Using Expert Judgment to Assess Adaptive Capacity to Climate Change: Evidence from a Conjoint Choice Survey

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Summary

We use conjoint choice questions to ask public health and climate change experts, contacted at professional meetings in 2003 and 2004, which of two hypothetical countries, A or B, they deem to have the higher adaptive capacity to certain effects of climate change on human health. These hypothetical countries are described by a vector of seven attributes, including per capita income, inequality in the distribution of income, measures of the health status of the population, the health care system, and access to information. Probit models indicate that our respondents regard per capita income, inequality in the distribution of income, universal health care coverage, and high access to information as important determinants of adaptive capacity. A universal-coverage health care system and a high level of access to information are judged to be equivalent to $12,000-$14,000 in per capita income. We use the estimated coefficients and country sociodemographics to construct an index of adaptive capacity for several countries. In panel-data regressions, this index is a good predictor of mortality in climatic disasters, even after controlling for other determinants of sensitivity and exposure, and for per capita income. We conclude that our conjoint choice questions provide a novel and promising approach to eliciting expert judgments in the climate change arena.

Keywords: Adaptive capacity, Climate change, Human health effects, Extreme events, Heat waves, Vector-borne illnesses, Conjoint choice, Vulnerability, Sensitivity

JEL Classification: Q54, I18

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I. Introduction and Motivation.

The issue of adaptation to climate change and to its effects on human health and economic activities has received considerable attention among researchers and in policy circles as of late (Intergovernmental Panel on Climate Change [IPCC], 2001). Adaptation policies may be adopted in lieu of, or in addition to, seeking greenhouse gases emissions reductions, and whether or not a country or region is assumed to engage in adaptation has been shown to affect considerably the damages of carbon emissions (Tol, 2005).[2]

Adaptive capacity is defined as the "potential, capability, or ability of a system to adapt to climate change stimuli or their effects of impacts" (IPCC, 2001), implying that in principle adaptive capacity has the potential to reduce the damages of climate change, or to increase its benefits. In other words, adaptive capacity affects a system's vulnerability to the stresses of climate change, along with the system's sensitivity and exposure.

One key question is whether it is possible to identify the characteristics of systems, such as communities or regions, that influence their propensity or ability to adapt (or their priorities for adaptation measures). The IPCC (2001) identifies eight broad classes of determinants of adaptive capacity, namely (i) available technological options, (ii) resources, (iii) the structure of critical institution and decisionmaking authorities, (iv) the stock of human capital, (v) the stock of social capital including the definition of property rights, (vi) the system's access to risk-spreading processes, (vii) information

[2] Yohe and Schlesinger (2002) note that some studies have been criticized for overstating the power of adaptation in reducing climate-related costs, especially when the adaptive capacity of developing countries

management and the credibility of information supplied by decisionmakers, and (viii) the public's perceptions of risks and exposure.

Presumably, adaptive capacity varies widely but, to date, it has been difficult to empirically measure it and establish the relative importance of the factors identified by the IPCC.[3]

Building on the conclusions of the IPCC report, Yohe and Tol (2002) propose a formal model where vulnerability (i.e., the losses caused by climate change) is a function of exposure and sensitivity, which in turn depend on adaptive capacity. Formally,

$$(1) \qquad \mathbf{V} = \mathbf{V}(\mathbf{E}(A), \mathbf{S}(A)),$$

where **V** is a vector of variables that capture vulnerability, **E** is a vector that measures exposure and **S** is sensitivity. *A* is adaptive capacity, which is expressed as a scalar and is a function of the economics, social and legal determinants D_j identified in IPCC (2001):

$$(2) \qquad A = A(D_1, D_2, ..., D_m),$$

where j=1, 2, …,m. Yohe and Tol argue that it is reasonable to expect vulnerability to increase at an increasing rate with exposure and sensitivity, and that the latter should decrease at a decreasing rate with adaptive capacity *A*. The multivariate functions in (1) are location-specific and path-dependent.

Yohe and Tol use data from several countries to estimate an empirical model of vulnerability to extreme events. Their regression models relate three alternate measures of vulnerability (fraction of population affected by disaster events, damages, and number of deaths) to the country's per capita income, Gini coefficient, and population density.

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was applied to the developing world. They also note that the amount of resources used up to reduce such costs is greatly affected by stochastic events and uncertainty.

