Running Head: CULTURAL THEORY AND RISK PERCEPTION

# A multilevel model of risk and benefit perception

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Abstract

Using nanotechnology as a case study, this study proposes a multilevel model for the examination of public assessment of benefits and risks. Specifically, this study focuses on the impact of *values*, including religiosity and trust at the micro level and cultural worldviews at the macro level. Based on data collected from 21 countries, including the US and 20 European countries, the results suggested that aggregate cultural worldviews and values not only exerted a direct impact on public perception of benefits and risks, they also moderated the influence of value predispositions at the individual level. The fact that survey respondents were nested within different cultures makes this research an ideal example to illustrate the value of multilevel modeling.

## A multilevel model of risk and benefit perception

The fields of communication and public opinion research have seen increasing calls for multilevel studies or theories from researchers who have recognized that people do not form an opinion in a vacuum (Pan & McLeod, 1991). In other words, public opinion is not only affected by an individual's cognition and social interaction, it is also affected by the larger context where people's life experience takes place. As researchers suggested, "the concept of public opinion must be viewed as representing complex social and political processes that involve individuals, groups, organizations, as well as institutions" (McLeod, Pan, & Rucinski, 1995, p. 56).

This is especially true in the area of science communication where public acceptance of technological innovations is often contingent upon the interplay between individual beliefs and their communication behaviors, on the one hand, and mobilization efforts of various interest groups, public policy, and the fundamental views about scientific innovation in a given culture, on the other hand. Therefore, a more granular understanding of how the public makes sense of scientific and technological issues would require researchers to take into account different levels of analysis.

Current research on public understanding of science often centers on the debate between the scientific literacy model and the cognitive miser model. Whereas the former suggests that public acceptance of new technologies may be driven by a heightened level of scientific knowledge, the latter maintains that public attitudes are shaped more by cognitive shortcuts, which provide people with a relatively easy way to reach decisions, than by knowledge. These cognitive shortcuts may include media frames (Scheufele &

Lewenstein, 2005), deference to scientific authority or social trust (Brossard & Nisbet, 2007; Earle & Cvetkovich, 1995; Siegrist, 2000), and religiosity (Brossard, Scheufele, Kim, & Lewenstein, 2008; Nisbet, 2005). Such value predispositions provide people with effective mental guidance about the way they should react to an innovation, including how they are going to support it, the interpretation of associated benefits and risks, and the impact of the scientific advancement on people's values and ethical concerns.

However, to the extent that the development, popularization, and regulation of a technology often transcend national borderlines and people in different cultures often hold different views on technologies, it is necessary for social scientists to go beyond investigating factors at the micro level. Therefore, this study examines public perception of benefits and risks associated with nanotechnology as an example to illustrate the importance of multilevel research.

An increasing number of studies in risk communication have embarked on the idea that risks are socially constructed (Dake, 1992; Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Kasperson et al., 1988). Things considered hazardous in one culture or society may not arouse the same fear in another (Wildavsky & Dake, 1990). Public perception of benefits and risks, as a result, is a multilevel process where individual judgment is made to reflect both personal preference and collective consensus about what an ideal society should be. Specially, we will focus on the influence of values, including individual value predispositions (i.e., religiosity and trust at the micro level) and cultural worldviews (i.e., individualism and egalitarianism at the macro level), on public perception of benefits and risks. As mentioned earlier, these values or worldviews shape

public judgment about benefits and risks both directly by providing convenient decision guidelines (e.g., Peters, Lang, Sawicka, & Hallman, 2007) and indirectly by altering the way people interpret information (e.g., Kahan, Braman, Slovic, Gastil, & Cohen, 2009).

As Figure 1 specifies, we hypothesize a relationship between value predispositions and perception of benefits and risks because of the lack of appropriate scientific knowledge on the public's part (Cobb & Macoubrie, 2004; Scheufele, Corley, Shih, Dalrymple, & Ho, 2009). At the same time, we also hypothesize that the perception of benefits and risks will be influenced by the prevalent worldviews in a given culture. Most important of all, these worldviews will not merely provide guidance for people regarding what to fear, they will also moderate the effects exerted by religiosity and trust. The reason lies in the fact that societies differ in the extent to which these two constructs are emphasized. For example, people in a hierarchical society tend to trust experts and authorities for their assessment of risks more than people in an egalitarian society (Kahan, Braman, Slovic et al., 2009). In short, the questions we will examine in this study are represented by the three arrows shown in Figure 1.

[Insert Figure 1 about here]

Different approaches exist when it comes to the study of benefits and risks perception. Before I review the literature about religiosity, trust, and cultural worldviews, it will be helpful to discuss some frameworks in which the perception of benefits and risks has been studied.

*Overview of risk perception*

Risk was traditionally regarded as a technical issue that involves professional computation of probability. The controversy of risks was expected to be resolved by "sound science." Although research still provides evidence regarding the relationship between the likelihood of a hazard and perception of risk (e.g., Lichtenstein, 1978), researchers recently have paid more attention to a different definition of risk; that is, the socially constructed nature of risk (Finucane & Holup, 2005). The most relevant lines of research about the constructed nature of risk are the *psychometric paradigm* and *social amplification of risk*, along with the Cultural Theory of risk perception that will be explicated later.

The psychometric explanation of risk perception was first developed in the context of nuclear power (Slovic, 1992; Slovic, Fischhoff, & Lichtenstein, 1982). It suggests that public perception of risk was determined mainly by two factors: the novelty of the technology and how fearful people are about the technology. The theory has also been used to explain risk perceptions in other fields, such as food safety (e.g., Fife-Schaw & Rowe, 1996) and genetically modified organisms (e.g., Moses, 1999).

However, the psychometric model suffered from some important criticisms. First, although the proponents of the model touted its ability to explain a large share of the variance of perceived risk with two factors, opponents have attributed the parsimony to the small sets of scales analyzed. As Sjoberg (2000) suggested, "Factor analysis of a matrix with only 9 or even 18 scales is bound to give few factors" (p.4). Second, the large explanatory power was also considered to derive from the analysis of mean data, rather than raw data (Gardner & Gould, 1989). Third, the psychometric model was criticized for

ignoring an important factor, that is, the moral concern of the public (Sjoberg & Torell, 1993; Sjoberg & Winroth, 1986). Research has shown that an addition of the "moral factor" would significantly increase the explanatory power of the model (Sjorberg, 2000).

Another line of research that takes into account the influence of society and culture on risk perception is the "social amplification of risk" model. This model was proposed to explain why "risk events with minor physical consequences often elicit strong public concern and produce extraordinary severe social impacts" (Kasperson et al., 1988, p. 177). This model suggests that technical assessment of risk, along with social, institutional, and cultural factors, can shape how an individual perceives risk. Specifically, individuals, groups, the media, or institutions all can serve as "amplification stations" that communicate the perceived magnitude of the risk (Renn, Burns, Kasperson, Kasperson, & Slovic, 1992).

However, both the psychometric model and the social amplification model cared more about how public perception of risk may be affected *within* a culture, less attention was paid to how people in different cultures may react to risks; that is, the *between-culture* differences. The Cultural Theory of risk perception addressed this gap and will be explicated later in this section.

