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Risk Perception and Technological Development at a Societal Level

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This article tests the hypothesis that the exposure to the threat to societies posed by the introduction of new technologies is associated with a normalization of risk perception. Data collected in 2000 by the International Social Survey Programme (ISSP) on environmental issues were used to explore this hypothesis. Representative samples from 25 countries were employed to assess the national levels of perceived threat to the environment associated with a series of technologies and activities. These values were correlated with economic indicators (mainly from the World Bank) of the diffusion of each of the technologies or activities in each country. Results indicate a negative association of risk perception with the level of technological prevalence (societal normalization effect) and a positive association with the rate of growth of the technology (societal sensitivity effect). These results indicate that the most acute levels of perceived environmental risk are found in those countries where the level of technological prevalence is low but where there has recently been substantial technological development. Environmental awareness is a mediator of the relationship between risk perception and the indices of technological diffusion. This result means that: (1) societal normalization of risk is not a direct consequence of prevalence of the technology, but is driven by awareness of technological development and that (2) societal sensitivity to risk is associated with lower levels of environmental awareness.

KEY WORDS: Risk perception; societal risk normalization; societal risk sensitivity; techological development

1. INTRODUCTION

This article focuses on the effects of the experience of threat on risk perception. Usually, the literature has approached this issue focusing on individual experience and the societal experience has often been forgotten. This article uses data from an international comparative survey of 25 countries (Table I) to explore the links between the presence of hazards and risk perceptions, and specifically to establish in a cross-cultural context whether the nature of these relationships is consistent with the normalization of risk perceptions.

A large body of literature shows that the continued experience of threatening situations leads to the development of strategies of risk minimization as a way to cognitively adapt to the situation. Contact with a threat has often been associated with becoming habituated to its presence; the association between a hazard and its negative consequences become normalized,[(1–4)] this being particularly true for voluntary risks[(5)] or those with less-visible consequences.[(6)] For instance, Halpern-Felsher *et al.* (2001) have shown, for a number of voluntary and involuntary health risks, that people who have experienced a threat tend to

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Table I. Description of the Sample and of the Main Variables in the 25 Countries

Country	Code	Sample Size	Risk Perception			GDP per Capita[b]
			Mean[a]	*SD*	Alpha	
Austria	A	1,011	3.898	0.542	0.73	26.8
Bulgária	BG	1,013	3.819	0.665	0.86	5.7
Canada	CD	1,115	3.776	0.652	0.81	27.8
Chile[c]	RCH	1,503	4.199	0.519	0.75	9.4
Czech Republic	CZ	1,244	3.798	0.546	0.70	14.0
Denmark	DK	1,069	3.518	0.697	0.79	27.6
Finland	FI	1,528	3.389	0.645	0.78	25.0
Germany	D	1,501	3.869	0.569	0.75	25.1
Ireland	IR	1,205	3.709	0.650	0.80	29.9
Israel	IL	1,205	3.709	0.650	0.74	20.1
Japan	JA	1,180	3.899	0.599	0.79	26.8
Latvia[b]	LV	1,000	3.738	0.641	0.79	7.1
Mexico[c]	MEX	1,262	3.930	0.569	0.67	9.0
Netherlands	NL	1,609	3.208	0.544	0.75	25.7
New Zealand	NZ	1,112	3.750	0.682	0.80	20.1
Norway[c]	NO	1,452	3.383	0.605	0.76	29.9
Philippines	PH	1,200	4.237	0.632	0.79	4.0
Portugal	PO	1,000	4.216	0.559	0.83	17.3
Rússia	RU	1,705	4.144	0.572	0.78	8.4
Slovenia[c]	SLO	1,077	3.860	0.580	0.78	17.4
Spain	ES	958	3.967	0.513	0.78	19.5
Sweden[c]	SW	1,067	3.588	0.598	0.76	24.3
Switzerland	CH	1,006	3.780	0.603	0.82	28.8
United Kingdom[c]	UK	1,717	3.757	0.662	0.82	23.5
United States[c]	US	1,276	3.620	0.635	0.80	34.1

[a]Mean rating of the six common items in the survey.
[b]Gross domestic product per capita in 2000 (PPP in 1,000 US$). Source: UNDP (2002).
[c]This country did not include the optional question about the danger to the environment caused by a nuclear power station.

underestimate its negative consequences, compared to those that have not had that experience. A more persuasive illustration of risk normalization is given by Lima (2004). Using a longitudinal design to look at residents' perceptions of the risk associated with an incinerator, it is clear that residents living near the facility gradually reduce the perceived risk associated with it. This is a much stronger effect than for those living further away. This normalization of the risk has been explained in terms of desensitization to danger,[(7)] as the result of the lack of immediate negative consequences of risk exposure[(1)] and through the development of positive illusions.[(8)]

