nuclear energy and use of local television. This finding calls for a content analysis of news media to assess whether different news media types have such differences in the quantity and quality of reporting. A methodical triangulation of such a content analysis with survey data could hold valuable empirical insights, especially from a perspective focused on the social amplification of risk (e.g., Kasperson et al., 1988). Furthermore, we need to develop a better understanding of public communication in times of severe crises that influence perceptions of risks. In the context of the Fukushima accident, the trigger event did not simply prompt regular levels of media coverage. Instead, the Fukushima accident became an issue that overshadowed all other current issues at the time. As such, the Fukushima accident was an event with *hypersalience*: It did not compete with other issues for salience because it completely dominated media coverage. Consequently, it is not surprising that we found no strong media effects in our models: The Fukushima accident as a *hypersalient* event was omnipresent in the media, and therefore, the amount of media usage did not matter—there was no way to avoid being exposed to communication about the Fukushima accident, even for individuals with low levels of media consumption.

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