*The role of individual religious beliefs*

Because many applications of modern technologies directly involve the manipulation of human bodies, animals, and plants, they bring about serious moral debates among scientists, policy-makers, and the general public. In the case of stem cell research, the debates center on whether stem cells should be considered a living organism

and whether extracting those cells from human embryos is an act of murder. In the case of plant biotechnology, the process of altering the genetic composition of plants for greater economic value is considered “unnatural” (Gaskell et al., 2000). Similarly, the tension between religiosity and science is also salient for nanotechnology, especially with respect to nano-bio-info-cogno (NBIC) applications, which may enable scientists to create life without divine intervention (Khushf, 2006).

Researchers have identified a relationship between risk perception and religiosity. For example, Miller and Hoffmann (1995) found that people who were risk-averse tended to be more religious, whereas those who were risk-taking tended to be less religious. In the context of nanotechnology, Brossard and colleagues (Brossard et al., 2008) found that religiosity served as a perceptual filter that shapes public perception. Specifically, religious people tend to see more risk and less benefit associated with nanotechnology than their less devout counterparts. Therefore, I formulated the following hypothesis.

H1: Religious strength at the individual level will be associated with the perception of more risk and less benefit.

However, things are less clear with respect to the impact of aggregate-level religiosity and whether the effect of individual religious belief on the perception of benefits and risks is similar in different countries. Although aggregate religiosity has been examined with respect to moral acceptability of nanotechnology (e.g., Scheufele et al., 2009), how it relates to perceived benefits and risks is still unknown. We, therefore, came up with the following research questions.

RQ1: Will the role of religiosity vary across countries? If yes, what explains the differences?

RQ2: Religious strength at the aggregate level will be associated with the perception of more risk and less benefit at the individual level.

*The role of trust*

In addition to religiosity, another important mental shortcut that helps public interpret technological risks is "trust." As mentioned earlier, the public needs to have professional knowledge in order to make rational judgments about the risk and benefit of a technology. However, the general public was not found to be very literate both in general science (Miller, 1998) and in nanotechnology (Cobb & Macoubrie, 2004; Scheufele & Lewenstein, 2005). One way for people to cope with this lack of knowledge, and perhaps a lack of interest, in science and technology is to relegate the decision-making tasks to experts, which may include scientists, researchers, and government authorities (Earle & Cvetkovich, 1995; Luhmann, 1979; Siegrist, 2000).

Although trust has been identified as an important factor shaping support for emerging technologies in general, and perception of benefit and risk in particular, there exist different approaches to exploring the concept. Some researchers conceptualize trust as having an emotional component and a competence component (Metlay, 1999). In other words, whereas the affective component was based on shared values between one person and another entity, the competence component, which is sometimes called "confidence," emphasized the belief that social and political institutions will function well and future events will occur as expected (Siegrist, Earle, & Gutscher, 2003). Other researchers

examined trust with respect to the subjects or institutions to which it refers such as trust in experts, trust in the media, or trust in the regulatory agencies. Because the measure this study uses taps more the belief about how well the government may perform in regulating nanotechnology, I will, therefore, focus on the literature in this domain.

Empirically, researchers have found a negative relationship between trust in regulatory agencies and risk concerns in various risk areas. For example, Grobe and colleagues found that people who trusted the US Food and Drug Administration more tended to be less concerned about the negative effects of the use of recombinant bovine growth hormone (Grobe, Douthitt, & Zepeda, 1999). Similarly, in the area of gene technology, Siegrist found that trust in institutions was associated positively with perceived benefit and negatively with perceived risk (Siegrist, 2000). A lack of trust was also found to result in increased risk judgments about hazardous waste disposal facility (Flynn, Burns, Mertz, & Slovic, 1992; Groothuis & Miller, 1997). The following literature was formulated based on the literature.

H2: The more trust people have in the regulatory systems, the more benefits, as opposed to risks, of nanotechnology will be perceived.

The role of trust, however, may not be identical across cultures. This is, in part, because trust in institutions originates from deeply rooted beliefs about people and societies that reflect broader cultural norms. These beliefs can be acquired from a variety of channels, including family, education, the media, and interaction with others. As a result, people growing up in different contexts will experience different socialization

processes and will have different views regarding how trustworthy their social and political institutions are (Mishler & Rose, 2001).

Specifically, researchers (Inglehart, 1997; Inglehart & Welzel, 2005) found that the level of post-industrialization in a country, defined by the proportion of labor force in the service sector, is associated with the prevalence of self-expression value, which corresponds to greater interpersonal trust. Other researchers also established a relationship between lower trust and income inequality (Alesina & La Ferrara, 2002; Kahan, Braman, & Mandel, 2009). In other words, trust is not a universally invariant concept. It is instead dependent upon the economic well-being and structure of a country.

Similarly, societies emphasizing different worldviews will also reflect different institutional and interpersonal trust. For instance, those living in societies where hierarchical worldviews are valued tend to have greater trust in experts and government agencies for their evaluation of hazards. In contrast, people in egalitarian societies are prone to trust social groups or consumer organizations (Douglas & Wildavsky, 1982; Wildavsky & Dake, 1990). In addition to the influences of worldviews and values, how the social and political institutions performed in the past in handling crises or hazardous events could result in different levels of trust afforded to them by the public. Research has shown that citizens who experienced communist sovereignty would initially have a lower level of trust for the new democratic institutions (Mishler & Rose, 2001). Therefore, how trust may influence the perception of benefits and risks should be examined both at the aggregate level and across different social contexts.

Empirical evidence also supports the idea that the role of confidence may vary with cultures. For example, an international attitude survey has found that the acceptance of GM soybeans in Japan was not increased despite government endorsement of safety (Hoban, 1997). The 2005 Eurobarometer survey used by this study also exhibited national differences in the level of trust with respect to regulatory agencies (see figure 5.2). It is, therefore, interesting to examine whether the relationship between trust and risk will be different across countries and whether aggregate trust may play a role in affecting people's perceptions of benefits and risks. Based on the literature, we formulated the following hypotheses and research questions.

[Insert Figure 5.2 about here]

RQ3: How will trust at the aggregate level affect public perception of benefits and risks?

RQ4: Will the role of trust vary across countries? If yes, what explains the differences?

*The role of cultural worldviews*

Cultural Theory is largely based on the work of Douglas and Wildavsky (1982). Cultural theorists suggest that not everybody cares about the same risks. What is considered a risk in one culture may not mean anything in another culture. Perception of risk, according to Cultural Theory, is dependent on values cultivated and shaped in different social conditions. Specifically, risk perception is determined by a society's (or an individual's) location in the quadrant defined by two axes—individualism-collectivism and egalitarianism-hierarchy.

Research has suggested that people in different cultures may define and perceive risks differently. Specifically, Cultural Theory scholars have viewed risk as the embodiment of deeply held cultural values and beliefs. They are defined, perceived, and managed according to principles that are inherent in particular forms of social organizations. For example, Vari and colleagues (Vari, Kemp, & Mumpower, 1991) found that people in the US, UK, and Hungary possessed different concerns in relation to the development of nuclear power. Specifically, Americans emphasized the environmental, economic, and health impacts, whereas the British were concerned about health and social questions. Still differently, Hungarians cared mainly about problems related to health, society, and technical-procedures.

