James K. Hammitt, Jonathan B. Wiener, Brendon Swedlow, Denise Kall, & Zheng Zhou, "Precautionary Regulation in Europe and the United States: A Quantitative Comparison," *Risk Analysis* 25: 1215-1228 (2005), available at:
http://www.blackwell-synergy.com/toc/risk/25/5
DOI: 10.1111/j.1539-6924.20052.00662.x

Duke Center for Environmental Solutions
Working Paper

Precautionary Regulation in Europe and the United States: A Quantitative Comparison

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May 2005

Abstract

Much attention has been addressed to the question of whether Europe or the United States adopts a more precautionary stance to the regulation of potential environmental, health, and safety risks. Some commentators suggest that Europe is more risk-averse and precautionary, whereas the US is seen as more risk-taking and optimistic about the prospects for new technology. Others suggest that the US is more precautionary because its regulatory process is more legalistic and adversarial, while Europe is more lax and corporatist in its regulations. The flip-flop hypothesis claims that the US was more precautionary than Europe in the 1970s and early 1980s, and that Europe has become more precautionary since then. We examine the levels and trends in regulation of environmental, health, and safety risks since 1970. Unlike previous research, which has studied only a small set of prominent cases selected non-randomly, we develop a comprehensive list of almost 3,000 risks and code the relative stringency of regulation in Europe and the US for each of 100 risks randomly selected from that list for each year from 1970 through 2004. Our results suggest that: (a) averaging over risks, there is no significant difference in relative precaution over the period, (b) weakly consistent with the flip-flop hypothesis, there is some evidence of a modest shift toward greater relative precaution of European regulation since about 1990, although (c) there is a diversity of trends across risks, of which the most common is no change in relative precaution (including cases where Europe and the US are equally precautionary and where Europe or the US has been consistently more precautionary). The overall finding is of a mixed and diverse pattern of relative transatlantic precaution over the period.

Keywords: precautionary principle, regulatory stringency, comparative regulation, environmental, health, and safety regulation, risk management

1. Introduction

Much attention has been addressed to the question of whether Europe or the United States adopts a more precautionary stance to the regulation of potential risks. Some commentators suggest that Europe is more risk-averse and precautionary, whereas the US is seen as more risk-taking and optimistic about the prospects for new technology[1]. Others suggest that the US is more precautionary because its regulatory process is more legalistic and adversarial, while Europe is more lax and corporatist in its regulations[2,3]. The flip-flop hypothesis, suggested by Vogel[4,5], asserts that the US was more precautionary than Europe in the 1970s and early 1980s, but that Europe has become more precautionary since then. A variety of other patterns have also been suggested.

There is a significant body of literature comparing the relative precaution embodied in European and US risk regulation[2-18]. However, past research has suffered from shortcomings in the methods used to select cases, collect data, and draw overall comparisons[19]. Some authors chose to study only one sector, such as chemical regulation[15] or workplace safety[17], or one policy area, such as genetically modified food[8,9], and then drew broad conclusions about the general characteristics of national regulatory approaches. Others tried to study diverse cases in various sectors[12], but did not choose their cases according to an unbiased selection method.

This paper provides a more comprehensive and rigorous approach to comparing relative precaution in risk regulation. As described in Section 2, we developed a comprehensive list of almost 3,000 risks identified in the literature over the last three decades, categorized them by risk type and endpoint (ecological, health, or safety), and randomly selected 100 for analysis. For each of the 100 risks, we sought information on the stringency of regulation in Europe and the US for each of the 35 years from 1970 through 2004, and summarized the relative stringency of regulation in the form of a score for each risk and year. The information sources and scoring methods are described in Section 3. We analyzed the distribution and trends in the scores across the sample of 100 risks, by risk type and by ecological, health, and safety endpoint, as described in Section 4. Conclusions are in Section 5.

2. Constructing a Representative Sample of Risks

The objective of our research was to accurately characterize the observed pattern of relative precaution in US and European risk regulation. In subsequent research, the data we collected may be used as the dependent variable to test the ability of other independent variables to explain the observed pattern. Drawing broad conclusions about the regulatory pattern, and the role of explanatory variables, based on case studies selected by convenience or prominence is an invitation to bias and error[20]. To guard against the selection bias evident in past studies requires a systematic method for developing a representative sample of risks that may be subject to regulation. As we were unable to identify a pre-existing comprehensive list, we developed a risk matrix: a comprehensive list of risks organized by two sets of categories (risk type and endpoint).

The matrix was constructed using an iterative search process. First, we identified lists of risks and pooled them. The task of finding risk lists began with a few well-known sources, such as Renn and Rohrmann[21], the US EPA's *Unfinished Business*[22], and numerous studies by Slovic and colleagues[23-30]. Next, we attempted to expand the risk list using a snowball method to pursue sources cited by these original sources. Third, we pursued other search methods, including searching library databases and the World Wide Web, to ensure a thorough search for risk lists in the existing literature.

We attempted to find and include every study of risk perceptions and every risk-ranking exercise published in the US or Europe since 1970. We focused on environmental, health, and safety risks, and ruled out sources that seemed to be exclusively about other kinds of risks. Although we did not include sources dealing exclusively with financial, business, or insurance risks, examples of these risks were included on some of the lists we included, and so these types of risks are represented in our matrix (although not as diversely or frequently as if we had drawn lists from those literatures). The search was also limited to English-language sources and focused on sources from the United States and Europe. But, again, our search methods led us to include sources that covered other countries or regions. Thus, our risk matrix includes risk lists from many areas outside the US and Europe.

While we intended to draw on a population of risk lists produced by scholars, governments, think tanks, and advocacy groups, our search resulted in a population drawn

primarily from academic sources, particularly the literature on risk perception. We assume (1) that the risks appearing on scholarly lists reflect risks that are of concern to the people and organizations that scholars studied, and (2) that the risk concerns of these people and organizations are representative of US and European populations.

The search produced an original matrix of 11,992 "verbatim risks" (i.e., risks described exactly as on the list from which it was taken). These risks come from 403 risk lists[1] from 252 sources. In almost all cases, the verbatim risks were associated with a geographic region. A total of 7,758 risks pertain to the US, 1,712 to Europe, and 1,635 to both. The greater number of risks for the US than for Europe may reflect the fact that the primary research was conducted in the US with easier access to US sources. It may also reflect a larger underlying volume of risk research produced in the US than in Europe. We are unsure whether it could reflect a larger variety of risks having been of concern to scholars, policy makers and the public in the US than in Europe.