[3] See Yohe and Schlesinger (2002) and Brooks et al. (2005) for a discussion of the time scale over which events and adaptation take place.

These vulnerability measures are generally negatively related to income, and—depending on the equation—positively related to inequality and population density.

Yohe and Tol's model confirms the expected relationship between resources and vulnerability, but its stylized nature does not allow one to disentangle institutional factors, the effects of the health stock in the population, and the existence of adequate infrastructure and information channels. Nor is it possible to identify the contribution of these factors to adaptive capacity, and by how much adaptive capacity mitigates exposure and sensitivity.

In this paper, we propose a somewhat different approach to identify the role of factors generally linked with adaptive capacity with respect to selected categories of human health effects of climate change (those associated with (i) extreme weather events, (ii) thermal stresses, and (iii) vector-borne illnesses). The goal of our paper is four-fold. First, we wish to infer what factors are judged by experts to be the most important determinants of adaptive capacity with respect to the abovementioned types of human health effects.

Second, we wish to find out how experts trade off such factors against each other in assessing a country's adaptive capacity. For example, when it comes to adaptive capacity, can a more egalitarian distribution of income make up for a lower income per capita? Or, how much wealthier does a country need to be to make up for the absence of a universal health care system?

Third, we use the experts' judgments to compute a simple index of adaptive capacity. We use this index—and this is the fourth goal of our study—as one of the independent variables in a regression relating vulnerability, which we measure as deaths per million in extreme weather events, to proxies for sensitivity, exposure, and adaptive capacity.

We accomplish these goals by surveying public health experts, climatologists, and emergency response officials intercepted at professional conferences and intergovernmental meetings using a structured questionnaire. We gathered a total of 100 completed questionnaires.

Our survey questionnaire relies on conjoint choice questions.[4] Given two stylized (and hypothetical) countries, which we describe in terms of resources and distribution of resources, population health and age, health care systems, and access to technology and information, which has, in the respondent's opinion, the higher adaptive capacity? The responses to these choice questions allow us to identify the factors that experts associate with a higher or lower degree of adaptive capacity to (i)-(iii), and the tradeoffs experts make between different factors. The statistical analysis of the responses to the choice questions relies on a random adaptive capacity framework and on a variant on the probit model.

We find that per capita income, inequality, universal health care coverage and access to information are judged to be important determinants of adaptive capacity. By contrast, our respondents do not consider the age structure of the population, life expectancy and the number of physicians per 100,000 to influence adaptive capacity. The effect of a more equitable distribution of income is deemed equal to about $4,600

[4] In a typical conjoint choice exercise (Louviere et al., 2000), respondents are presented with a set of K hypothetical alternatives (the so-called "choice set," where $K \geq 2$) representing situations, goods or public policies. The alternatives are described by a vector of attributes, and differ from one another in the level of two or more attributes. Respondents are asked to indicate which of the K alternatives they deem the most attractive, K being at least two. It is assumed that in choosing the most preferred alternative, the

worth of per capita income, while universal coverage in health care and high access to information are equivalent to $12,000-14,000 in per capita income.

The theoretical construct—the random adaptive capacity model—and the estimated coefficients from the probit model are used to produce the index of adaptive capacity. Within Europe and Central Asia, the index is low for transition economies and the former Soviet Republics, and higher for Western European countries. Even the poorest countries in Europe and Central Asia, however, are well ahead of countries in Asia and Africa.

As a final check on the quality of the adaptive capacity index, we run a regression relating deaths in climatic disasters in a country in a year (normalized by population) to determinants of exposure and sensitivity *and* to our index. Based on panel data from over 140 countries over 1990-2003, we find the adaptive capacity index is negatively correlated with deaths. Although explaining climatic disaster fatalities is generally difficult (the R^2 of the regression generally do not exceed 0.13), the adaptive capacity index account for a relative large share of the explanatory power of the regression, even controlling for the country's GDP per capita.