Wildavsky and Dake (1990) went a step further to explore *why* people in different cultures worry about different types of risks. They identified five broad approaches to the study of public reactions to risks, including the knowledge theory, the personality theory, the economic theory, the political theory, and the Cultural Theory. Their findings suggested an empirical superiority of the cultural approach as it provided larger explanatory power than the other approaches.

Specifically, they argued that people's concern about risks varied depending on the type of social relations that characterize the given culture, that is, whether the culture is a hierarchical, individualist, or egalitarian society. According to Cultural Theory, adherents to hierarchy tend to care about the behaviors of social deviances because they challenge the preferred or established way of life. However, they perceive lower risks associated with the development of technologies because they believe that the government will

handle the issue well. Similarly, individualists support the development of technology because they see it as an opportunity for prosperity and progress. Nonetheless, individualists differ from hierarchists in that they tolerate acts of deviance insofar as these behaviors do not undermine economic development and the function of the free market, which they value the most. In regard to egalitarians, who advocate diminishing the distinction between people, they are concerned about risks associated with technologies. They are afraid that those socially or economically advantaged elites may advance technology at the expense of the environment, just like they exploit the poor.

Opponents of Cultural Theory, however, have pointed out several pitfalls. First, the bulk of evidence supporting the theory has based on qualitative and ethnographic approaches. No empirical examination has been conducted to test the validity of the theory. In addition, very rarely has research developed reliable scales that allow replication across studies. Second, Cultural Theory explains only about 5 percent of the variance of risk perception, a figure that is not very impressive. Third, Cultural Theory did not explain risks associated with the environment and technology very well. Sjorberg (2000) even concluded that “Cultural Theory is simply wrong” (pp. 149).

Despite the critique, Cultural Theory has been applied to examine risk perception with respect to various issues. A recent study published in Nature Nanotechnology suggests that cultural worldviews exerted impact on public perception of benefits and risks in relation to nanotechnology (Kahan, Braman, Slovic et al., 2009). These worldviews were also found to moderate the effect of information. Consistent with previous studies that found religiosity serving as a “perceptual filter” that helps people

interpret and process incoming information (Brossard et al., 2008), cultural worldviews exerted similar effects.

Kahan and colleagues are the main scholars who apply Cultural Theory to the examination of technological issues. As a variant of Cultural Theory, their "Cultural Cognition" model was used to explain risk perception with respect to biotechnology and nanotechnology. However, both Dake (who developed quantifiable measures for Cultural theory) and Kahan investigated the Cultural Theory indicators at the individual level. They also examined these worldviews within a country. No research so far has placed Cultural Theory within a cross-cultural context, as the name of the theory may explicitly suggest. This study addresses the gap by empirically linking risk perception across countries with country-level cultural worldviews.

Based on the literature discussed above, we formulate the following research questions and hypotheses. The first three hypotheses and the first research question examined factors at the individual level, whereas the last two hypotheses and the second research question dealt with the analysis at the country level.

H3: Individualist values at the aggregate level will be associated with an increased level of perceived benefits.

H4: Egalitarian values at the aggregate level will be associated with an increased level of perceived risks.

RQ5: How will the relationship between individualism and perception of benefits and risks vary according to the level of egalitarianism?

## *Methods*

The 21 countries examined in this study are Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Finland, Poland, Portugal, Slovenia, Spain, Sweden, the UK, and the US. The countries were selected because information about both individual perception of nanotechnology and government investment in nanotechnology was available. The amount of government funding was used as a selection criterion because it reflects how much efforts were dedicated to the popularization and development of the technology, including the amount of research activity, outreach efforts, and information people will get.

The data used in this study came from three sources — (1) the 2007 Public Awareness of Nanotechnology Study in the US, (2) the Eurobarometer 64.3 in 2005, and (3) a dataset containing various indicators of a country's human, infrastructure, economic, political, and nanotechnology development. Whereas the first two sources provided information about individual differences in predispositional values, the third source was used to measure between-country differences in cultural values, economic well-being, and government investment nanotechnology.

The U.S. survey was conducted by the University of Wisconsin Survey Center under the auspices of the Center for Nanotechnology in Society at Arizona State University. Data collection for the study began on 15 February and ended on 27 June 2007, using a dual frame method of national random digit dial and listed household phone survey. The total sample size was 1,015, with a response rate of 30.60% (calculated using AAPORs formula for RR3; ref. 21).

The Eurobarometer 64.3 survey was collected by the European Committee in 2005. The Eurobarometer public opinion surveys were conducted on behalf of the European Commission. Using a multistage national probability sampling technique, the Eurobarometer 64.3 provides opinion data collected from 29 countries through face-to-face interviews of 29,193 Europeans aged 15 and above. The fieldwork was conducted between 5 November and 7 December 2005. We excluded interviewees under 18 in order to make the U.S. and European samples comparable. Also, there were slight variations in wording for scale anchors across countries, that is, “strongly disagree” and “strongly agree” were used in the U.S. survey, and “totally disagree” and “totally agree” in the English version of the Eurobarometer. Undecided respondents were coded into a middle category in all countries to make metrics comparable.

*Dependent variable*

The dependent variable is the extent to which the perception of benefits outweighed the perception of risks. The *benefit of nanotechnology* was measured by asking the extent to which people agree with the statement that nanotechnology is useful. As mentioned earlier, although the US survey and the Eurobarometer asked the two questions in exactly identical manner, the scales of the response categories were different. In order to make the two datasets comparable, the variables were recoded so that they ranges from -2 to 2 in both datasets, with zero being the midpoint. For example, in the Eurobarometer survey, -2 would indicate “totally disagree” and 2 would indicate “totally agree,” with “don’t know” being imputed as the midpoint “zero” ($M$=0.67, $SD$=1.05). On the other hand, the r*isk of nanotechnology* was measured by asking the extent to which people agree with the

statement that nanotechnology is risky. A similar transformation process was employed (*M*=-0.25, *SD*=1.09).

We then subtracted the score of risk perception from that of benefit perception to form a 9-point scale index. This decision to combine perception of risk with perception of benefit was primarily based on the theoretical argument that the public considers risks and benefits at the same time when forming attitudes toward science and technology (Kahan, 2008). In fact, many researchers have examined benefits and risks together by integrating them in the same survey question (e.g., Cobb & Macoubrie, 2004; Kahan, Braman, Slovic et al., 2009).

*Independent variables at the individual level*

*Awareness of nanotechnology*. The level of awareness was measured by asking survey respondents how much have they heard, read or seen about nanotechnology. In the US survey, this question was measured on a one to 10 scale, where one indicates knowing nothing about nanotechnology and 10 indicates knowing everything. However, in the Eurobarometer survey, the response categories include only yes and no. In order to make the two datasets comparable, the variable in the US survey was dichotomized in a way that reflected only awareness and no awareness. The average proportion of the respondents who had heard of nanotechnology in the 21 countries was 44.2 percent.