Since this study focuses on the United States and Europe, the 887 risks (from 29 risk lists and 24 sources) pertaining to other regions were deleted, leaving a total of 11,105 verbatim risks, 374 risk lists, and 228 sources. The final matrix includes only 10,869 risks because 122 unique risks were deleted when we decided they were not really risks or were too vague to study,[2] and 19 risks were inadvertently overlooked when transferring risks from one worksheet to another.

The matrix of 10,869 verbatim risks was condensed to 2,878 "unique risks" by combining essentially identical verbatim risks by reducing plurals and singulars to a common form, standardizing punctuation, and removing unique expressions.[3]

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[1] The 403 risk lists are not unique, because some were replicated in articles or book chapters. We include not only tables of risks, but also multiple risks appearing in figures, tables of contents, and even risks appearing in text. Case studies including two or more risks were also included.

[2] We used strict criteria to eliminate as few risks as possible, but some initially included in the matrix appeared unsuited to regulation (e.g., friend does not appreciate a gift) or too broad or vague (e.g., lifestyle, children, all accidents, exposure) to permit study of regulation. We erred on the side of including risks if we believed it was at all possible to study their regulation, leaving many difficult-to-study risks in the matrix.

[3] For example, "police work" became the common label for risks that appeared as "policework" and "being a policeman." More controversial relabeling collapsed different aspects of the same risk into the relabeled risk. For example, if nuclear power was selected,

Although we attempted to develop as unbiased a process as practical for constructing the risk matrix, the snowball literature-search method we adopted may favor particular lines of research. We are confident, however, that if other researchers followed our procedures and criteria, they would produce a matrix substantively comparable to ours, albeit with some differences in distribution. While acknowledging the many constraints and weaknesses of our matrix, we believe that given the time and resources available to us, it represents a comprehensive list and a substantial improvement over previous studies.[4] We believe our method of comprehensive literature search is superior to other possible methods such as surveying risks that are currently regulated, compiling lists from governmental publications, or focusing only on visible, salient risks (e.g., from news media coverage), because those methods omit risks that could be of concern but not yet regulated in one legal system or the other – precisely the kind of emergent risks that might in time be subject to precautionary regulation, or that might illustrate interesting contrasts across the legal systems.

2.1 Risk-Type Categories

No single method of categorizing risks can serve all useful purposes[31]. We developed two approaches to categorizing the universe of 2,878 unique risks: by type of source or cause, and by endpoint (ecological, health, or safety). The risk types are mutually exclusive, so that each risk appears in exactly one risk-type category. In contrast, the endpoint categories are not exclusive, as a risk may pose ecological, health, and/or safety

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a reasonable person would consider nuclear power plants, nuclear power accidents, radiation from nuclear power plants, employees at nuclear power plants, residents living near nuclear power plants, and so forth. Therefore, any unique risk that would clearly be studied if one was studying nuclear power was labeled as nuclear power. (Nuclear waste risks were kept distinct from nuclear reactor risks.) Unique risks that were more specific and might be considered in a case study were labeled more specifically. More specific risks were usually hyphenated with the more general risk first, followed by specifics. For example, the unique risk "East European nuclear power plants" was relabeled as "nuclear power – East European."

[4] Assembling the list of 11,992 verbatim risks from 252 sources and organizing it into the list of 2,878 unique risks took approximately one year of work by a full-time postdoctoral fellow and six part-time research assistants, plus a few additional temporary research assistants. Categorizing the risks and scoring the sample of 100 took an additional year of work by two full-time graduate research associates.

consequences. The categorization of the risks was primarily of interest as a way to characterize the terrain of the universe of risks. The categories were not necessary to nor used in our random sampling and scoring of 100 risks, though they could be used in a future stratified sampling exercise.

To the best of our knowledge, ours is the first attempt to categorize the risk universe. Of course, no single or static set of risks could encompass the risk universe, because awareness of risks is continuously changing as technology, science, perceptions, and values change.

Initially, we read through the list from top to bottom assigning number 1 to the first risk and every subsequent risk that appeared similar to it, the number 2 to the first risk that appeared different from category 1 and every subsequent risk that appeared similar to it, and so on. This helped us group similar risks together and allowed us to begin to see what subcategories might exist and how risks might have to be re-categorized to gain the greatest logical coherence. This coding exercise also helped us to see that there was no one right way to code all risks, that there were tradeoffs in different coding systems, and that some risks resisted categorization.

The coding effort required many judgment calls. For example, many risks could fall into more than one category (e.g., environmental tobacco smoke could be classified as tobacco or air pollution). Many of the challenges involved whether to establish a new category or subcategory, what to name it, and how broad or specific to make it. We relied on our intuitions based on our knowledge of the world today, such as how different regulatory agencies deal with different risks.

Table I lists our 18 major risk-type categories together with the distribution of the 2,878 unique risks among them. The categories include: (1) crime and violence, (2) alcohol, tobacco and other drugs, (3) medication and medical treatment, (4) transportation, (5) accidents not elsewhere classified, (6) recreation, (7) war, security and terrorism, (8) toxic substances, (9) food and agricultural, (10) pollution, (11) energy, (12) political, social and financial, (13) ecogeological, (14) global, (15) human disease/health, (16) occupational, (17) consumer products, and (18) construction. The categories are further divided into 92 subcategories (not reported).

The frequency distribution of unique risks by category in the overall matrix of 2,878 risks is presented in the third column of Table I. The smallest category (construction risks) includes only 1.4 percent of the unique risks, while the largest category (occupational risks) includes 15 percent of the unique risks. The mean fraction of risks per category is 5.6 percent, the standard deviation is 3.8 percent, and the median is 4.5 percent.

2.2 Endpoint Categories

We also categorized the risks according to whether they affect ecological, health, or safety endpoints. Although these terms are frequently used to describe risks, the definitions are not precise, and many risks can be reasonably included in more than one category.

We categorized risks as ecological, health, or safety depending on the endpoint, not the agent or vector. By our definition, health and safety risks threaten humans directly, while ecological risks threaten non-human endpoints. The US Environmental Protection Agency defines an ecological impact as "the effect that a man-caused or natural activity has on living organisms and their non-living (abiotic) environment"[32].[5] We restate this definition as: *ecological risks are risks that may harm non-human organisms and their supporting physical conditions.* We describe these risks as ecological rather than environmental to encompass risks to both the abiotic environment and its organisms. We restrict attention to non-human organisms because risks to humans are classified under health and safety. Examples of ecological risks include biodiversity loss, oil spills, acid rain, pesticide and chemical pollution, and hazardous-waste sites.