The remainder of this paper is organized as follows. In section II, we describe the structure of the questionnaire and the conjoint choice questions, and present the survey data in section III. In section IV, we provide a theoretical framework to interpret the responses to the conjoint choice questions and describe the corresponding statistical model of the responses. In section V, we present estimation results. In Section VI we further interpret the model results, which we use to calculate (i) the rates of tradeoffs

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respondent chooses the one that gives him the highest utility (here, the highest adaptive capacity) and that he trades off the attributes of the alternatives.

between of determinants of adaptive capacity and (ii) an index of adaptive capacity. In section VII, we further check the quality of the index of adaptive capacity in vulnerability regressions. We offer concluding remarks in Section VIII.

II. Structure of the questionnaire and sampling frame.

A. Structure of the Questionnaire

Our questionnaire is divided into 5 sections. Section A provides a brief description of global climate change and its effects. Respondents are told that climate change may have numerous effects on human health, but that in this survey we would like them to focus on three, namely (i) deaths and injuries associated with floods and landslides caused by sustained rains or extreme weather events, (ii) cardiovascular or respiratory illnesses and deaths during heat waves, and (iii) vector-borne infectious diseases.[5]

In section B, we ask respondents how important (i), (ii) and (iii) are to the respondent's organization and to the respondent himself (or herself). We then briefly introduce the concept of adaptive capacity, explaining that country and local governments may in some cases implement adaptation policies to reduce (i)-(iii).

Section C contains the conjoint choice questions. Respondents are explicitly told that they will be asked to consider pairs of hypothetical countries that could be located anywhere in the world. Based on the countries' description, the respondent must indicate

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[5] Other possible effects of climate change on human health include psychosocial effects, hunger and malnutrition due to famine and drought, foodborne and waterborne illnesses, etc. We recognize that these effects may be potentially severe, but they are disregarded within the context of our survey questionnaire. The cCASHh project focused primarily on Europe, where these costs are likely to be small or cannot be measured or predicted reliably.

which of the two countries in a pair he believes to have the higher adaptive capacity. A sample conjoint choice question is reported in the Appendix.

Respondents face a total of four choice questions. The first two refer to countries with relatively high population densities (400 people per square kilometer), a mild climate, significant amounts of coastline and mountains, a relatively high degree of deforestation, and are moderately subject to floods and landslides. The last two choice questions refer to pairs of countries with a cold climate, relatively low population density, little deforestation, significant amounts of coastline and mountains, and little experience with extreme weather events in the past.

Section D asks questions about the professional background of the respondents, and section E concludes with debriefing questions that inquire about the clarity of the questions and of the choice exercises.

B. The Choice Questions

While researchers have discussed the potential role of many social, economic, and institutional factors in determining a community's adaptive capacity to climate change, we rely on a relatively small number of attributes in our conjoint choice tasks due to sample size considerations and to limit the cognitive burden imposed on the respondent.

Our stylized, hypothetical countries are defined by a total of 7 attributes: (i) per capita income (in US dollars), (ii) a qualitative description of the level of inequality in the distribution of income ("high" or "low"), (iii) the proportion of the country's population of age 65 and older, (iv) life expectancy at birth, (v) physicians per 100,000 residents, (vi) the type of health care system (universal coverage, or based on private health insurance), and (vii) access to information via television, radio, newspaper, and internet ("high" or "low"). These attributes may capture both macro/national level and micro/local factors discussed in Yohe and Tol (2002).

We arrived at this set of attributes after reviewing the literature, consulting with public health and climate change researchers, and developing a first list of candidate descriptors, which was pared down after pre-testing earlier versions of the questionnaire at the World Health Organization (WHO) and CCASHH project coordination meetings held in Freiburg in May 2003, in Prague in June 2003 and in Potsdam in July 2003.

Our experimental design calls for three possible levels of income per capita: 13,000, 20,000 and 27,000 US dollars. These were selected because they reflect the per capita incomes of countries that have recently joined the European Union, such as the Czech Republic (13,991 US dollars), and of certain European Union countries. For example, in 2000 Spain's per capita income was 19,472 US dollars, Italy's was 23,626 US dollars and Belgium's was 27,178 US dollars.

We use two possible levels for the percentage of the elderly in the population: 12%, which corresponds to a relatively "young" country (such as Ireland), and 18%, which corresponds to a relatively "old" country (e.g., Italy) in 2000. Regarding the number of physicians per 100,000, which is a measure of access to health care widely used in public health, the statistics compiled by WHO suggest that there is much variability across countries in this index.[6] In the end, we selected three possible levels: 250, 300 and 400 per 100,000.