*Trust.* The variable was measured by asking the respondents: "How confident would you say you are in the safety and regulatory approval systems governing nanotechnology?" The variable was on a 5-point scale with -2 indicating "not at all confident and 2 indicating "very confident" (*M*=-0.01, *SD*=1.11).

*Controls*. This study included age, gender, and moral acceptability as controls. The respondents' age ranged from 18 to 98, with a mean of 48.49 and standard deviation of 17.52. It should be noted that the Eurobarometer included respondents younger than 18. In order to make it comparable with the US survey, these minor respondents were excluded. About 45 percent (44.65%) of the respondents were male. *Moral acceptability* was tapped by asking the extent to which people agree with the statement that nanotechnology is morally acceptable. It ranged from -2 to 2 after a similar process of transformation ($M$=0.59, $SD$=1.09).

*Independent variables at the national level*

Cultural theorists divided cultures worldwide into four dimensions based on two axes—the level of individualism and the level of egalitarianism. We used Hofstede's (2001) individualism index to represent the extent to which a culture emphasize individual entitlement and personal interests. Such an index is perhaps the most widely used and reliable measure in cross-cultural comparisons (Schimmack, Oishi, & Diener, 2005). On the other hand, we used the egalitarianism index developed by Schwartz to indicate the extent to which a culture emphasizes social equality. These two indices were employed not only because most of the countries under study were covered by them, but also they were measures with great validity and reliability.

*Individualism vs collectivism.* Each country's individualism scores were imputed based on Hofstede's individualism index, which included 50 countries and three regions (Hofstede, 2001). The individualism index (IDV) was one of the four "dimensions of culture" developed by Hofstede. The other three dimensions are power distance,

uncertainty avoidance, and masculinity/femininity. The values for IDV and the masculinity index were derived from the two factors generated based on 14 questions about employee's "work goals." Specifically, IDV was associated with the six questions about employ's personal time, freedom, challenge, use of skills, physical condition, and training. It accounted for 24 percent of the variance in the average country scores about work goals.

*Egalitarianism vs hierarchical value*. The index was based on the egalitarianism scores derived from the 2005 wave of the Schwartz Value Survey (SVS), which has been conducted since 1985. The survey involved more than 60,000 respondents in 64 countries and divided worldwide cultures into seven types—harmony, embeddedness, hierarchy, mastery, affective autonomy, intellectual autonomy, and egalitarianism. Based on the survey, Schwartz and colleagues assigned values to each country on the seven cultural indicators (Siegel, Licht, Schwartz, Hall, & Field, 2008). The indices range from 1 to 7. In our case, higher number indicates a higher level of egalitarianism.

*Power distance index (PDI)*. Hofstede's PDI was measured by three survey questions, with two pertaining to subjective perception and the other about personal values. First, respondents were asked about the frequency at which they were afraid of expressing disagreement with their managers. Second, they were asked about their managers' decision making styles; i.e., whether the boss communicated with the subordinates in an autocratic way, a paternalistic way, a consultative way, or a democratic way. Third, respondents were also asked about their preferred styles of decision making. These variables were combined and calculated so that the final scores of

PDI ranged from zero (small power distance) to 100 (large power distance).

*Religiosity*. I imputed aggregate responses on religiosity for each country from the World Values Survey. Possible responses ranged from one to ten, with one indicating that religious guidance was "not at all important" and ten indicating "very important" in respondents' lives.

*Trust*. The average level of confidence was measured by aggregating the responses at the individual level about people's confidence in regulatory systems. Each country obtained a score ranging from -2 to 2, with a higher number indicating an increased level of aggregate trust.

*Human development values.* Human development values were employed to explain the varied impact of individual-level trust and religiosity across countries. The human development values, including the "traditional vs secular/rational" and the "survival vs self-expression" values, were based on Inglehart and Welzel's (2005) research on the relationship between modernization, value change, and democracy. These values were measured by 9 relevant items extracted from the World Value Survey (WVS). They are: (1) the importance of god; (2) the extent to which people disapprove of abortion; (3) the importance of "obedience" and "religious faith" as ideal child qualities; (4) the level of national pride; (5) the preference for materialistic or post-materialistic lifestyle; (6) the level of unhappiness; (7) the extent to which people disapprove of homosexuality; (8) people's tendency to sign a petition; (9) the degree to which others can be trusted. Based on the result of a factor analysis, the first four items were combined to form an index for

the traditional value (Cronbach's Alpha=.73), whereas the other five items were used to measure the self-expression value (Cronbach's Alpha=.71).

*Controls*. A few aggregate-level variables were included as controls. *Government funding (GDP adjusted)* was adjusted by GDP. I divided government funding on nanotechnology, obtained from the European Commission, by each county's GDP per capita, retrieved from the International Monetary Fund (IMF). *Awareness of nanotechnology* was measured by the proportion of respondents in each country who had heard of nanotechnology before the time of survey. The measure of *Economic openness* was established by a three-step procedure. First, the information about export and import was obtained from the CIA Factbook. Second, a trade variable was formed by combining export and import. Third, the natural log of trade was regressed on the natural log of country GDP. The residuals from the regression analysis form the "economic openness" variable. (See Yang & Shanahan, 2002 for an overview). *Country development* was characterized by two indicators—*Industrialization* was formed by subtracting the proportion of the labor force in the agricultural sector from that in the industry sector, whereas *post-industrialization* was formed by subtracting the proportion of the labor force in the industry sector from that in the service sector. Information about the distribution of the labor force in each country was obtained from the CIA Factbook (CIA, 2008).

The analysis of this study was based on *hierarchical linear modeling* (HLM), which takes into account variables measured at different levels simultaneously. One advantage of HLM rests with the fact that it provides a parsimonious way of estimating

between-group variation (Raudenbush & Bryk, 2002). Specifically, in HLM, researchers are able to observe whether the estimated intercepts and slopes were, in fact, different for each nested higher-level group (Snijders & Bosker, 1999). This technique proves to be appropriate in the context of this study not only because the data were collected using multi-stage sampling but also because individuals in these data were nested within countries and were subject to the influence of shared worldviews, living habits, standard of living, and cultures. Seventeen countries were included in the analysis pertaining to *cultural worldviews*. Four countries—Belgium, Luxembourg, Lithuania, and Latvia—were left out due to the unavailability of data. However, all 21 countries were included in the examining the effect of *religiosity and confidence*. Descriptive statistics of the variables used in this section are illustrated in Table 1.

[Insert Table 1 about here]

*Results*

Before I tested the effect of the aforementioned independent variables, I ran a null model with only the dependent variable. This model provided an estimation of overall variances at both the individual level (2.88) and the national level (0.20), as Table 5.3 suggests. Therefore, the intraclass correlation, which indicates the proportion of level-2 variance to the total variance, is about 6.5 (0.20/ (0.20+2.88)). In other words, in predicting public perception of benefits and risks, about 6.5 percent of the variance may exist at the national level. In addition, by comparing the variances of the null model to those of other subsequent models, we will know the amount of variance explained by the independent variables.