Another dimension of the relationship between experience and risk perception emphasizes not its individual nature (as a unique experience), but rather its social nature (as a shared experience of a group). Certainly, a focus upon the risk perceptions of aggregates rather than individuals underlies the psychometric approach to risk perception[(9)] and this is one of the grounds upon which the approach has been criticized.[(10)] However, the focus on aggregation was oriented toward showing the universal applicability of the psychometric paradigm; that the structuring of risks is similar across nations. Much less emphasis has been given to exploring differences between aggregations, and more particularly of the reasons for these. Boholm (1998) in a review of 20 years of comparative studies of risk perception provides evidence that the different countries can be concerned about different risks and that the magnitude of risk ratings also varies across countries although relative risk rankings tend to be similar. It is less clear, however, what is responsible for variation across countries. Size of country, annual injury and fatality rates, and the influence of the media have all been considered as explanations.[(11)]

The work noted above suggests that experience of a risk may be instrumental in normalizing the association between a hazard and negative consequences. Does this also happen at the societal level? This article explores this hypothesis in relation to the extent and speed of technological development within a country.

The studies within the psychometric approach itself have systematically shown within the same society that new and unknown risks are much less tolerated than familiar ones.[(12)] Drawing on studies of individual patterns of risk normalization, we might expect that where technologies are established within a country (that is, that they are experienced by citizens—either directly or indirectly[(13)]) that risks are normalized and that they are associated with lower levels of risk perception. There are a few studies in cross-national research in risk perception that are relevant here but in fact they do not support our idea that greater experience of technological development is associated with lowered risk perceptions. The study by Nyland (1993, referred by Boholm 1998) deals, not with technological development *per se,* but with the consequences of the technology. Comparing the mean rates of risk perception between comparable Brazilian and Swedish samples, much higher levels of risk perception in Brazil were interpreted as a consequence of the "factual risk" of annual injury and fatality rates, which were higher in Brazil. Sokolowska and Tyszka (1995), in another rare multinational comparative study in this field, demonstrated that Polish individuals (in particular those that live in very polluted areas) assess environmental and technological risks that surround them as higher, compared to Polish citizens who live in less-polluted areas, and more importantly, to a Swedish sample.[(14)] Since pollution levels in Poland are much greater than those in Sweden, these results suggest that greater consequences of technological development are associated with higher levels of risk perception. This is not in line with the notion that experience of technological development leads to risk normalization.

There is some precedent in the literature for exploring risk normalization at a societal level.[15,16] Barnett and Breakwell (2003) explored processes of risk amplification around the 1995 oral contraceptive pill scare and noted that exposure to the hazard, in the form of a series of notifications about the hazard, was associated with the risk becoming normalized. This work is instructive in highlighting the role of mediated—rather than direct—experience in risk normalization and in positing the processes through which this occurred.

This article took advantage of the opportunity to explore the societal relationship between technological diffusion/development and risk perception across 25 countries. This approach overcomes the methodological problems of previous studies that contrasted only two highly dissimilar cultures.[17] In fact, van de Viejer and Leung posit quite clearly that culture by itself "is not a meaningful variable from a substantive point of view" and that "we need to unpackage the concept into more meaningful antecedents."[18,p.140] The methodological approach undertaken in this study is known as an external validation study,[17] where the meaning of cross-cultural differences are explored with the aid of contextual factors.

Using this methodological approach, and extending the pattern of results of individual risk perception to a societal level, we expect that risks will be normalized in countries where the societal experience with the technology is high. How might technological diffusion best be operationalized at a societal level? Unlike previous work in this area, we will use direct indicators of the existence of the technology. In relation to the effects of individual experience on risk perception, some authors[6] have suggested the importance of multidimensional measures of experience. In line with this we will use societal indicators of both the "*prevalence* of the technology" (the current extent of diffusion of a technology) and the "*evolution* of the technology" (the rate of growth of that technology in the past decade). These two measures will allow us to explore both the effect of the prevalence of the technology on the normalization of risks, and the relationship between novelty (reflected in the speed of the evolution of the technology) and risk normalization. In fact, just as studies on perception and learning teach us that there is habituation to stimuli with frequent exposure, they also teach us that sensitivity thresholds exist. Hence, we can think that the fast growth rates of certain types of technology in a society might lead to the risks of the technology being more salient, and be accompanied by concerns about the robustness of the framework of regulation surrounding that technology, whereas the gradual introduction of that same technology may render it much less salient and of less concern. We are thus proposing what might be called a societal sensitivity effect.

To the extent that we find a relationship between the measures of technological development and risk perception, it is necessary to consider the processes that might explain this. It is a truism to observe that no risk can be perceived unless there is communication[13] and that people know about it. It is thus a reasonable first step to consider the relationship between technological diffusion and risk perception in relation to extent of environmental awareness. In doing this it is assumed that there are signals or notifications[15] within a country about the level of technological diffusion in any particular area. These might be inferred from, for example, the visibility of new employment possibilities or the construction of new buildings. Signals may also take the form of information or images within, for example, media communication. To consider these possibilities, we tested the mediation effects of environmental awareness on the relationship between societal technological experience and risk perception.