[6] For example, there are 164 physicians per 100,000 in the UK, 345 in Bulgaria, and 554 in Italy.

For life expectancy, we focus on 70 and 79 years. The former is life expectancy at birth in Eastern European countries such as Rumania and Bulgaria, while the latter is the approximate figure for Italy, France and Sweden, among other Western European countries. The remaining three attributes (health care system, inequality in the distribution of income, and access to information) are of a qualitative nature.

In our conjoint choice questions, each choice set consists of two artificially created, hypothetical countries. To form these pairs, we first created the full factorial design, i.e., all possible combinations of the levels of the attributes.[7] Next, we randomly selected two country profiles, but discarded pairs containing dominated alternatives.[8] This was repeated for a total of four conjoint choice questions per respondent, making sure that each set of four pairs did not contain duplicate pairs. We created 32 different versions of the questionnaire following this approach. Respondents were randomly assigned to a questionnaire version.

The first two conjoint choice questions refer to countries A and B, and C and D, respectively, which are portrayed as enjoying a mild climate, but a relatively high propensity to extreme events, and high deforestation. The countries in the remaining two pairs (E and F, and G and H, respectively) have colder climates, are relatively unlikely to experience extreme events, and have had little deforestation.

C. Sampling frame and Survey Administration

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[7] This is comprised of $2^5 \times 3^2 = 32 \times 9 = 288$ possible combinations.

[8] An alternative in a pair is dominated if it is obviously worse than the other. In deciding whether there is a dominating alternative, we reasoned that countries with higher income should be judged to have higher adaptive capacity, and so should countries with lower inequality in the distribution of income, longer life expectancy, more numerous physicians per capita, and better access to information.

Our questionnaire was self-administered by a sample of public health officials and climate change experts intercepted at random at professional conferences and intergovernmental meetings from October 2003 to August 2004.[9] This was a pen-and-paper questionnaire, so study participants were offered the option to fill out the questionnaire on the premises, or to return it by fax or mail. We received a total of 100 completed questionnaires.

III. The Survey Data

We cannot make any claims that our sample is representative of the population of these professions, so our first order of business is to describe the individual characteristics of our respondents. Males account for over two-thirds (67.35%) of our sample, and the age ranges from 24 to 70 years, for an average of 48. Our respondents were from a total of 29 countries (67% from Western Europe, 15% from former Eastern bloc countries, 5% from the United States, with the remainder coming from Thailand, Turkey, Brazil, Japan, Congo, Israel and Nigeria).

Table 1 reports information about their professional background, showing that the medical, public health/epidemiology, engineering, and economics or business fields account for about two-thirds of the sample.

[9] These conferences include the 2003 International Healthy Cities Conference, Belfast, Northern Ireland, 19-22 October 2003; the World Climate Change Conference, Moscow, 29 September-3 October 2003; the 2003 IPCC Conference, Orlando, Florida, 21-24 September 2003. Additional participants were recruited among the participants of the MIT Global Climate Change Forum XXI, Cambridge, Massachusetts, 8-10 October 2003.

Table 1 – Professional background of the respondents.

	Percentage (frequency)
Medical	19.15% (18)
Public health or epidemiology	15.96% (15)
Engineering	12.77% (12)
Economics or business administration	19.15% (18)
Other	32.98% (31)

In table 2, we show the composition of our sample by type of organization. Public health organizations are well represented in our sample (22.4% of the respondents), as are Universities or other research institutions, which account for 38% percent of the sample. About 19% of our respondents work for government agencies, and the remainder of the sample is comprised of persons who work for health care organizations (both public and private), emergency response agencies, and other organizations.

Table 2 – Type of organization where the respondent works.

Type of organization	**Percentage of the sample**
1. Public health organization	22.4
2. Private or public health care organization	7.5
3. Emergency response agency	2.1
4. University or research institution	38.3
5. Another government organization	19.2
6. Non-government, non-profit organization	2.1
7. Private company	4.2
8. Another type of organization	4.2

Table 3 displays the frequencies of the responses about concern for the effects of climate change on human health within the respondent's organization. Table 4 reports the respondents' professional concern about these issues.

Table 3 – Organization concern about the effects of climate change. Percentage selecting each response category.