**H1**, which suggests a negative relationship between the strength of religious belief at the individual level and perceived benefits, was also supported. The finding was also consistent in the two models. With the finding that more religious people were inclined to perceive more risks, it is reasonable to ask whether this relationship holds across countries. **RQ1** explored this question and the results suggest that the association between religiosity and perceived benefits and risks did vary across social contexts. Statistically, this was supported by the significant random slope variance associated with religiosity, as Model 4 and Model 9 in Table 5.3 suggest. However, the variables included in this study failed to explain the differential slopes. In other words, although the effects of religiosity were not the same in every country, the differences were not attributable to country characteristics such as GDP, the amount of funding, and the traditional value (see Table 2). The results were identical in both the "religiosity/ confidence" model and the "cultural worldviews" model.

**RQ2** investigated the impact of aggregate religiosity on perceived benefits and risks. The results indicated that overall religious strength was negatively related to perceived benefits. In other words, people who lived in a more secular country would perceive more benefit and less risk of nanotechnology.

[Insert Table 2 about here]

**H2** predicted that the more confidence people have in their regulatory system, the less likely that they will consider nanotechnology as more risky than useful. This hypothesis was supported. A similar result was found in relation to the effect of confidence at the aggregate level, which was examined in **RQ3**. The results suggested

that people perceived increasing benefits if they lived in a society where public confidence in institutions regulating nanotechnology was high. **RQ4** explored whether the positive relationship between confidence and perceived benefit varied across countries, and if yes, whether the differential effects can be predicted by some country-level characteristics. The results suggested that not only were the effects of confidence (at the individual level) varied in different countries, they can be explained by factors related to the level of human development. Specifically, both GDP per capita and the prevalence of the survival value *weakened* the positive effect of confidence. In other words, confidence exerted a stronger impact on public perception of benefits and risks in countries where people had a lower level of economic well-being and a greater emphasis on the self-expression value.

In short, in the analysis about the effect of "religiosity/ confidence," which involved 21 countries, age, gender, moral acceptability, awareness, religiosity, and confidence together explained about 52 percent of the variance existent at individual-level (comparing Model 1 and Model 2 in Table 3). Furthermore, more than 80 percent of the variance at the national level was explained by the five predictors examined (comparing Model 2 and Model 3 in Table 3). In the next few paragraphs, I will present results derived from the analysis pertaining to the effect of cultural worldviews.

[Insert Table 3 about here]

**H3** indicated that as the strength of people's individualist values increases, the chance for them to perceive more benefits than risks also increases. The results supported this hypothesis by showing a positive association between individualism and perception

of benefits (see table 2). Similarly, **H4**, which stipulated a negative relationship between egalitarianism and the level of perceived benefits and risks, was supported. The more a society appreciates egalitarian values, the more likely it is that people in that society would see more benefits and less risk associated with nanotechnology.

In addition to the effect of cultural worldviews, the results also indicated a negative relationship between government funding and perception of benefits (as opposed to risks). People who lived in a country whose government has invested a great deal of money in nanotechnology tended to perceive less benefit. On the contrary, GDP per capita, economic openness, and power distance were found to exert a positive impact on the perception of benefits. These second level factors together explained about 44 percent of the variance at the national level (comparing Model 7 and Model 8 in Table 3).

**RQ5** examined the interaction effect of individualism and egalitarianism on perceived benefits and risks. The results indicated that the interaction effect was statistically significant. Specifically, as cultural theorists suggest, people living in a society that emphasizes hierarchical and egalitarian values tended to perceive nanotechnology as most risky. On the contrary, those under the influence of individualist and hierarchical values were more likely to perceive more benefits than risks.

[Insert Figure 3 about here]

As Figure 3 suggested, the relationship between individualism and perceived benefits and risks was different for people having different levels of appreciation for egalitarian values. Higher levels of individualism widened the gap between people who

emphasized egalitarian values and people who emphasized hierarchical values with respect to their perception of benefits and risks associated with nanotechnology.

## Discussion

The results of this study corroborated previous research findings in risk communication as they suggested that public assessment of benefits and risks was determined by the level of trust people had in regulatory systems and the strength of people's religious beliefs (e.g., Brossard et al., 2008; Evensen, Hoban, & Woodrum, 2000). However, this study went a step further to examine whether the associations between these variables and the perception of benefits and risks were different across countries. The results gave an affirmative answer. It is noteworthy that the differential effect of trust was found to depend on the extent to which a society emphasizes the survival values. Specifically, trust exerted a stronger effect in countries emphasizing self-expression values. In contrast, we were unable to find any factor that can account for the varied effect of religiosity in a statistically satisfactory manner. These findings suggested that, although religiosity and trust served as important "perceptual filters" that help people form opinions and interpret information, the magnitude of their influences vary across societies.

Policy-makers and outreach specialists should be aware of the results so that they can develop strategic campaigns or messages effectively. For example, emphasizing the credibility of regulatory agencies may increase benefit perception better in countries where the self-expression value is considered important. In contrast, such an emphasis may bring about less satisfactory results in countries where the survival value prevails.

The results also indicated that cultural worldviews, although showing mixed results at the individual level in previous research (e.g., Kahan, 2008; Kahan, Braman, Slovic et al., 2009), exerted a statistically significant impact at the country level. The findings suggested that the evaluation of benefits and risks was more complicated than merely being the product of individual perception, values, and beliefs. It was also related to the predominant cultural worldviews that determine people's basic attitudes toward the society in general and technology in particular.

By expanding Cultural Theory to the aggregate level, this study showed how people connect their attitudes toward an emerging technology to their "preferred ways of life." The results confirmed pervious research that suggested a relative similarity of people on some predominant values or worldviews *within* a culture despite educational, ethnic, and occupational differences (Inglehart and Welzel, 2005).

The perception of benefits and risks was also shaped by a country's level of economic openness and the amount of government funding on nanotechnology (in the 17-country sample), on top of predominant cultural values and worldviews. The results not only justified the importance of employing "government funding" as a criterion for country selection, but also suggested the significant role of government support and economic structure.

*Caveats*

However, this study was not able to address the possibility that people may perceive risks associated with different applications differently. In the case of genetic engineering, researchers have found that people showed different levels of support and

risk assessment with respect to different applications (e.g., Bauer, 2005; Bauer & Gaskell, 2002). Nonetheless, current studies focused mainly on people's opinion about whether the risks of nanotechnology outweigh its benefits, or the other way around, without much effort dedicated to differentiating risks associated with nano-bio-info-cogno (NBIC) from those associated with less controversial applications, such as the development of micro-processors. Future research should address this gap.

Second, it will also be fruitful for future research to examine different risk targets, which has not received much attention in risk studies (Sjoberg, 2000). Research has suggested that people often claim that others are more likely than themselves to be affected by hazards, a tendency termed unrealistic optimism or optimistic bias (Weinstein, 1989). The differentiation between "self and other" will not only give a very different picture about public risk perception, it also has important implications for policy making. Research has shown that policy attitudes are driven more by general risk than personal risk (Sjorberg, 2002). It is, therefore, important for future research to go beyond the study of general risks.