Distinguishing between health and safety risks is more difficult because both are risks to humans. Drawing from Center for Disease Control and Prevention[34], Koren[35], and Webster's Third International Dictionary[36],[6] we define health as human physical,

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[5] EPA[32] defines ecological/environmental risks as "the potential for adverse effects on living organisms associated with pollution of the environment by effluents, emissions, wastes, or accidental chemical releases; energy use; or the depletion of natural resources." This definition includes humans, but not the abiotic environment. Kolluru's[33] description of ecological/environmental risks focuses on habitat and ecosystem impacts. Risk characteristics include "subtle effects, myriad interactions among populations, communities, and ecosystems (including food chains) at micro and macro level" (p. 1.11).

[6] Webster's Third International Dictionary[36] defines health as "the condition of an organism or one of its parts in which it performs its vital functions normally or properly: the state of being sound in body or mind." Similarly, the Center for Disease Control and

mental, and social well-being,[7] where well-being is the unimpaired ability to perform vital functions. Characteristics that differentiate health risks from safety risks are identified by Kolluru[33]. Health risks typically derive from "chronic (long-term) exposure to low-concentrations"[33: 4.6] and have long-latency, delayed effects. However, diseases can manifest years later from acute (short-term) exposures as well. Therefore, we define *health risks as risks that may cause latent illness, disease, or other impairments of health to humans as a result of acute or chronic exposure.* Examples of health risks include AIDS, pesticides in food, hazardous-waste sites affecting humans, air pollution, cigarette smoking, and alcohol.

Kolluru[33: 4.6] states that "safety risks stem from acute hazards", are usually characterized by a low probability of high exposure, high-consequence accidents, and have acute, immediate effects. "The endpoints are well defined: fatalities, injuries, and economic losses"[33: 1.13]. We define *safety risks as risks that may cause injury or fatality to humans as an immediate result of acute (i.e., short-term) exposure.* Safety risks include workplace accidents, automobile crashes, airplane crashes, bridge collapses, and terrorism. Although these safety risks may impair one's health, these are immediate effects instead of long-latency, so for our purposes we classify them as safety risks.

Table II reports the distribution of the 2,878 unique risks by endpoint category. Most risks affect more than one endpoint category. More than one third of the risks affect all three endpoints, one quarter affect two endpoints (usually health and safety), and one third affect only a single endpoint. About two percent of the risks are classified as affecting none of these endpoints.[8] About three quarters of the risks affect health or safety, and almost half affect ecological endpoints.

Prevention[34] defines health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." Koren's[35] definition is comparable: "the avoidance of disease and injury and the promotion of normalcy through efficient use of the environment, a properly functioning society, and an inner sense of well-being" (p. 191).

[7] We include social and mental well-being for their own sake and where they influence physical well-being.

[8] Examples include burglary and social/ethical/cultural impacts of technology.

2.3 Sample Selection

From the final matrix of 2,878 unique risks, we drew a simple random sample of 100 risks (without regard to category). Randomness in case selection is critical to controlling selection bias and permitting valid inference. We recognize that our sample is not randomly drawn from the universe of risks, because we had no list (or random sample) of the universe to begin with and had to construct our matrix of 2,878 risks using non-random methods as described above. Nevertheless, we believe this represents a substantial improvement over past studies focusing on a few cases selected by convenience or prominence, or on one industry sector.

The random sample appears to be highly representative of the matrix of unique risks. As shown in Table 1, the sample includes risks from all 18 major risk-type categories except one, construction, which has the smallest number of unique risks and hence the smallest probability of being sampled. The largest number of risks (17) comes from the largest category, occupational risks. The difference between the percentage of the random sample of 100 and the percentage of the matrix of 2,878 is 2.5 percentage points or less for all categories except transportation, which includes 13 percent of the random sample but only 8.2 percent of the matrix, a difference of 4.8 percentage points. The randomly selected risks span about half of the 92 subcategories.

The random sample is also representative with respect to endpoint categories, as shown in Table II, although safety risks appear to be slightly over-represented. The fractions of risks that affect ecological, health, or safety endpoints are 45, 72, and 78 percent in the sample, respectively, compared with 48, 76, and 73 percent in the matrix.

3. Characterizing Relative Precaution

To evaluate relative precaution between the United States and Europe, we compared regulation of the 100 randomly selected risks from 1970 through 2004. This comparison involved two stages: collecting information on regulation of each risk in the United States and Europe, and using that information to develop a score indicating which region was more precautionary for each risk. These stages are described in the following subsections.

3.1 Regulatory Information

The first step was to gather all relevant regulatory information for each of the sampled risks in both regions over the past 35 years. The goal was to collect information about all major regulations, including date of enactment, quantitative measures of stringency, narrative legal language, expressions of or allusions to the Precautionary Principle or precaution, and other relevant information. Researchers scoured numerous sources for such information, including US statutes, the Federal Register, and the Code of Federal Regulations; US state laws and regulations; European Union legislation, directives, and regulations; European national (member state) laws and regulations; judicial decisions (case law) in these jurisdictions; and scholarly commentaries, the World Wide Web, and library catalogs and databases. For each risk, a dossier was prepared synthesizing this research and scoring relative precaution over the 35-year period.

Several problems arose in this search process. One dilemma was the question of which jurisdictions to compare. Given our interest in precautionary behavior, we were interested in the first populous political entity to regulate a risk. We defined populous political entities as the federal government and state governments in the United States, and the EU and national governments in Europe, while recognizing that this definition omits cities or other local governments which have sometimes been the first to attend to particular risks.

For the US, the federal government regulates many risks and sets minimum national standards, so information was sought at the federal level for all risks. State information was also gathered for risks that were regulated at the state level and might have been more precautionary than the federal regulations. In general, we used the federal laws and regulations for comparison unless a risk was regulated only at the state level, or was regulated earlier or more strictly at the state level.

For Europe, the task was more challenging, as many risks are regulated by the national governments of the EU member states, and we were unable to investigate the regulation of all 100 risks in every member state. Moreover, even the set of states that are "European" has changed over the 1970 to 2004 period we analyze (e.g., the number of states comprising what is now the European Union has grown from six in 1970 to 12 at the 1992 Treaty of Maastricht to 25 in 2004). We defined "Europe" as Western Europe,

including the 15 member states that comprised the EU in 2003 plus non-EU members such as Norway and Iceland. If a risk was regulated at the European Union level, we searched for directives and regulations by the EU institutions (i.e., Council, Commission) that prescribe basic actions and harmonized standards. We also attempted to find the most precautionary country in Europe for each risk, starting with Germany, Sweden, the United Kingdom, France and the Netherlands, which are often said to be among the countries from which more precautionary standards emerge.