In summary, data from an international survey of 25 countries were used to test the normalization of risk perceptions in a societal and cross-cultural context, extending hypotheses validated at an individual level. Survey data relating to risk perception and environmental awareness were compared to national indicators of the societal diffusion of technologies.

Building on the results obtained in relation to individual risk experience, we would predict that countries with greater prevalence of technology will be associated with lowered risk perceptions in relation to those technologies. Second, we would suggest that there will be a societal sensitivity effect such that greater speed of technological development will offset risk normalization and be associated with higher perceptions of risk. Third, we would anticipate that environmental awareness will mediate the relationship between technological development and risk perception.

2. METHODS

2.1. Respondents

The International Social Survey Programme (ISSP) is an ongoing annual survey program of cross-national collaboration, with rotating themes of interest. ISSP country members are represented in the program by university research units that are responsible for collecting individual data in each country, using representative samples of the population. ISSP has mechanisms to control the quality of the sampling and data collection process (see GESIS[19] for more specific information on the requirements of this process). In 2000, the survey focused on environmental issues. Data was collected in different countries, through face-to-face or, in some countries, telephone interviews. Twenty-five countries (Table I) had their data validated by ISSP, and data from all of them was used in this study. Although this sample is far from representative of all countries of the world, the use of all the societies included in the study overcomes the limitations of using bicultural or convenience samples in cross-societal contrasts.

Based on these national samples, mean values of the variables were obtained for each nation because, for our level of analysis, only the positioning effect of the society was at stake.[20] Moreover, the use of representative samples in each country ensures that the average value of the variables correctly represents the average opinion of the overall population, and increases the confidence in the results.[21] Some authors[17] advise the use of similar samples across cultures to control the effects of confounding background variables (e.g., education). However, as the harmonization or equivalence of educational systems in 25 countries is very problematic,[22] this important variable could not be considered as a covariate in the analysis. A mixed strategy was then used to validate our results: similar analyses were conducted with a subsample of respondents coded as having initiated or completed university studies. However, as this was not a criterion of the sampling procedure and the results are not nationally representative at this level, these results will only be presented as footnotes.

The national samples used are identified in Table I. In order to maximize the correspondence between the ISSP data and the indices of technological diffusion, some conversions had to be made. Data from the United Kingdom are produced in two different sets: Great Britain and Northern Ireland. An aggregated score was produced from the weight of each population in the 1997 census: 0.97 for Great Britain and 0.03 for Northern Ireland. The same procedure was followed to create a German score from the West (0.65) and East data (0.35).

2.2. Risk Perception

To assess risk perception, questions on the perceived environmental threat of six technologies or technological problems were used. Respondents were asked to rate the level of danger for the environment (in a 5-point Likert-type scale from "5 = extremely dangerous" to "1 = not dangerous at all") associated with the following targets: (i) air pollution caused by cars; (ii) air pollution caused by industry; (iii) pesticides and chemicals used in farming; (iv) pollution of rivers, lakes, and streams; (v) a rise in the world's temperature caused by the "greenhouse effect"; and (vi) modifying the genes of certain crops. Some countries also included a question with the same formulation in respect of nuclear power stations. Responses were recoded so that higher values corresponded to higher levels of environmental threat. A mean score of the six common items was computed for each individual, low scores standing for low level of perceived risk.

Use of existing large-scale surveys that were not designed for the purpose of this study force us to work with indicators that are not ideal. Here, we obtain an overall estimation of risk, although more specific and content-related issues are not considered. In addition, rating perceived environmental threat is not the most common way of operationalizing risk perception. Slovic,[23] however, notes that risk perception is a subtle concept that can have different meanings in different framings, but "if we are interested in threat potential, risk seems the most appropriate term" (p. 286), as "the meaning of risk incorporates some blend of both probability and loss" (p. 283). The items used to assess risk perception include these dimensions of danger and threat, which are essential to the construct of risk perception.

In cross-cultural research, translation procedures are fundamental to guarantee an equivalent meaning of the items in different societies. ISSP meetings with all countries involved are a way of promoting construct equivalence. Measurement equivalence of the mean risk index was analyzed with internal consistency measures (Cronbach's alpha) for each country (Table I). Results show that the risk construct is coherent across countries as alpha values are above 0.70 for all countries except Mexico (0.67).