Another limitation inherent in this study is its lack of media use measures. The media serve as an important source of information, especially for complex issues, such as science and technology (Conrad, 1999). Specifically, how media frame nanotechnology has been found to affect public attitudes and their perception of benefits and risks (Cobb, 2005; Scheufele & Lewenstein, 2005).

It is also noteworthy that, although the macro level variables did play an important part, the variance existed at that level was relatively small (less than 10 percent

of the total variance), as Table 3 would suggest. Part of the explanation may be that the differences among European countries or the differences between Europe and the US were not really obvious. It will be enlightening if future research could incorporate countries in Asia or South America because counties in these areas may have much more different worldviews than those in Europe or North America.

## Conclusion

Using nanotechnology as a case study, this study proposes a multilevel model for the examination of public assessment of benefits and risks. Specifically, by integrating both micro- and macro-level data from the US and 20 European countries, we found that aggregate cultural worldviews and values not only exerted a direct impact on public perception of benefits and risks, they also moderated the influence of value predispositions at the individual level (i.e., religiosity and trust).

As mentioned earlier, although many researchers have recognized the socially-constructed nature of risk perception, not many of them have turned the idea into empirical studies. This study, therefore, directly responds to the call for multilevel research. Despite some limitations, a multilevel model toward risk perception, especially in contexts that involves comparisons across nations, is conceptually and methodologically more appropriate than a single-level model. On the one hand, a multilevel model addressed the fact that people in the same social context were actually subject to the influence of common social and cultural forces. On the other hand, such a model may predict human attitudes in a manner that are closer to social reality (Ritchie & Price, 1991; Shen, 2009; Slater, Snyder, & Hayes, 2006).

It is noteworthy that a multilevel model not merely allows researchers to explore macro-level variables, it also makes it possible to test whether the effect of micro-level variables may vary by contexts. For example, the differential effects of trust and religiosity in different cultures would not be identified if this study failed to employ a multilevel model, which provided a parsimonious way of performing such a test (Raudenbush & Bryk, 2002).

Even though a study examines only a single country, a multilevel model will still be valuable because different regions of a country may vary with respect to their local media system, the amount of outreach activity, the clout of social groups (e.g., church), local economy, and so on. Public opinion results are likely to be biased or subject to wrong interpretation if contextual factors were left unaccounted for.

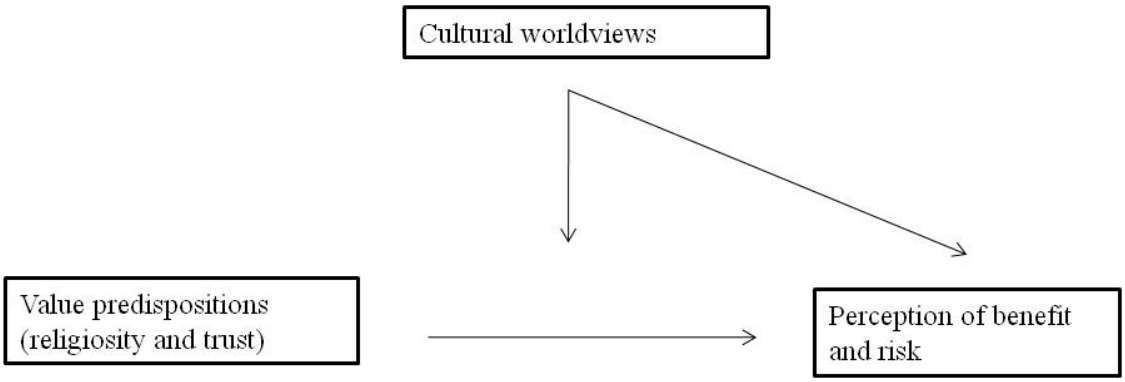
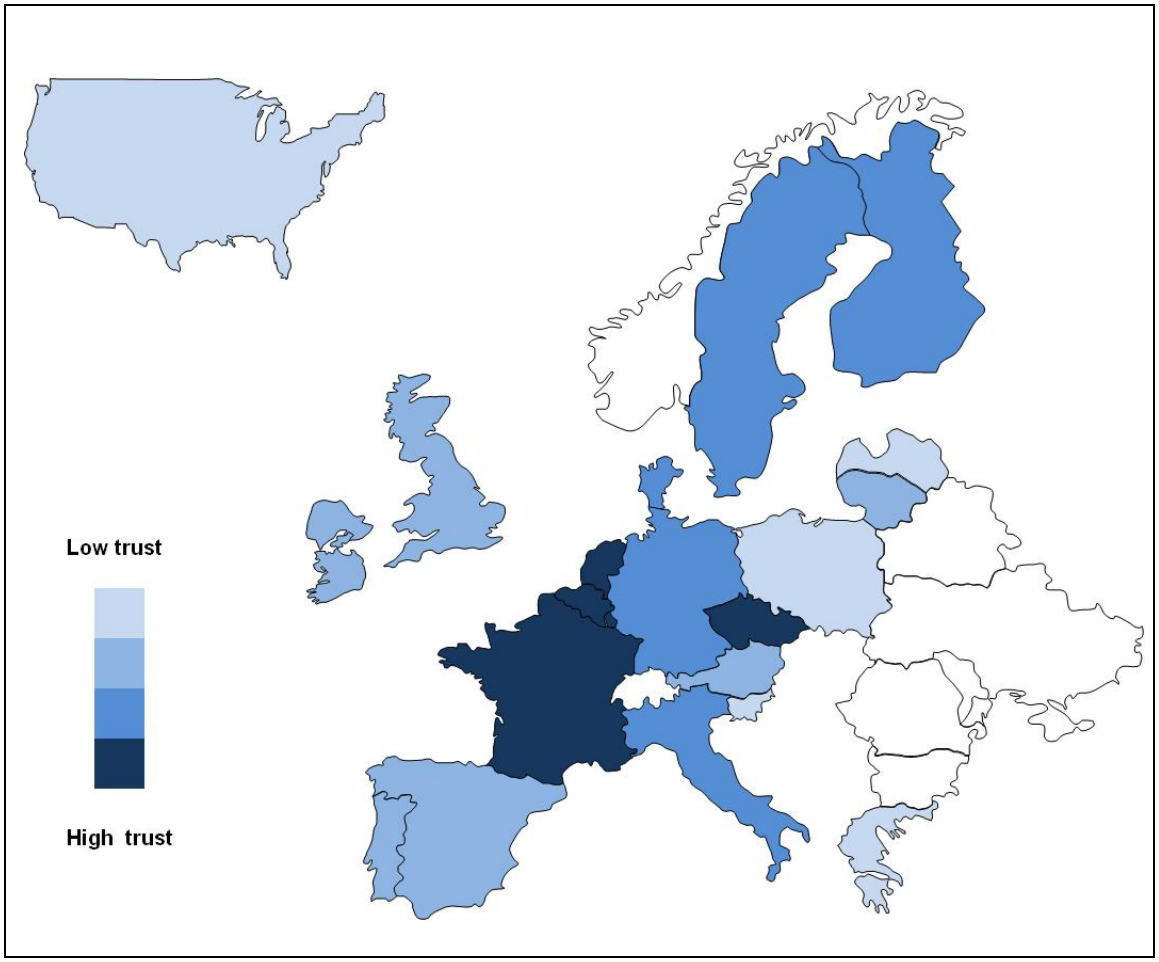