The quality of our data collection was also affected by several factors. First, our ability to collect information on European regulations was hindered by differences in language. We attempted to overcome this obstacle by enlisting several secondary researchers from Europe (including Europeans studying at Duke Law School) who provided additional information on countries such as Germany. Second, the quality of our data varies over time because of the advancing use of the World Wide Web. Information about recent regulations is much more easily accessed than information on regulations from the 1970s and hence our information is more complete for the latter part of the period. For 12 risks in the sample, we were unable to find any information on regulation in Europe or the US, possibly because these risks are unregulated in both polities.

3.2 Scoring

We evaluated the information on US and European regulations to determine which polity was more precautionary in each year from 1970 to 2004. We measured precaution by two components: earliness and stringency[37: 1513-1514]. The polity that regulates a risk earlier and more stringently than the other is considered more precautionary. We developed a comparison of the stringency of existing regulations in each year from 1970 through 2004. Regulations were analyzed by the date of enactment, not date of implementation. This choice reflects which region first took action. Neither compliance nor effectiveness of regulations was considered in this task due to the extreme time and effort required to evaluate those highly contextual attributes. Our results thus reflect announced standards more than actual standards in practice. If there is a systematic tendency of one legal system to use more precautionary language, but to enforce that language less stringently than the other legal system, our scoring results would reflect the language alone. Our comparison of regulatory stringency is purely categorical. In each

year, we judge whether the US or Europe has the more stringent regulation, but we did not attempt to distinguish cases where one regulation is only slightly more stringent than another from cases where one regulation is much more stringent than the other. We also made no attempt to determine the date at which information or awareness about a risk began to arise, and so we cannot compare earliness of regulation, relative to emerging information, across risks. Nor could we assess relative precaution in terms of earliness of regulation compared to the eventual manifestation of a risk.[9]

For each year, a polity received one point if its overall regulation of a particular risk is more stringent than regulation in the other polity in that year. The score for a year is +1 if the European regulations are more stringent, -1 if the US regulations are more stringent, and 0 if the regulations are equally stringent or if we were unable to determine which are more stringent. Therefore, positive scores represent greater European precaution and negative scores represent greater US precaution. Each risk received a score for each of the 35 years from 1970 through 2004. The more stringent (and thus precautionary) polity receives one point every year until a change in regulation occurs. When a change occurs, we evaluate how the change influences relative stringency. This approach automatically incorporates the earliness component because if one polity regulated a risk before the other, then until the second polity started to regulate that risk, the former is considered more precautionary. We calculated the average score for each risk over time, which is bounded between -1 and +1. An average score at the boundary of -1 or +1 would be achieved for a risk where the US regulations were more stringent than the European regulations in *all* 35 years, and a risk where the European regulations were more stringent than the US regulations in *all* 35 years, respectively.

The scoring of regulatory stringency in each year presented several challenges and required extensive judgment. Many risks are multidimensional and thus have many aspects to compare. In cases where we were able to obtain sufficient information, all aspects were compared and the region that was more precautionary on the most important aspects was

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[9] These limitations of our quantitative study, which is broadly representative but shallow in its investigative detail, highlight the need for complementary research on comparative law in context and in action[38], and on case studies of the policy process over time[39], which are narrower in scope but deeper in detail.

scored as the more precautionary. Some risks were too broad to compare all aspects and were scored as a tie by default.

Another challenge is that regulations may be difficult to compare for a variety of reasons. For example, regulations may use different strategies or approaches. One country may rely on command-and-control regulations while another uses a tax or a tradable-permit system. The default judgment in such cases is to score the regulations as a tie unless we have a solid reason to make a judgment about which regulation is more precautionary. Similarly, regulations may use different quantitative measures. For example, as noted by Haward et al.[40], US and EU policy differ in the frequency with which concentrations of ozone in ambient air can exceed the legal standard, with the US permitting only one exceedence per year and the EU permitting 26 exceedences per year but with the EU imposing a more stringent concentration standard. Without knowing the time distribution of ozone levels over a year, it is difficult to judge which standard is the more stringent.

The time resolution of our scoring is limited to calendar years, so that if both the US and Europe regulated a risk in the same year (at the same level of stringency), they would be treated as equally precautionary. This limitation is probably not important to the interpretation of our results, because regulations typically require more than a year to develop and it is unlikely that both polities would adopt regulations in the same year unless the risk had attracted significant concern in both of them.

We developed confidence weights to indicate our degree of assurance about which polity had the more stringent regulations in each year. The confidence weights range from 0 to 3, with 0 representing no confidence and 3 representing very high confidence in the relative-precaution score. Weighted scores were calculated for each year as the product of the confidence weight and the precaution score and normalized so the weighted scores are bounded by -1 and +1. This approach gives less weight to precaution scores that may be less reliable due to incomplete information. We prefer to rely on the confidence-weighted scores rather than the unweighted scores, as the confidence-weighted scores provide a more accurate picture of our judgments about relative precaution.

We also entered codes to document missing information for each risk and year, distinguishing between cases where the information was missing for Europe, for the US, and for both polities. In addition, we recorded the jurisdictional level at which the

regulations were promulgated, whether it was at the US federal level, US state level, EU level, European national level, or any combination of these levels.

Scores were assigned by two of the authors (Kall and Zhou), working independently. As described in the following section, the two sets of scores are similar, which provides some evidence for the reliability of the scoring process. The two sets of scores and confidence weights were combined to provide a single set of consensus scores and confidence weights for analysis (consensus weighted scores for each risk and year are the product of the corresponding consensus confidence weight and consensus score). In cases where the researchers assigned the same score or weight, that value became the consensus value. In cases where they assigned different values, the consensus value was achieved by discussion. This method permits sharing information and understanding between the researchers. Empirically, the consensus values are similar to a simple average of the two scores.

To evaluate overall precaution and trends in precaution, we averaged the weighted and unweighted scores across risks. This procedure gives equal weight to each risk: we made no attempt to account for the magnitude of the risks or the effectiveness of the regulation as measured, e.g., by the actual impact on health, safety, or ecosystems. If one region is systematically more precautionary with respect to large or important risks, and the other is systematically more precautionary with respect to small or less significant risks, our method would not allow us to identify this difference.

4. Results

In this section, we report our estimates of the extent to which one or the other region has exhibited more precautionary risk regulation. We analyze average relative precaution over the 35 year period, examine trends over the period, and conclude with an evaluation of the reliability of our scoring procedure.