2.3. Environmental Awareness

Environmental awareness was measured with three items. For each ("All man-made chemicals can cause cancer if you eat enough of them," "If someone is exposed to any amount of radioactivity they are certain to die as a result," and " The greenhouse effect is caused by a hole in the earth's atmosphere"), respondents were asked to define them as true or false in a 4-point Likert-type scale (1 = definitely true to 4 = definitely not true). As the three phrases are false, to produce a final score of environmental awareness the sum of the three items was computed, after recoding true answers (1 or 2) as 0 and the false answers (3 and 4) as 1. The final scores ranged from 0 to 3; that is, respondents who had correctly adjudged all three items to be false received a score of 3. Again we should note the limitations of working with measures that were not designed for this purpose; the questions are somewhat crude as a measure of environmental awareness and such true/false assessments do not tell us how people feel about a hazard. For our current purposes, however, the inclusion of these questions in the ISSP survey offers a useful opportunity to explore the hypothesis that environmental awareness may mediate any relationship between technological development and risk normalization.

2.4. Diffusion of Technology

National indicators of diffusion of technology were collected from the environmental and development indicators of the World Bank, the United Nations Organization, and the OECD.[24–29] For each of the seven distinct technologies in the ISSP survey, two values were taken for each country: (a) a measure of how widespread/prevalent the technology is in the country and (b) a measure of the speed of the evolution of that technology. For example, the perception of environmental risk due to air pollution caused by cars was associated (i) with the number of automobiles in the country and (ii) with the rate of increase in the number of cars in that country during the last decade. The choice of these national measures was determined not only by their relevance and specificity but also by their availability in credible international sources of validated data. More specifically, the following proxy indicators were used for the seven technologies.

2.4.1. Air Pollution Caused by Cars

For each country the number of passenger vehicles per 1,000 inhabitants in 1999 was used as the prevalence measure (World Bank, 2001, *Environment. Traffic and congestion. Table 3.12*). The same source also provided information about the situation a decade before (1990). A ratio was computed to indicate the progression of the technology. In this case, the growth in passenger motor vehicles between 1990 and 1999 was computed as follows: [(pass99 − pass90)/pass90].

2.4.2. Pollution of Rivers, Lakes, and Streams

For each country the rate of emissions of organic water pollutants per billion cubic meter of freshwater was computed. The water pollution referred to the emissions per kilogram per day in 1998 (World Bank, 2001, *Environment. Water pollution. Table 3.6*), and the fresh water values apply to the annual freshwater withdrawals in the country (World Bank, 2001, *Environment. Fresh water. Table 3.5*). The same sources also provided information about the same situation in 1980, and thus a similar ratio was computed corresponding to the evolution of water pollution in each country, since 1980: [(waterpol98 − waterpol80)/waterpol80].

2.4.3. Air Pollution Caused by Industry

For each country the amount of carbon dioxide emissions per capita for the year of 1997 was noted (World Bank, 2001, *Environment. Energy efficiency, dependence, and emissions. Table 3.8*) as an indicator of prevalence of air pollution. The evolution of this type of pollution was computed with a similar index, in relation to the values of those emissions in 1980: [(airpol97 − airpol80)/airpol80].

2.4.4. Pesticides and Chemicals Used in Farming

To assess the use of these materials in each country, the amount of fertilizer consumption in 1996–1998 in hundreds of grams per hectare of arable land was noted (World Bank, 2001, *Environment. Agricultural inputs, Table 3.2*). The evolution of this consumption was calculated in the same way, between the years of 1979 and 1981: [(pest97 − pest80)/pest80].

2.4.5. A Rise in the World's Temperature Caused by the "Greenhouse Effect"

No direct indicator of this type of environmental threat exists (yet) in this type of national indicators. To overcome this problem, a less-specific indicator was used: the amount of carbon dioxide emissions per capita, as this is the principal cause of global warming. For this reason, the same indicators collected for air pollution were used both for the prevalence and evolution indices.

Table II. Percentage of Respondents Considering Each of the Issues as Very or Extremely Dangerous to the Environment

	Philippines	Portugal	Norway	Netherlands
How dangerous to the environment is:				
Air pollution caused by industry	88.4%	86.0%	54.9%	61.6%
Pollution in rivers, lakes, and streams	76.1%	87.4%	39.4%	38.4%
Global warming (greenhouse effect)	80.8%	86.6%	40.9%	44.5%
Pesticides & chemical products in farming	79.3%	79.3%	43.2%	43.1%
Air pollution caused by cars	84.2%	82.7%	43.1%	31.4%
Genetic modification of crops	67.5%	77.5%	33.1%	24.8%
Nuclear power stations	82.8%	90.5%	–	42.3%

2.4.6. Genetic Modification of Crops

This item clearly focuses on genetic research, and the indicators collected are associated with it: the GERD (Government expenditure on R&D) as a percentage of the gross domestic product (GDP) (OECD, 2002, Table 7) and the expenditures in R&D as a percentage of the gross national income (World Bank, 2001, *Science and Technology, Table 5.11*). These two sources were used because the World Bank, although more complete in terms of the countries covered by the information, does not provide evolution data. On the contrary, OECD tables allow the comparison since 1990 for many of the countries used in this study. For this reason, the evolution of investment in R&D activities was computed using the OECD data: [(GERD2000 – GERD1990)/GERD1990]. For those countries that did not have the information about 2000 available, the last available year was used.