*Figure 1*. A multilevel model of risk and benefit perception




| | | | | | |
|---|---|---|---|---|---|
| Luxembourg | 0.47 | Germany | 0.14 | Poland | -0.14 |
| Netherlands | 0.45 | Denmark | 0.13 | Slovenia | -0.23 |
| Belgium | 0.44 | Spain | 0.04 | US | -0.39 |
| France | 0.37 | UK | 0.04 | Latvia | -0.62 |
| Czech | 0.35 | Lithuania | 0.01 | Greece | -0.71 |
| Sweden | 0.29 | Austria | -0.05 | | |
| Italy | 0.28 | Portugal | -0.05 | *Mean* | 0.04 |
| Finland | 0.20 | Ireland | -0.13 | *SD* | 0.33 |

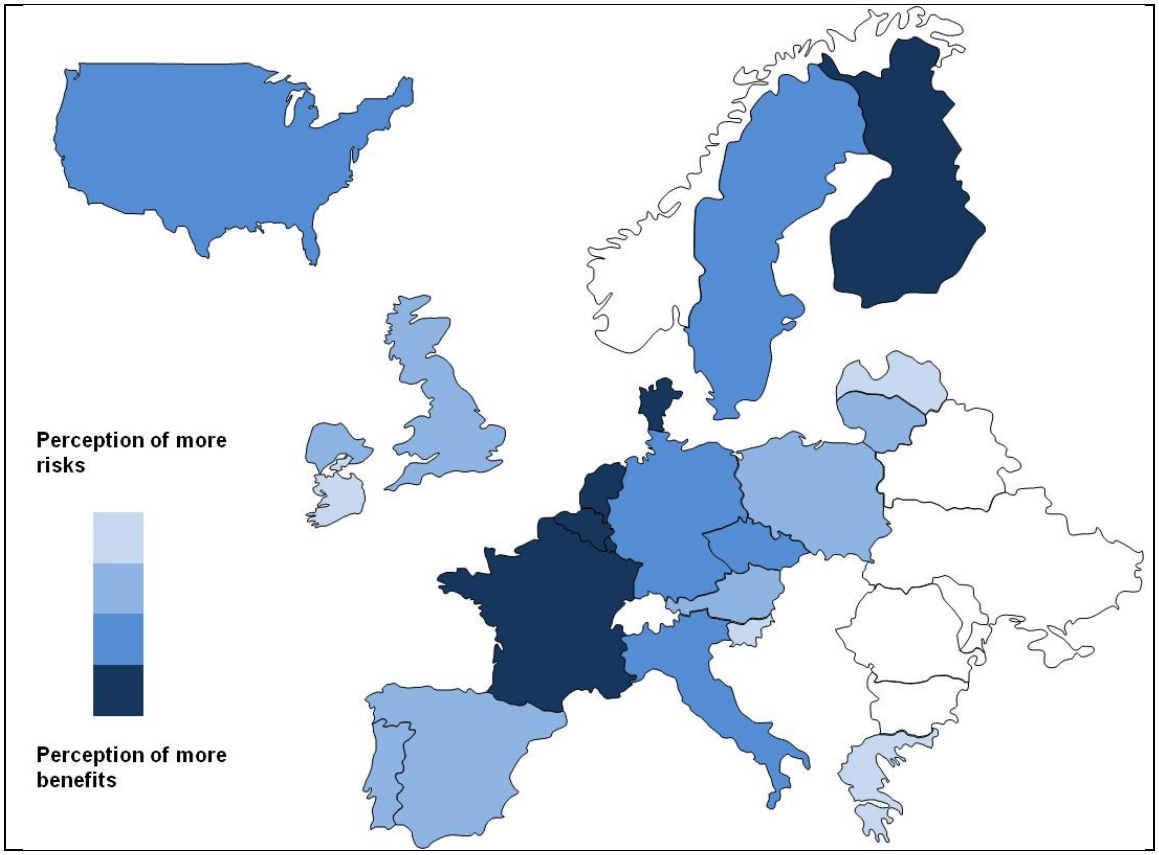
*Figure 2*. Mean aggregate "confidence" across 21 countries

Table 1

*Descriptive statistics of variables used in predicting public perception of benefits and risks*

| Variables | N | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|---|
| **Analysis of religiosity and confidence** | | | | | |
| Level-1 descriptive statistics | | | | | |
| Age | 10,779 | 48.72 | 17.62 | 18.00 | 97.00 |
| Sex | 10,779 | 44% male | | 0.00 | 1.00 |
| Moral acceptability | 10,779 | 0.59 | 1.09 | -2.00 | 2.00 |
| Awareness of nanotechnology | 10,779 | 44% aware | | 0.00 | 1.00 |
| Confidence | 10,779 | -0.01 | 1.11 | -2.00 | 2.00 |
| Religious belief | 10,779 | 2.52 | 1.13 | 1.00 | 4.00 |
| Perception of benefits and risks | 10,779 | 0.92 | 1.75 | -4.00 | 4.00 |
| Level-2 descriptive statistics | | | | | |
| Funding/GDP (standardized) | 21 | -0.05 | 1.03 | -1.04 | 2.37 |
| GDP per capita | 21 | 35306.19 | 16876.31 | 9840.00 | 75880.00 |
| Economic openness | 21 | 0.00 | 0.97 | -2.08 | 1.90 |
| Religiosity | 21 | 5.96 | 1.48 | 3.76 | 8.53 |
| Confidence | 21 | 0.04 | 0.33 | -0.71 | 0.47 |
| Survival value | 21 | 0.00 | 0.98 | -1.71 | 2.19 |
| Traditional value | 21 | 0.00 | 0.95 | -1.42 | 1.73 |
| **Analysis of cultural worldviews** | | | | | |
| Level-1 descriptive statistics | | | | | |
| Age | 9,132 | 48.73 | 17.64 | 18.00 | 97.00 |
| Sex | 9,132 | 45% male | | 0.00 | 1.00 |
| Moral acceptability | 9,132 | 0.58 | 1.10 | -2.00 | 2.00 |
| Awareness of nanotechnology | 9,132 | 45% aware | | 0.00 | 1.00 |
| Confidence | 9,132 | -0.01 | 1.12 | -2.00 | 2.00 |
| Religious belief | 9,132 | 2.53 | 1.13 | 1.00 | 4.00 |
| Perception of benefits and risks | 9,132 | 0.91 | 1.76 | -4.00 | 4.00 |
| Level-2 descriptive statistics | | | | | |
| Funding/GDP | 17 | -0.05 | 0.96 | -1.04 | 2.01 |
| GDP per capita | 17 | 35587.65 | 13064.75 | 9840.00 | 54910.00 |
| Economic openness | 17 | 0.01 | 0.90 | -2.08 | 1.57 |
| Post-industrialization | 17 | 41.18 | 12.37 | 19.90 | 62.20 |
| Survival value | 17 | -0.15 | 0.85 | -1.71 | 1.47 |
| Traditional value | 17 | 0.02 | 1.06 | -1.42 | 1.73 |
| Power distance index | 17 | 43.88 | 17.47 | 11.00 | 71.00 |
| Individualism index | 17 | 63.12 | 19.15 | 27.00 | 91.00 |