	Very concerned	Somewhat concerned	Not concerned at all	No position/outside the organization's mission
1. Deaths and injuries due to floods, landslides and mudslides	31.00% (31)	45.00% (45)	10.00% (10)	14.00% (14)
2. Cardiovascular and respiratory illnesses due to heat waves	43.00% (43)	34.00% (34)	12.00% (12)	11.00% (11)
3. Increased cases of vector-borne diseases	34.00% (34)	35.00% (35)	17.00% (17)	14.00% (14)

Table 4 – Respondent professional concern about the effects of climate change. Percent selecting each response category.

	Very concerned	Somewhat concerned	Not concerned at all	No position/ outside of professional duties
1. Deaths and injuries due to floods, landslides and mudslides	27.55% (27)	37.76% (37)	12.24% (12)	22.45% (22)
2. Cardiovascular and respiratory illnesses due to heat waves	33.67% (33)	36.73% (36)	7.14% (7)	22.45% (22)
3. Increased cases of vector-borne diseases	30.61% (30)	32.65% (32)	9.18% (9)	27.55% (27)

These tables show that roughly one-third or more of the respondents stated that their organization was highly concerned about the three classes of effects of climate change covered in the survey. Similar percentages selected the highest category of professional concern for these effects.

Regarding the choice questions, the responses were well balanced, in the sense that our experts chose the first of the two countries in a pair (e.g., A between A and B) 45.60% of the times, and the second country of the pair 54.40% of the times. This is a nice split that suggests that there were no obvious choices, and that people did indeed trade off attributes.[10]

In debriefing questions at the end of the questionnaire, about 66% of the respondents stated that they took into account all of the three major effects of climate change on human health when answering the choice questions, as we instructed them to do. Almost 19% of the sample said that they had thought exclusively about extreme weather events, and 5.3% told us that they had considered only thermal stresses. Vector-borne diseases were cited as the only reason for the responses to the choice question by 2.1% of our sample, and, finally, 7.4% said that their choice responses were motivated by other effects of climate change.

IV. The Model.

This section provides a theoretical framework to motivate our statistical models of the responses to the choice questions. This framework is similar to the random utility model generally used with conjoint choice surveys where the alternatives are private goods, environmental goods or natural resource management plans (e.g., Adamowicz et al., 1994; Boxall et al., 1996; Hanley et al., 2001), and other public policies (Alberini et al., 2005).

[10] Further inspection of our data reveals that most of our study participants (92%) found the description of the consequences of climate change adequate, and that only 15.5% noted that the information on climate change provided in the questionnaire was new to them. Roughly 89% of the respondents found the concept

We assume that when answering the conjoint choice questions, individuals select the alternative with the higher level of adaptive capacity out of the two in the choice set. We further assume that the level of adaptive capacity individual i associated with alternative j, A_{ij}, is comprised of two components: a deterministic component, which is a linear function of the attributes of the alternative via a vector of unknown, fixed coefficients, β, and a stochastic error term. Formally,

(3) $$A_{ij} = \overline{A}_{ij} + \varepsilon_{ij} \,,$$

where $\overline{A}_{ij} = \mathbf{x}_{ij}\beta$, $\mathbf{x}_{ij}$ is the 1×p vector of attributes describing alternative j (j=1, 2) to individual i, β is a p×1 vector of coefficients, and ε is the error term. The error term captures individual- and alternative-specific factors that affect the choice and are known to the respondents, but not to the researcher. The vector **x** is comprised of continuous variables for income, physicians per capita, and life expectancy, and 0/1 dummy indicators for high/low inequality in the distribution of income, universal coverage, and access to information.

Since we observe a discrete choice out of two possible alternatives, the appropriate statistical model is a binomial model that describes the probability that the respondent selects, say, option 1 between alternatives 1 and 2 in the choice set. Selecting 1 means that this country is deemed to have a greater adaptive capacity, and hence that A_{i1} is greater than A_{i2}:

(4) $$\Pr(1) = \Pr(A_{i1} > A_{i2}) \,,$$

which in turn implies that the probability of choosing country 1 is

of adaptive capacity clearly explained, and a similar fraction of the sample (88%) found the text and table

$$\text{(5)} \qquad \Pr(1) = \Pr\left((\varepsilon_{i2} - \varepsilon_{i1}) < (\overline{A}_{i1} - \overline{A}_{i2})\right) =$$

$$= \Pr\left(\eta_i < (\mathbf{x}_{i1} - \mathbf{x}_{i2})\boldsymbol{\beta}\right),$$

where $\eta_i = \varepsilon_{i2} - \varepsilon_{i1}$. If we assume that η_i is normally distributed with mean zero and variance 1, probability (5) is equal to:

$$\text{(6)} \qquad \Pr(1) = \Phi\left(\eta_i < (\mathbf{x}_{i1} - \mathbf{x}_{i2})\boldsymbol{\beta}\right),$$

where $\Phi(\cdot)$ is the standard normal cdf. Equation (6) is, therefore, the contribution to the likelihood in a probit model where the dependent variable is a dummy indicator taking on a value of one if the respondent chooses country 1, and zero otherwise. The independent variables of the probit equation are the differences in the level of the attributes between country 1 and 2, i.e., $(\mathbf{x}_{i1} - \mathbf{x}_{i2})$.

Probit equation (6) may be amended to include variables capturing individual characteristics of the respondent, which means that the probability of picking country 1 over country 2 is

$$\text{(7)} \qquad \Pr(1) = \Phi((\mathbf{x}_{i1} - \mathbf{x}_{i2})\boldsymbol{\beta} + \mathbf{z}_i\boldsymbol{\gamma}).$$

It is also possible to include interaction terms between the individual characteristics of the respondents and $(\mathbf{x}_{i1} - \mathbf{x}_{i2})$ to allow the same attribute to appeal to a different extent to different individuals.

Finally, since respondents engage in a total of four choice tasks, it is necessary to spell out our assumptions about the possible correlation between the errors η_{im}, where *m* denotes the choice task (*m*=1, .., 4), within the same individual. The simplest model treats these errors as mutually independent, so that the log likelihood function of the data is:

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presentation of the hypothetical countries clear.

(8) $$\sum_{i}\sum_{m=1}^{4}\sum_{j=1}^{2} I_{ijm} \cdot \log \Pr(j \text{ in task } m) .$$

Alternatively, a random-effects probit (see Greene, 2003) can be specified to account for the presence of unobserved heterogeneity, i.e., unobserved factors that influence choice and are common to all of the responses contributed by the same individual. The random-effects probit assumes that $\eta_{im} = \nu_i + \xi_{im}$, where ν_i is the individual-specific effect, which remains unchanged over all of the error terms of the same respondent (but varies across individuals), while ξ_{im} is a completely random error term. Both are assumed to be normally distributed, have mean zero, and be independent of one another. These assumptions imply that the pairwise correlation between any two η_{im} within individual *i* is the same.

Once the β coefficients are estimated by the method of maximum likelihood, we check their statistical significance using asymptotic t tests (for individual coefficients) and likelihood ratio tests (for subsets of the vector of coefficients). This allows us to tell whether the socio-economic variables we have used to describe adaptive capacity to our respondents *are* truly judged by them to determine adaptive capacity. The magnitude of the coefficient can be judged by examining the impact of changing attribute *k* on the probability of choosing country *j*.

Finally, we compute the rate of substitution between any two attributes. For example, if we wish to know what increase in GDP per capita is necessary to offset a one-year reduction in life expectancy at birth, to keep adaptive capacity the same, we compute the ratio between their respective estimated β coefficients.

Implicit in equation (8) is the assumption that the coefficients of the attributes are the same for the first two and the last two pairs of countries. Our first order of business is, therefore, to test empirically whether this is the case.

V. Conjoint Choice Responses: Model Results.

In this section we report the results of several variants on probit model (8). We first check whether people's β coefficients were different across the first two and the second two pairs of countries (first two and last two conjoint choice questions). We remind the reader that the first two pairs of countries share high population density, mild climate, extensive coastline and mountains, high deforestation, and moderate experience with extreme weather events. The second two pairs of countries differ from the first two in that they have low population density, colder climates, little deforestation, and little experience with extreme weather events. They should thus reasonably be expected to have different exposures to the most damaging consequences of climate change.

To test for structural change, we do a likelihood ratio (LR) test based on a relatively parsimonious specification of the probit equation that includes (the differences in) country attributes, but no individual characteristics of the respondents or interaction terms.[11] The LR ratio statistic is equal to 6.16, for a p-value of 0.62, failing to reject the null of no structural change at the conventional levels.