2.4.7. Nuclear Power Stations

For those countries that included the item about the threat caused by the nuclear power stations, an environmental indicator was also used. It referred to the percentage of the energy in the country produced by nuclear power in 1998 (World Bank, 2001, *Environment. Sources of electricity, Table 3.9*). The evolution of the importance of this source of electricity was computed with an index referring to 1980: [(nuclear98 – nuclear80)/nuclear80].

2.4.8. Overall Indicators of Diffusion of the Technology

Many of the individual measures of the diffusion of technology used in this article are very much related to the GDP per capita of the country. In fact, in this sample, only the water pollution (Spearman's $\rho(25) = -0.06$) and the nuclear power indicators ($\rho(15) = -0.00$) are not significantly correlated with GDP. The other indicators present solid positive relationships (ρ values ranging from 0.42 for pesticides and 0.67 for CO_2 emissions and air pollution to 0.75 for genetic research and 0.66 for automobiles). For this reason, GDP per capita in 1999 (UNDP, 2001) was used as overall indicator of technology prevalence. The overall evolution indicator was computed similarly to the other evolution indices: [(GDP99 – GDP89)/GDP89], higher values meaning faster evolution. For those countries where there were no values for GDP per capita in 1989 (e.g., Latvia and Slovenia), the GDP per capita annual growth rate since 1990–2001 (UNDP, 2003) was used.

3. RESULTS

The mean scores, standard deviations, and reliability indices (Cronbach's alpha values) for the overall risk perception index are presented in Table I. Reliability results show that these items are well related in every sample, as alpha values range from 0.67 to 0.86. Although all mean values of perceived risk are higher than 3, they range widely. The highest value is found in the Philippine sample (M = 4.24), followed by the Portuguese one (M = 4.22), while the lowest composite risk ratings were found in the Netherlands (M = 3.21) and Norway (M = 3.38).[4] Table II shows for each item the percentage of respondents stating a strong sense of environmental threat in these four countries. For most of the items, double the percentage of people in Portugal and the Philippines considered the issues as very or extremely dangerous to the environment as in the Netherlands. However, the rank ordering of the issues is similar in all countries.

[4] Analyses conducted with the university subsample show a means profile quite similar to this one. In fact, the correlation between the two in high ($\rho(25) = -0.98$; $p < 0.001$), and the extreme values are also found in the Philippines (M = 4.27) and in Norway (M = 3.38). In addition, no significant difference was found between the results in this subsample and in the overall sample ($t(24) = -1.607$; $p = 0.121$).

Table III. Association Between Perceived Risk and its Societal Diffusion (Spearman's Rho; Results Per Country)

	Prevalence	*N*	Evolution	*N*
Air pollution caused by industry	−0.407*	25	0.735***	19
Pollution in rivers, lakes, and streams	−0.424*	25	0.572**	19
Global warming (greenhouse effect)	−0.530**	25	0.575**	19
Pesticides & chemical products in farming	−0.404*	25	0.281	21
Air pollution caused by cars	−0.439*	25	0.540***	25
Genetic modification of crops	−0.316	25	0.310	10
Nuclear power stations	−0.064	11	0.297	10
Overall environmental risk perception	*−0.564****	*25*	*0.550****	*25*

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

In order to explore the relationship between risk perception and technological diffusion, a correlation between each risk perception indicator and the two measures of technology diffusion was computed. As the number of cases is low, a nonparametric association measure was used (Spearman's *rho* or ρ). Table III shows the results obtained both for the prevalence of the technology and the evolution of the technology.

As we can see in Table III, all correlations with the prevalence of the technology were negative, and all but two are significant. These results are in line with the normalization of risk hypothesis: the greater the prevalence of a technology in a country, the less the danger attributed to it. This result is similar to the effects of familiarity noted earlier in relation to individual risk perceptions.

Another interesting result of this analysis emerges from the correlations between perceptions of environmental threat and the evolution of the technology in each country. In this case, all the correlations are positive, and four of them are significantly different from zero. This pattern of results suggests that a fast growth rate of technology is associated with higher levels of risk perception, while its gradual establishment is seen as less threatening (societal sensitivity effect).