| | | | | | |
|---|---|---|---|---|---|
| Egalitarianism index | 17 | 5.03 | 0.28 | 4.55 | 5.51 |




| | | | | | |
|---|---|---|---|---|---|
| Finland | 1.70 | Sweden | 0.94 | Portugal | 0.61 |
| Belgium | 1.61 | US | 0.85 | Slovenia | 0.60 |
| Netherlands | 1.51 | Italy | 0.82 | Latvia | 0.46 |
| Denmark | 1.48 | Spain | 0.80 | Ireland | 0.46 |
| France | 1.32 | Lithuania | 0.77 | Greece | -0.14 |
| Luxembourg | 1.28 | UK | 0.75 | | |
| Germany | 1.24 | Austria | 0.73 | *Mean* | 0.94 |
| Czech | 1.23 | Poland | 0.64 | *SD* | 0.82 |

*Figure 1*. Mean perception of benefits and risks across 21 countries

Table 2.

*Multilevel models of public perception of benefits and risks*

| | Perception of benefits and risks (-4=more risks; 4=more benefits) | |
|---|---|---|
| | Religiosity/ confidence | Cultural worldviews |
| **Individual level** | | |
| Age | 0.00 | 0.00 |
| Gender | 0.02 | 0.04 |
| Moral acceptability | 0.95*** | 0.96*** |
| Awareness | 0.14*** | 0.12*** |
| Confidence | | |
| Intercept | 0.30*** | 0.31*** |
| GDP per capita | -0.00 | -0.00** |
| Survival value | -0.11* | -0.20** |
| Funding/ GDP | -0.02 | 0.03 |
| Individualism | | 0.00 |
| Religiosity | | |
| Intercept | -0.05** | -0.04* |
| GDP per capita | 0.00 | 0.00 |
| Traditional value | -0.01 | -0.02 |
| Funding/ GDP | -0.00 | -0.01 |
| **Country level** | | |
| Funding/ GDP | 0.10 | -0.30* |
| GDP per capita | -0.00 | 0.00* |
| Economic openness | -0.00 | 0.32* |
| Confidence | 0.78** | |
| Religiosity | -0.11* | |
| Level of post-industrialization | | -0.02 |
| Power distance | | 0.03* |
| Individualism | | 0.01* |
| Egalitarianism | | -0.97* |
| Individualism*egalitarianism | | -0.18† |

*Note*. (1) Entries are unstandardized regression coefficients. (2) N= 10,779 in the "religiosity/ confidence" analysis and N=9,132 in the "cultural worldviews" analysis.

***p<0.001, **p<0.01, *p<0.05, †p<.10.

Table 3.

*Variance components of the multilevel models predicting perception of benefits and risks*

| | | Level-1 variance (DF) | Intercept variance (DF) | Slope variance (DF) |
|---|---|---|---|---|
| **Religiosity and confidence** | | | | |
| Model 1 | Null model | 2.88 | 0.20 (20)*** | |
| Model 2 | Level 1 predictors+ random intercept | 1.39 | 0.19 (20)*** | |
| Model 3 | Random intercept + 2nd level predictors | 1.39 | 0.03 (15)*** | |
| Model 4 | Random slope | 1.35 | 0.03 (15) *** | |
| | Moral acceptability | | | 0.01(20)*** |
| | Confidence | | | 0.01(20)*** |
| | Religiosity | | | 0.00 (20)** |
| Model 5 | Random slope + 2nd level predictors | 1.35 | 0.06 (15)*** | |
| | Moral acceptability | | | 0.01(20)*** |
| | Confidence | | | 0.01(17)*** |
| | Religiosity | | | 0.00 (17)** |
| **Cultural worldviews** | | | | |
| Model 6 | Null model | 2.94 | 0.19 (16) *** | |
| Model 7 | Level 1 predictors+ random intercept | 1.40 | 0.18 (16) *** | |
| Model 8 | Random intercept + 2nd level predictors | 1.40 | 0.10 (8) *** | |
| Model 9 | Random slope | 1.35 | 0.12 (8) *** | |
| | Moral acceptability | | | 0.02 (16)*** |
| | Confidence | | | 0.01 (16)*** |
| | Religiosity | | | 0.00 (16)** |
| Model 10 | Random slope + 2nd level predictors | 1.35 | 0.12 (8) *** | |
| | Moral acceptability | | | 0.02 (16)*** |
| | Confidence | | | 0.01 (12)*** |
| | Religiosity | | | 0.00 (13)** |

***p<0.001, **p<0.01, *p<.05.

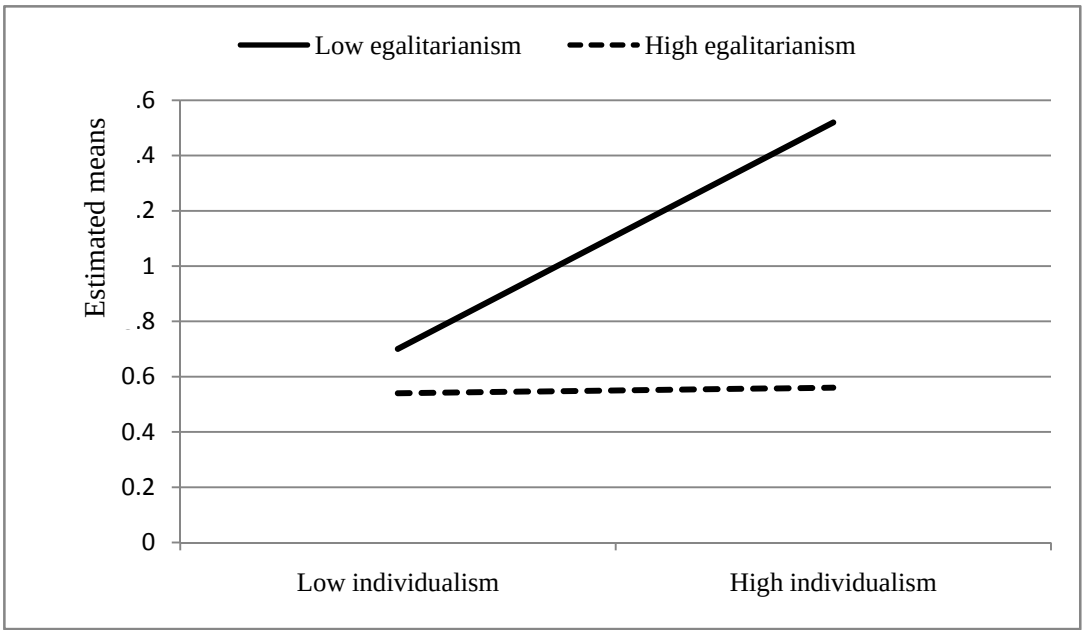



*Figure 4*. Interaction effect of individualism and egalitarianism at the aggregate level.

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