This has two important implications. The first is that the experts view adaptive capacity as independent of exposure or risk of climatic disasters. The second is of a

[11] In addition, this model assumes that the responses to the conjoint choice questions are independent within a respondent. This assumption is reasonable, because, as discussed below, a random effects probit model finds no evidence of a significant correlation between the responses.

statistical nature, and means that it is reasonable to pool the data and fit probit models with one vector of coefficients β for the responses to all of the four choice tasks.[12]

We report the results of two such models in table 5. Model A is an independent probit model, while model B is a random-effect probit. In both models, expected adaptive capacity depends only on country attributes.

The results for model A show that adaptive capacity is judged to increase with income per capita, and to be lower when inequality is high. The coefficients on these variables are large and significant at the 1% level or better. They imply, for example, that, all else the same, raising per capita income by $5,000 increases the likelihood that a country is selected as the higher adaptive capacity country to 68%.[13]

By contrast, the age distribution and life expectancy at birth of the population are not significant predictors of the probability of choosing a country, even though the sign of the coefficients on these variables (negative and positive, respectively) are consistent with our expectations. There are two possible explanations for these results. The first is that our respondents may have thought that unfavorable levels of these factors would be offset by sufficient resources, and would thus be only of secondary importance relative to per capita income. Alternatively, our respondents may have thought that the age

[12] The log likelihood function for the pooled data model (restricted likelihood) is -214.93. When the same probit equation is fit to the responses from the first two choice questions (196 observations), we get a log likelihood function equal to -104.83. A probit model of the responses to the last two choice questions (190 observations) produces a log likelihood function of -107.02. The likelihood ratio statistic is, therefore, 6.16 (p-value = 0.62).

[13] This figure represents a 36% increase over 0.5, the likelihood of selecting either one of two completely identical countries.

distribution of the population and its life expectancy capture sensitivity, but not adaptive capacity.[14]

Regarding the type and quality of the health care system, our respondents indicate that they associate a universal coverage system with a higher degree of adaptive capacity, as is implied by the positive sign of the coefficient on this dummy. The effect is strongly statistically significant (t statistic: 5.89). All else the same, the probability of selecting a country drops to only 0.23 if universal health care is removed.[15] Quality of health care as measured in physicians per capita, however, is not significantly associated with the likelihood of selecting a country over another. High access to information via newspaper, television, radio and internet is associated with a higher adaptive capacity.

As shown in column (B) of table 5, we find no evidence of random effects. The coefficient of correlation between the error terms underlying the choice responses within an individual is pegged at 0.11, and is not statistically significant. A likelihood ratio test (1.84, p value=0.17) confirms that the model can be simplified to the independent probit.

We experimented with adding (i) individual characteristics of the respondents, such as a gender dummy and dummies for the professional background of the respondent, and (ii) interactions between selected country attributes and professional background dummies in both the independent and the random effect probit, but LR tests indicated that the coefficients of these newly added variables were not different from zero.[16]

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[14] Brooks et al. (2005) identify life expectancy at birth as a key indicator of vulnerability to the human mortality effects of extreme weather events, providing support for this possible interpretation of the statistical insignificance of the coefficient on life expectancy at birth.

[15] This is a 54% decline from 0.5, the equal chance of selecting either one of two perfectly identical countries, both of which have universal health care.

[16] For example, when we add a gender dummy and dummies for the professional background of the respondent in the independent probit model the appropriate LR statistics is 5.18 (4 degrees of freedom, p-value=0.27). Similar results were obtained when we added (income×engineer), (life expectancy×public

Table 5. Probit Model Results. N=100 respondents, total number of observations 386.

Variable	Model A Coeff.	Model A T statistic	Model B Coeff.	Model B T statistic
ONE	-0.1046	-1.2558	-0.1023	-0.9298
INCOME	5.59E-05	5.3674	6.07E-05	5.1523
HIGHINEQ	-0.25516	-2.3957	-0.2829	-2.2073
PCT65	-0.01916	-1.0670	-0.0220	-1.2027
LIFEEXP	0.0021	0.1463	0.0028	0.1932
DOCTORS	0.0013	1.1888	1.40E-03	1.1184
UNIVERSA	0.7173	5.8917	0.7454	5.4462
HIGHINFO	0.7886	6.9080	0.8480	6.8674
Correlation rho between error terms in random effects model			0.1090	1.1964
Log likelihood	-214.93		-214.01	

Legend: INCOME= per capita income in US dollars; HIGHINEQ= high inequality in the distribution of income (dummy); PCT65= percentage of the population older than 65; LIFEEXP= life expectancy at birth; DOCTORS= number of physicians per 100,000; UNIVERSA= universal health care system coverage (dummy); HIGHINFO= high access to information via newspaper, television, radio, internet (dummy).