Fig. 1 shows the pattern of results for the two diffusion-of-technology measures in relation to air pollution caused by cars. It is clear that there is a

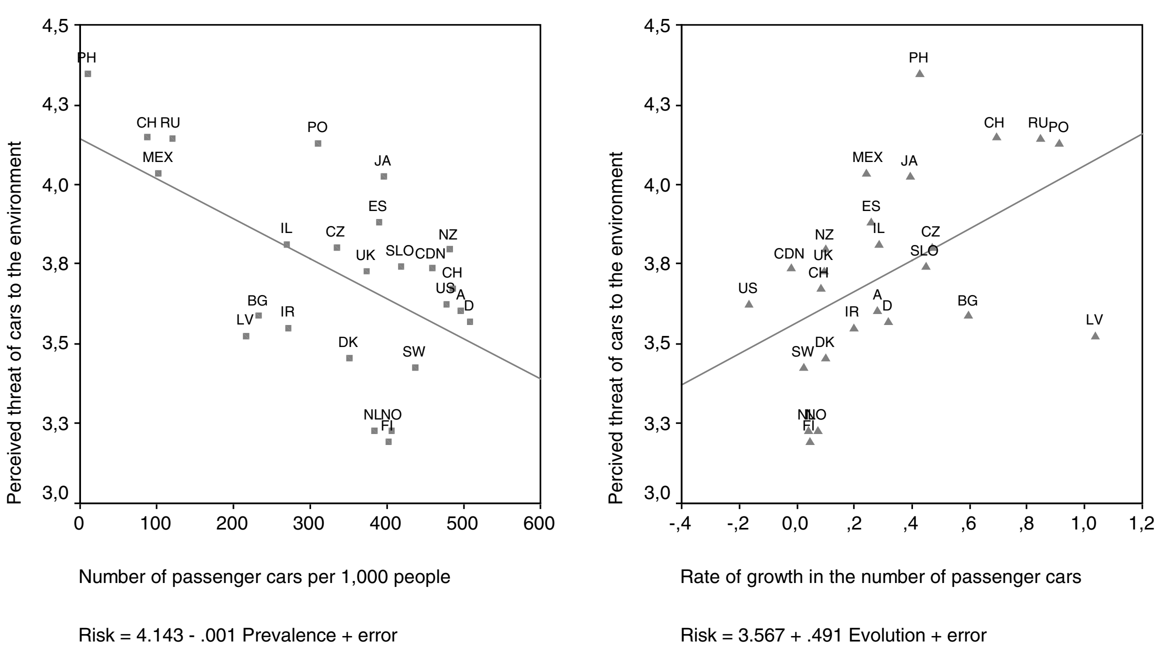

Fig. 1. Plotting of the data concerning the cars: relationship with prevalence and evolution of the number of passenger cars in each of the countries.

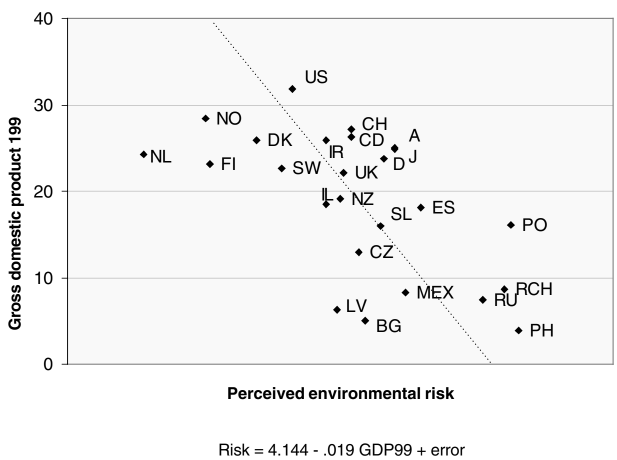

Fig. 2. Plotting of prevalence of technology and risk perception by country.

negative relationship with the prevalence of the technology and a positive one with the evolution of the technology.

One further analysis was conducted with the overall mean score per country of risk perception and the overall index for technology prevalence and evolution. The resultfor prevalence of technology (plotted in Fig. 2) clearly shows the negative association ($\rho(25) = -0.56; p < 0.003$): countries with higher level of GDP show lower levels of perceived environmental risk, while those less economically developed show much higher scores of risk perception. The results for the evolution of technology also show a significant positive correlation ($\rho(25) = 0.54; p = 0.004$).[5] These results also confirm those obtained before, showing that higher levels of risk perception are found in countries with low diffusion but high evolution rates of technology.