4.1 Average Precaution 1970-2004

To construct an aggregate measure of relative precaution over the entire period, we averaged both the unweighted and confidence-weighted annual consensus scores over each of the 35 years from 1970 through 2004. The resulting average scores are reported for the 18 major risk-type categories in Table III, and for the endpoint categories in Table IV.

As shown in Table III, the average relative precaution over the 35 year period differs across risk categories, with Europe apparently slightly more precautionary than the US in a majority of categories. Using the weighted scores, Europe appears to have been slightly more precautionary than the US for the average risk in ten categories (68 risks), slightly less precautionary than the US for the average risk in five categories (29 risks), and equally precautionary for two categories (3 risks).

To test whether the difference in apparent precaution for a risk category could be due to sampling variability, we construct t-statistics on the assumption that the scores assigned to risks in the same category are probabilistically independent. This test is likely to overstate the degree of statistical significance, because information about risks in the same category is likely to come from similar sources and scoring errors resulting from limitations of the data we collected or misinterpretation of regulations are likely to be positively correlated across risks. Using the confidence-weighted scores, the difference in relative precaution appears to be statistically significant in two cases (alcohol, tobacco, and drugs; recreation). Using the unweighted scores, the difference appears to be statistically significant for these two cases plus a third (pollution). In all three cases, the US appears be more precautionary than Europe. Because these tests are likely to overestimate the degree of statistical significance, we conclude that there is little evidence of any variation in relative precaution between broad risk categories.

Aggregating over all 100 risks, the average weighted and unweighted scores are both very close to zero, and neither differs from zero by a statistically significant amount. The average weighted score is slightly greater than zero (suggesting greater European precaution), and the average unweighted score is slightly less than zero (suggesting greater US precaution).

Table IV reports the average weighted and unweighted scores for the risks aggregated by endpoint categories. None of the t-statistics approach conventional significance levels, so we cannot reject the hypothesis of no transatlantic difference in relative precaution in any of the endpoint categories. As in Table III, the t-statistics are calculated on the assumption that errors in coding are independent between risks, and so these tests are likely to overstate the degree of statistical significance.

4.2 Trends in Relative Precaution

To examine whether the degree of relative precaution has changed over the 35 year period, we average the relative precaution scores across risks for each year and plot the results as a function of time. Figure 1 shows the resulting patterns for the average of the 100 risks. The results are weakly consistent with Vogel's[4,5] flip-flop hypothesis. The unweighted score suggests that the US exhibited greater precaution than Europe from 1970 through the late 1980s, including increasing relative US precaution during 1980-89, and that Europe became relatively more precautionary during the 1990s and early 2000s. The confidence-weighted score suggests a relatively static balance of relative precaution from 1970 through the late 1980s, followed by increasing relative precaution in Europe during the 1990s and early 2000s. In contrast to the unweighted score, the weighted score is uniformly greater than zero, suggesting Europe was more precautionary on average in the 1970s as well as in later periods. Both scores, but especially the unweighted values, suggest a shift toward greater relative precaution in the US during the 1980s, which is surprising because the Reagan administration (1981 – 1989) is not usually seen as an advocate of more stringent environmental, health, and safety regulation. Consistent with the slightly decreasing relative precaution of US regulation we observe after 1990, Lazarus[41] notes that voting on environmental bills in the US Congress reflected bipartisan support until 1990, after which voting increasingly diverged along partisan lines, with Democrats increasingly voting for, and Republicans increasingly voting against, more stringent environmental laws. This increasing polarization may have contributed to a decline in relative precaution in the US if it impeded the enactment of new laws and regulations.

The estimated magnitude of the change in average relative precaution is quite modest. By the year 2004, European regulation is less than 0.1 points more precautionary on average than US regulation (on a range from –1 to +1). Comparing average relative precaution in the last five years of the period to average relative precaution in the first five years, the weighted and unweighted scores increase by 0.06 and 0.12, respectively. To put these changes in perspective, note that a change of 0.06 in the weighted score would be achieved if the regulations of three percent of risks unambiguously changed from greater precaution in the US to greater precaution in Europe, with no change in the relative

precaution with which the remaining 97 percent of risks were regulated. A change of 0.12 in the unweighted score would be achieved by a shift in regulation of six percent of risks (from more precautionary in the US to more precautionary in Europe) with no change to the remaining 94 percent.

A statistical test for the change in relative precaution is difficult to construct because the annual scores for each risk are not independent, since incomplete data on regulations about a risk and errors in the coders' judgments about relative stringency will tend to be common across multiple years. Moreover, it is difficult to know how to model the dependence of scores across years. It seems reasonable to suppose that the degree of dependence declines with temporal distance, because changes in regulation are more likely to be introduced over a longer time span. Hence, we test for the apparent change in trend by comparing the average scores across all 100 risks in 1970 and in 2004 with the average score in 1989. Under the assumption that the scores in 1970 and 2004 are independent of the scores in 1989, we cannot reject the hypothesis of no change in relative precaution between 1970 and 1989 (the t-statistic equals 0.32 for the weighted scores and 0.33 for the unweighted scores). Comparing 2004 with 1989, we cannot reject the hypothesis of no change using the weighted score and can reject this hypothesis at the 10 percent significance level using the unweighted scores (the t-statistic equals 1.46 for the weighted scores and 1.71 for the unweighted scores). Because these tests are likely to overstate the confidence with which we can reject the hypothesis of no trend, we conclude there is suggestive evidence of a slight trend between 1989 and 2004.

Figure 2 presents the time patterns for the risks classified by endpoint, using the weighted scores. The results suggest that the pattern observed for all risks in Figure 1 is also observed for risks having ecological, health, or safety effects. The apparent trend is strongest for ecological risks, where the mean weighted score increased by 0.19 between 1970 – 1974 and 2000 – 2004. For health and safety risks the corresponding changes are 0.07 and 0.05, respectively.

In evaluating the trends by endpoint category, it is important to recognize that the endpoint categories are not independent, because many of the risks are included in more than one category. As shown in Table IV, 39 risks are included in all three endpoint categories and 16 are included in both health and safety endpoint categories. The numbers

of risks that are included in only a single endpoint category are 3 in ecological, 16 in health, and 21 in safety.