The final analysis tests the role of environmental awareness as mediator of the relationship between the two measures of diffusion of technology and risk perception.[6] These analyses were conducted following the procedure suggested by Baron and Kenny.[(30)] First of all, we analyzed the relationship between risk perception and the two GDP measures. Both GDP—prevalence ($R^2 = 0.36$; $F(1.24) = 12.88$; $p < 0.002$) and GDP—evolution ($R^2 = 0.39$; $F(1.24) = 14.99$; $p < 0.001$) are good predictors of environmental risk perception. As we have seen, countries with higher levels of prevalence of technology show lower levels of risk perception ($\beta = -0.599; p = 0.001$) and countries with faster diffusion rates of the technologies show higher levels of risk perception ($\beta = 0.628; p = 0.001$). Then the relationship of diffusion variables with the mediator (environmental awareness) was tested. Both the prevalence indicator ($R^2 = 0.51$; $F(1.23) = 23.16$; $p < 0.001$) and the evolution indicator ($R^2 = 0.48$; $F(1.23) = 20.54$; $p = 0.001$) were strongly associated with levels of environmental awareness. This result means that countries with higher GDP ($\beta = 0.716$; $p = 0.000$) and countries with slower increases in GDP ($\beta = -0.695$; $p = 0.001$) present higher levels of environmental awareness. Finally, when the initial predictor and the mediator were together in the same regression equation, only environmental awareness significantly predicted environmental risk perception. In fact, the final equation for prevalence of technology ($R^2 = 0.53$; $F(2.23) = 12.04$; $p = 0.001$) shows that GDP—prevalence is no longer a significant predictor of environmental risk ($\beta = -0.298$; $p = 0.18$) but environmental awareness is a strong one ($\beta = -0.487$; $p = 0.03$). The same happens when GDP—evolution is the measure of technological diffusion ($R^2 = 0.54$; $F(2.23) = 12.41$; $p = 0.000$): evolution in the diffusion of technology is no longer a significant predictor of environmental risk ($\beta = 0.313$; $p = 0.14$) when environmental awareness is added to the regression equation ($\beta = -0.483$; $p = 0.03$). These results mean that environmental awareness completely mediates the relationship between diffusion of technology and risk perception: prevalence of technology is directly associated with higher environmental awareness, and that predicts risk perception; rapid evolution of technology is associated with lower levels of environmental awareness and this, in turn, with risk perception.[7] A final regression was computed to test the relative predictive value of the two diffusion measures on environmental awareness ($R^2 = 0.58$; $F(2.23) = 14.52$; $p < 0.001$), and the results show that the predictive power of the prevalence indicator is twice as important as the evolution indicator.[8] Fig. 3 depicts these analyses.

5 These values are slightly higher in the university subsample: for prevalence $\rho(25) = -0.61$ ($p = 0.001$) and for evolution $\rho(25) = 0.59$ ($p = 0.001$).

6 Results of this index are well correlated with the ones obtained in the university subsample ($\rho(25) = 0.93$; $p = 0.001$). However, the mean value in the subsample (M = 1.47) is significantly higher than that obtained in the overall sample (M = 1.15; $t(23) = -9.96$; $p < 0.001$).

7 The mediator role of environmental awareness was also found in the university subsample.

8 The same type of results were found in the university subsample. The regression of environmental awareness on risk perception has even more explanatory power in this case than in the overall sample ($R^2 = 0.55$; $F(1.23) = 26.9$; $p < 0.001$).

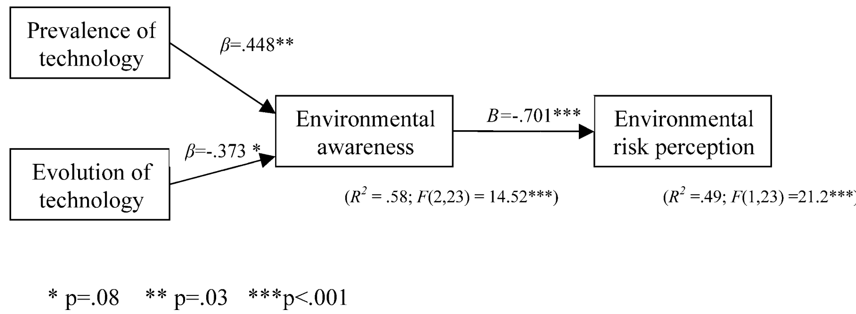

Fig. 3. Diffusion of technology and its relation to risk perception as mediated by environmental awareness.

These results are very important because they show a cognitive mediation between the indicators of technological diffusion and societal risk perception. They suggest that environmental awareness is related to the normalization of risk and, less markedly, that sensitivity to the rapid evolution of technological change is associated with lower levels of environmental knowledge/awareness.

4. DISCUSSION

This study constitutes an attempt to explore risk perception at a societal level, and the results provide a cross cultural extension of the studies exploring the processes underlying risk perception at a national level. It has been suggested that the notion of risk normalization, previously explored at the individual level, can be extended to help conceptualize different patterns of national risk perception. The results also suggest that people "notice" societal signals about the evolution and prevalence of technological growth and respond to these. Drawing on individual learning responses we call this a societal sensitivity effect.

Further light was shed upon this in relation to the measures of technological growth and diffusion that were used. On the one hand, lower levels of risk are found in countries where the technology is more common. On the other hand, they indicate that the countries with a faster growth rate of technology are the ones with higher levels of risk perception, and countries with slower rates of diffusion are associated with risk normalization. This is broadly in line with the notion of a "temporal continuum." However, diffusion rates are likely to vary across time within any one country and thus a more thoroughgoing test of the relationship we are proposing between speed of diffusion and risk normalization would require time series data for both rate of diffusion and risk perceptions.[9] We hope that data from future ISSP surveys on environmental issues will provide the possibility of testing this interpretation.

The most acute levels of perceived environmental threat are found in those countries where the level of technological development is low, despite recent substantial technological growth. In fact, the countries with higher levels of environmental risk perception (Philippines, Portugal) are simultaneously those that still have low levels of diffusion of the technology, but also those that, in recent years, have made a concerted effort to increase the rate of uptake of technologies. In those cases, this high sense of threat may not be directly related to environment concerns, but to a sense of fear of technology. On the contrary, those who perceive low levels of environmental risk are the countries that, now and during the last decade, present a good level of technological diffusion. These countries (such as Norway or the Netherlands) have reached a stable position in terms of technological development, and thus the growth rate is small.

As a consequence of these results, gross national product (GNP) per capita is inversely associated with the global level of perceived environmental threat. This result apparently contradicts what has been called the "wealth hypothesis" of environmental concern: developed and postmaterialistic countries giving more importance to the preservation of environment than the others.[31] However, in line with our results, several studies have shown that less-developed countries are also concerned with environmental issues.[32,33] In particular, some authors[34] showed that the "affluence hypothesis" applies only to the economic dimension of priority for the environment (more related to the willingness to pay to protect the environment). In this case, systematic positive correlations are found between GNP per capita

[9] We are grateful to an anonymous reviewer who suggested this as a way of establishing the explanations that we are offering.

and environmental concern. However, the other dimension of environmental concern, related to health risks, shows a different pattern of results that is compatible with our own: a negative correlation between GNP and this dimension of environmental concern.

These results, however, should be contextualized before they are simply considered as a result of psychological or individual responses. In this article, we used a societal approach to risk perception, and these results should be interpreted in that context in order to avoid an ecological fallacy.[21] Our approach took hypotheses that were previously validated at an individual level and tested them at a societal level. In order to do that, results from representative samples of 25 countries on risk perception and environmental awareness were linked with nation-level measures of technological experience. The use of secondary data has many advantages, but as noted earlier,[35] it constrained our choice of measures in relation to risk perception, environmental awareness, and the proxies for technology diffusion. In order to have the opportunity to use data from representative samples of different countries—an important requirement of the present study—we are aware that this involved the concepts being operationalized in a way that was less than ideal. Similarly, the validated economic indicators chosen as proxies of national technological development are broad and thus we cannot rule out alternative explanations of the results. In order to test the hypotheses, a regression analysis approach was used, similar to what is done by many cross-national studies in many areas (well-being,[36] helping behavior,[37] or environment[34]). Recently, some authors[38] claim that multilevel modeling techniques allow a more appropriate handling of the variance in individual answers nested within countries. However, even with these methodologies, cross-cultural research is always very difficult to interpret, particularly when the measures are limited by availability, and many factors can be confounded in the national-level indicators. In this article, we tried to control one obvious one (the level of education within each country) by comparing the overall results with a cross-national subsample of respondents with similar qualifications (university). Results in this subsample are quite similar to the general ones, although environmental awareness is associated with educational level, as might be expected. This approach allows some increased confidence in the results, but careful interpretation remains essential.

One important question brought into focus by the results of this study is exactly how these technological changes translate into environmental awareness and changed patterns of risk perception. This is one of the questions that is broadly conceptualized within the social amplification of risk framework (SARF).[13,39] The introduction of technology in a society is a complex process, where different groups and institutions need time to adapt to it.[40] For example, legal adjustments have to be made in order to control the emissions of the industry, to protect public health, or to create structures to followup the consequences of new technologies. However, these adjustments take some time. As SARF suggests, they are often the result of collective movements, frequently supported by the media coverage of the introduction of the technologies. It is then plausible to think that national media, in years of rapid technological diffusion, give particular attention to the negative consequences of this development (e.g., accidents or incidents related to that technology), supporting the creation and adjustment of more strict and careful laws. As a consequence of this adjustment, the legal system in developed countries presents a low toleration level for environmental pollution and stronger structures to guarantee environmental protection. Consequently, the societal normalization of the risk process that we identified is not simply the result of the contact with technology but is also likely to be a consequence of efforts to understand and to contain the environmental risks. And the societal sensitivity process we described is not simply the rejection of new risks that society has to face, but the result of a complex societal process of adaptation to them. Of course, there are many other variables that are likely to mediate the relationship between risk perceptions and technological development, such as trust in political or institutional mechanisms to deal with hazards, or the national connotation of each hazard in national media. The mediating role of environmental awareness proposed in this article is an illustration of how these processes have a complex cognitive counterpart. This research thus again highlights the nature of a crucial challenge in risk research,[16,41] that is, to identify the "relational rules" that specify how individual, intra- and inter-group, and societal factors interact in order to produce trajectories of risk amplification—both intensification and attenuation.

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