A complementary method for evaluating time patterns of relative precaution is to identify a set of possible patterns and investigate how many risks are consistent with each pattern. Figure 3 reports the number of risks in our sample of 100 that are consistent with each of 10 alternative patterns (using the unweighted scores). The most common pattern, exhibited by 33 risks, is that Europe and the US are equally precautionary over the entire period. To some extent, our analysis is biased in favor of finding no difference in precaution (or trend in relative precaution) because this is the default score in the absence of information to the contrary. For 12 risks we have no specific information on regulations and so scored these as equally precautionary in every year. Excluding these 12 risks leaves 21 risks showing equal precaution across the full period, still almost twice as many as showing any other pattern. The second most frequent pattern is an oscillation or other complex pattern (12 risks). A total of 20 risks show a difference but no change in the direction of relative precaution. Of these, Europe is more precautionary in 11 cases and the US is more precautionary in 9 cases.

The slight trend suggested in Figures 1 and 2 is generated by the difference between 21 risks for which Europe has become relatively more precautionary and the 14 risks where the US has become relatively more precautionary. The 21 risks for which Europe has become relatively more precautionary include nine for which the US and Europe were originally equally precautionary and Europe has become more precautionary, seven for which the US was initially more precautionary and the two polities are now equally precautionary, and five for which the US was more precautionary and Europe has become more precautionary. The 14 risks where the shift has gone the other direction include 11 for which the two polities were equally precautionary and the US has become more precautionary, two for which Europe was more precautionary and the two polities are now equally precautionary, and one for which Europe was more precautionary and the US

has become the more precautionary.[10] As indicated in Figure 3, this is a diverse mixture of patterns, and not a very strong overall trend.

Finally, we note that the apparent modest shift toward greater relative precaution in Europe than in the US may reflect an artifact of our data-collection methods. As noted above, information on current regulations is much more frequently accessible through electronic means than is information on older regulations. To the extent that information on older US regulations is more readily accessible to our US-based research team than information on older European regulations, our results would be biased toward finding greater relative precaution in the US in the earlier years we studied, i.e., the 1970s. This factor should have less effect on the weighted scores than on the unweighted scores, as the risks and years for which we have limited information on European regulations are given low confidence weights. Indeed, Figure 1 shows less relative US precaution in the period 1970-89 using the weighted scores than using the unweighted scores.

4.3 Reliability of Scoring

To evaluate the reliability of the scoring procedure, all 100 risks were scored independently by two of the authors. In cases where their scores or confidence weights differed, the coders discussed the cases and reached a consensus score and confidence weight, which are used in the main analysis. In this section, we compare the original scores with each other and with the consensus scores.

The time patterns for each of the two coders' scores, together with the average of their scores and the consensus score, are presented in Figure 4 (weighted scores). Both researchers' scores yield the same pattern of little change in relative precaution from 1970 through about 1990, and a reasonably steady albeit slight trend toward relatively greater precaution in Europe after about 1990. However, the researchers appear to differ systematically in their judgments about relative precaution, with Researcher 1 assigning higher scores on average (indicating greater European precaution). Over the 35 years, the

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[10] The effect of these changes on the unweighted score can be calculated as [9 (+1) + 7 (+1) + 5 (+2) + 11 (-1) + 2 (-1) + 1 (-2)] / 100 = 0.11. Note that this value is almost identical to the change in the unweighted score between the first and last five-year subperiods, 0.12.

average difference between the researchers' scores is 0.10 for the weighted score and 0.11 for the unweighted score.

For both weighted and unweighted scores, the consensus scores are similar to the average of the two researchers' scores, but are closer to Researcher 1's original scores than to Researcher 2's. The differences in scores appear to reflect a variety of factors. Some of the variation is simply random, as when one of the coders missed or misunderstood some information that the other noticed. Other variations were systematic. In cases where the researchers had limited information on European regulations but believed such regulations to exist, and had good information on US regulations, Researcher 1 scored the risk as one of equal precaution (0) and Researcher 2 scored it as greater US precaution (-1). This pattern appears to account for a significant part of the difference in unweighted scores, but should have less effect on the weighted scores because Researcher 2 assigned small confidence weights in these cases.

In assigning confidence weights, Researcher 2 had a tendency to give higher confidence weights in general, and Researcher 1 had a tendency to give lower confidence weights when unsure whether all the European information was available. In cases where good European information was available, Researcher 1 typically assigned greater confidence weights, which tends to shift the weighted scores toward larger values (indicating greater European precaution). In general, Researcher 1 assigned lower confidence weights and more ties in cases where Researcher 2 judged the case one of greater US precaution, a pattern which contributes to Researcher 1's higher average weighted scores.

5. Conclusions

This analysis represents the most methodologically rigorous attempt of which we are aware to investigate the relative extent of precautionary regulation of ecological, health, and safety regulations in Europe and the United States. In developing our methodology, we identified and developed workable answers to a number of challenges, including the need to describe the set of risks that might potentially be subjected to precautionary regulation; the need to assemble a database representing the universe of risks and draw a representative sample from that list; the difficulty of obtaining comprehensive

and comparable information on regulation in the US and Europe; and the difficulties in comparing the stringency of regulations at a point in time because of the multidimensional nature of risks and the differences among the structure, locus, and approach of counterpart regulatory measures.

Overall, our results suggest that the degree of precaution exhibited in European and American risk regulation is very similar. Averaging across the 100 randomly-selected risks and 35 year period, we find no difference in relative precaution. Examining each of the 18 risk-type categories averaged over the period, we find that European regulations appear to have been more precautionary for 10 categories (including 68 risks) and US regulations appear to have been more precautionary for five categories (including 29 risks). However, our statistical tests suggest that we cannot reject the hypothesis that these apparent differences are due to sampling variability except, perhaps, for two or three of the risk categories, in which the US appears to have been more precautionary.

The results offer some limited support to the flip-flop hypothesis – that the US was more precautionary than Europe in the 1970s and 1980s, but Europe has become relatively more precautionary than the US. Trends in both weighted and unweighted scores suggest little change in relative precaution from 1970 through about 1990, followed by a slight shift toward greater relative precaution in Europe from about 1990 through 2004. However, the magnitude of the shift is quite modest. It is less than a 10 percent overall edge by 2004, and it is equal to the change that would occur if regulation of three to six percent of risks shifted from more precautionary in the US to more precautionary in Europe, with no change in the relative precaution with which other risks are regulated.

Our analysis of the patterns by individual risk suggests a much greater diversity of patterns. By far the most common pattern we identified (accounting for a third of the risks) is that the US and Europe are equally precautionary over the 35 year period. To some extent, this finding of equal precaution reflects our inability to obtain full information about regulations in each region, and to make confident judgments about which of two sets of multidimensional regulations is, on balance, more stringent. But even excluding those risks we could not score for lack of information, equal precaution remains the modal pattern. Patterns reflecting a difference but no change in the direction of relative precaution are also common, accounting for 20 percent of the risks we examined. These cases are

almost exactly divided between the 11 cases where Europe appears to be more precautionary over the entire period and nine cases where the US appears to be more precautionary. Of the cases in which there was a change in relative precaution, the change is more often toward greater relative precaution in Europe, but even here many cases show the opposite result. The direction of movement was toward greater relative precaution in Europe for 21 cases, and toward greater relative precaution in the US for 14 cases.

In summary, our results provide some support for the view that there has been a slight shift toward relatively greater precaution in European risk regulation compared with US regulation, but also that patterns of regulation are quite diverse. This suggests that there are no simple or categorical national styles of regulation, but that regulation is highly contextual, with policy choices that are specific to the particular risk. The history of US and European risk regulation over the period 1970-2004 has been one of selective precautionary particularity, not of overarching precautionary principle[19: 260-262]. The broad but shallow quantitative comparison presented here should be complemented by more narrow but more detailed examination of specific risks and policy processes to shed light on the contextual factors that influence the timing, stringency, enforcement, and type of regulation selected to address particular risks.

Acknowledgments

The authors thank JoAnn Carmin, Robert Keohane, Kathryn Saterson, and participants at conferences hosted by Duke University and Université Toulouse 1 for helpful suggestions, Joshua Cohen for assistance with data analysis, and Zia Cromer, Shannon Frank, Dylan Fuge, Lena Hansen, Clayton Jernigan, Chris Kocher, Chloe Metz, Jessica Regan, Caitlin Snyder, and Ivan Urlaub for invaluable research assistance. This research was supported by the Duke Center for Environmental Solutions.

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Figure 1. Trends in relative precaution
(all risks)

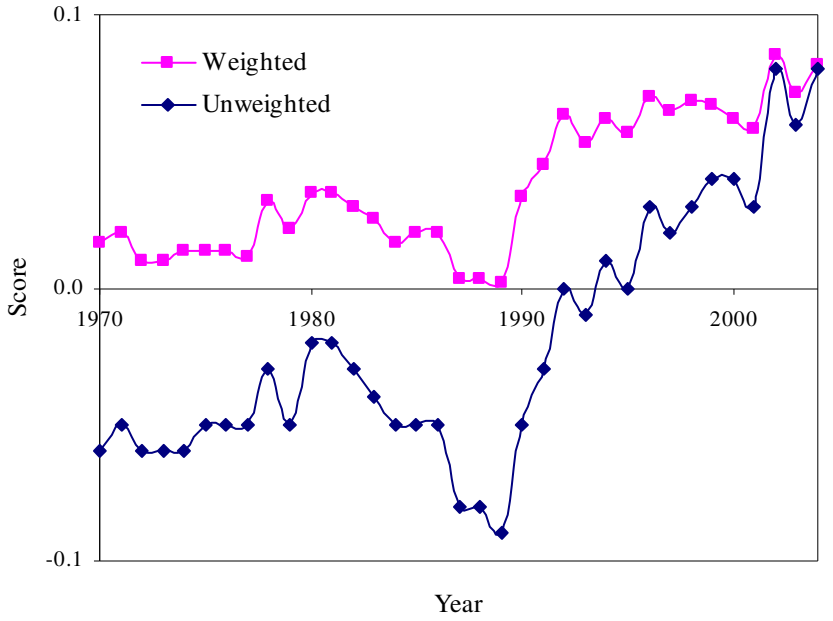

Figure 2. Trends by endpoint category
(weighted scores)

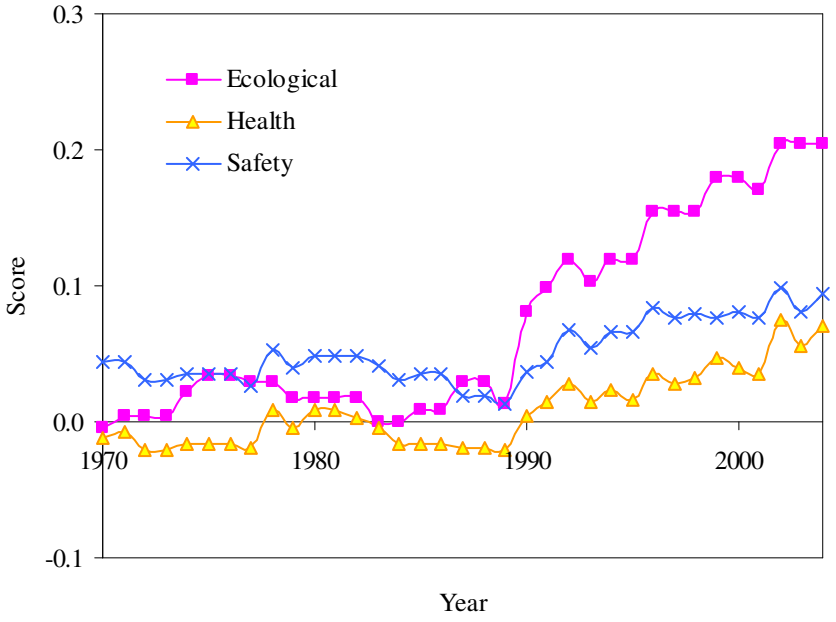

Figure 3. Patterns of relative precaution

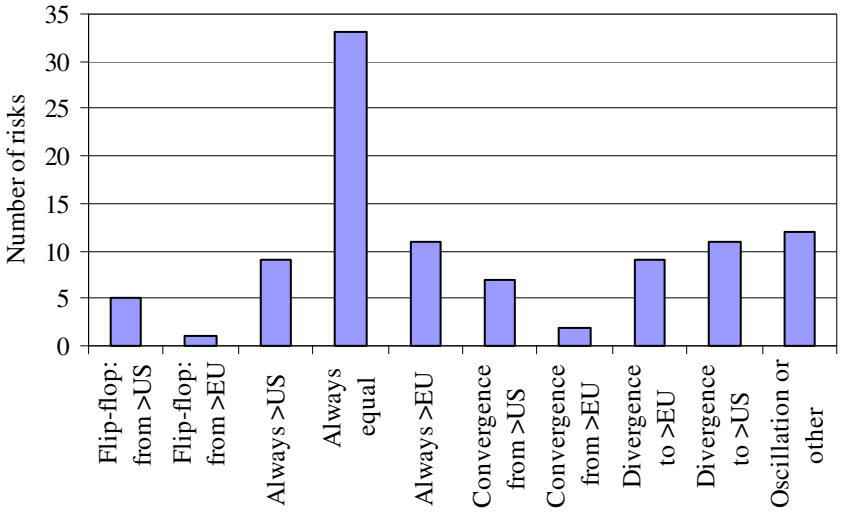

Figure 4. Comparison of individual and consensus scores (weighted)

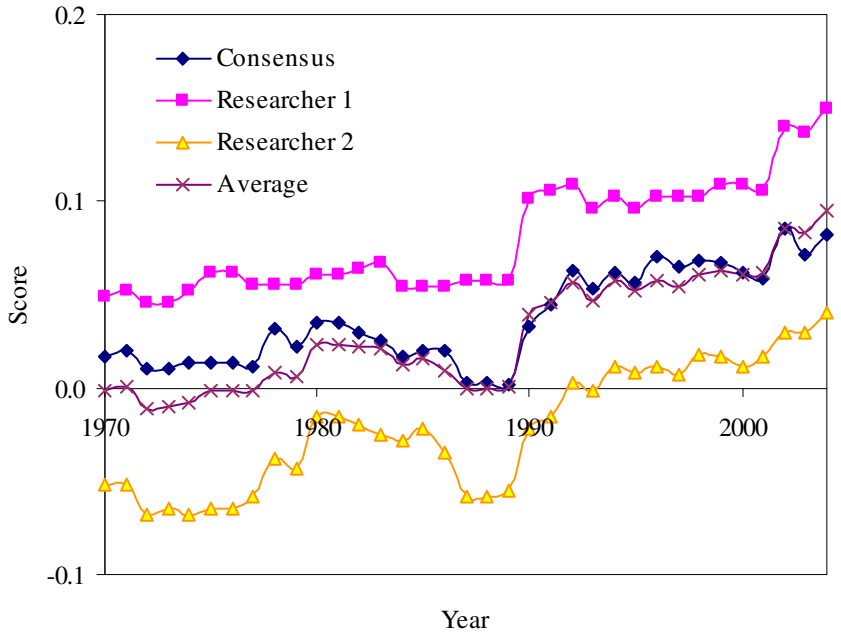

Table I. Risks by type

Code	Category	Percentage in Matrix	Percentage in Sample
1	Crime and violence	1.8	3
2	Alcohol, tobacco, and other drugs	3.0	3
3	Medication and medical treatment	6.8	8
4	Transportation	8.2	13
5	Accident risks not elsewhere classified	2.4	2
6	Recreation	5.5	8
7	War, security, and terrorism	1.5	3
8	Toxic substances	9.8	8
9	Food and agriculture	9.5	9
10	Pollution	7.5	8
11	Energy production	5.0	3
12	Political, social, and financial	3.4	1
13	Ecogeological	4.0	2
14	Global	2.2	1
15	Human disease/health	9.7	9
16	Occupational	15.0	17
17	Consumer products	3.4	2
18	Construction	1.4	0
	Total percentage	100	100
	Total number	2,878	100

Table II. Risks by endpoint category

Endpoint category	Percentage in Matrix	Percentage in Sample
0 None	2.2	2
1.1 Ecological	2.7	3
1.2 Health	17.7	16
1.3 Safety	15.3	21
Total – one category	35.6	42
2.1 Ecological and health	4.2	1
2.2 Ecological and safety	3.6	2
2.3 Health and safety	17.2	16
Total – two categories	25.0	19
3 Ecological, health, and safety	37.2	39
Total – All	100	100
Total - All Ecological (1.1, 2.1, 2.2, 3)	47.7	45
Total - All Health (1.2, 2.1, 2.3, 3)	76.3	72
Total - All Safety (1.3, 2.2, 2.3, 3)	73.2	78

Table III. Relative precaution by risk type

Risk type		Number	Weighted		Unweighted	
			Score	t-statistic	Score	t-statistic
Greater US precaution						
2	Alcohol, tobacco, and other drugs	3	-0.56	-10.51**	-0.79	-6.82**
10	Pollution	8	-0.17	-1.80	-0.50	-2.43**
5	Accident not elsewhere classified	2	-0.17	-1.00	-0.50	-1.00
6	Recreation	8	-0.13	-2.09*	-0.28	-2.53**
3	Medication and medical treatment	8	-0.01	-0.04	-0.10	-0.44
Equal precaution						
12	Political, social, and financial	1	0.00	NA	0.00	NA
17	Consumer product	2	0.00	NA	0.00	NA
Greater European precaution						
11	Energy production	3	0.01	1.00	0.02	1.00
9	Food and agriculture	9	0.03	0.33	-0.11	-0.64
15	Human disease/health	9	0.05	0.55	0.02	0.10
16	Occupational	17	0.09	1.62	0.12	1.12
1	Crime and violence	3	0.11	0.38	0.00	0.00
4	Transportation	13	0.15	1.61	0.14	0.91
8	Toxic substances	8	0.15	1.30	0.16	0.76
13	Ecogeological	2	0.25	1.00	0.50	1.00
7	War, security, and terrorism	3	0.41	1.83	0.60	1.68
14	Global	1	0.52	NA	1.00	NA
	Total	100	0.04	1.19	-0.02	-0.34

Note: *, ** denote statistically significantly different from zero at 10 and 5 percent significance level, respectively. Scores are normalized so minimum and maximum possible scores are -1 and +1, respectively. NA when standard error = 0.

Table IV. Relative precaution by endpoint category

		Weighted		Unweighted	
Category	Number	Score	t-statistic	Score	t-statistic
0 None	2	-0.17	-1.00	-0.50	-1.00
1.1 Ecological	3	0.00	-1.00	-0.01	-1.00
1.2 Health	16	0.01	0.10	-0.08	-0.53
1.3 Safety	21	0.13	1.60	0.14	1.01
2.1 Ecological and health	1	0.00	NA	0.00	NA
2.2 Ecological and safety	2	0.26	1.00	0.50	1.00
2.3 Health and safety	16	-0.06	-0.80	-0.16	-1.12
3 Ecological, health, and safety	39	0.04	0.92	-0.03	-0.29
All	100	0.04	1.19	-0.02	-0.34
All Ecological	45	0.05	1.17	0.00	-0.02
All Health	72	0.01	0.30	-0.05	-0.70
All Safety	78	0.05	1.36	0.00	0.06

Note: *, ** denote statistically significantly different from zero at 10 and 5 percent significance level, respectively. Scores are normalized so minimum and maximum possible scores are -1 and +1, respectively. NA when standard error = 0.