VI. Implications of the Responses to the Conjoint Choice Questions.

We use the results of our probit regressions for two purposes. First, we compute the marginal "value" of each country attribute. Second, we compute a simple index of adaptive capacity and illustrate its use with a sample of countries from Europe and Central Asia.

The marginal value of an attribute is computed by dividing the probit coefficient on that attribute by the coefficient on GDP. The results of the probit model A, table 5, imply that a more equitable distribution of income is worth roughly $4600 in per capita income. For comparison, this is almost equal to the difference between the per capita incomes of the Czech Republic and Spain in 2000. Removing universal health care and replacing it with a private health insurance system would require an increase in per capita income of

health official) and (physicians per 100,000×medical doctor)) to see if respondents tended to weigh more heavily country attributes that might appeal or relate to their professional background.

about \$12,800 to keep adaptive capacity the same. A change from low to high access to information is considered equivalent to a change in per capita income of \$14,107.

These figures show clearly that universal health care and access to information are judged crucial determinants of adaptive capacity: it takes a very large increase in resources to compensate for their absence, and they are judged as roughly equivalent to one another.[17]

Based on the random adaptive capacity model and the probit equation, we compute the following simple index of adaptive capacity:

$$(9) \qquad AC_l = \mathbf{x}_l \hat{\boldsymbol{\beta}}$$

where *l* denotes the country of interest and $\hat{\boldsymbol{\beta}}$ is the vector of probit coefficients.[18] One difficulty in computing this index for any desired country of interest is that we must create indicators for high or low inequality in the distribution of income, and high or low access to information. (Fortunately, GDP per capita, life expectancy, and physicians per 100,000 are easily obtained from the World Bank and other official databases, while information on health care systems based on universal coverage or private insurance can be obtained at http://www.euro.who.int/InformationSources/Evidence.[19])

Inequality in the distribution of income is generally measured using the Gini coefficient, which ranges between 0 (perfect equality) and 1 (perfect inequality, where

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[17] That the presence of a universal health care system is judged so vital may well reflect the composition of our sample, which is comprised primarily of European nationals and has very few respondents from the US, a country that does not have universal health care coverage and that tends to feel strongly against such a system. Had our study relied on a US-based sample, we would perhaps reach the opposite conclusions.

[18] This index is defined between negative and positive infinity, as is implied by the probit model. We do not try to normalize it to make it lie within a specified range.

[19] When we were unable to locate information about a country's universal versus private health care coverage, we relied on the ratio of private to public health care expenditures from the World Development Indicators database. In countries with universal health care coverage, this ratio is less—generally much

one has all the income, and everyone else has zero income)(available from the World Bank's World Development Indicators database). Researchers generally agree that countries with a Gini index of 0.50 or more have relatively high inequality in the distribution of income. Following this practice, we therefore construct an indicator equal to one if a country's Gini index is 0.50 or more, and zero otherwise (Leith, 2005).

Regarding access to information, we proxy it with total phone lines (landline and mobile phones), and assign a value of one to the high access dummy if a country's total number of phones per 1,000 residents is greater than 900.

We report the adaptive capacity indices for selected European and Central Asia countries based on these assumptions in Figure 1, where index value imply higher adaptive capacity. This figure shows that the country with the lowest adaptive capacity in Europe and Central Asia is Albania, where the index is equal to 1.076. The one with the second lowest adaptive capacity index is Turkey (1.079). The former Soviet Republics score poorly, the former Eastern Bloc countries such as the Czech Republic and former Yugoslavia republics are in the middle of the pack, and the wealthier Western Europe countries are the ones with the highest adaptive capacity scores, due to their high incomes, universal health care coverage, and high access to information. The countries with the highest adaptive capacity scores are Norway and Luxembourg.

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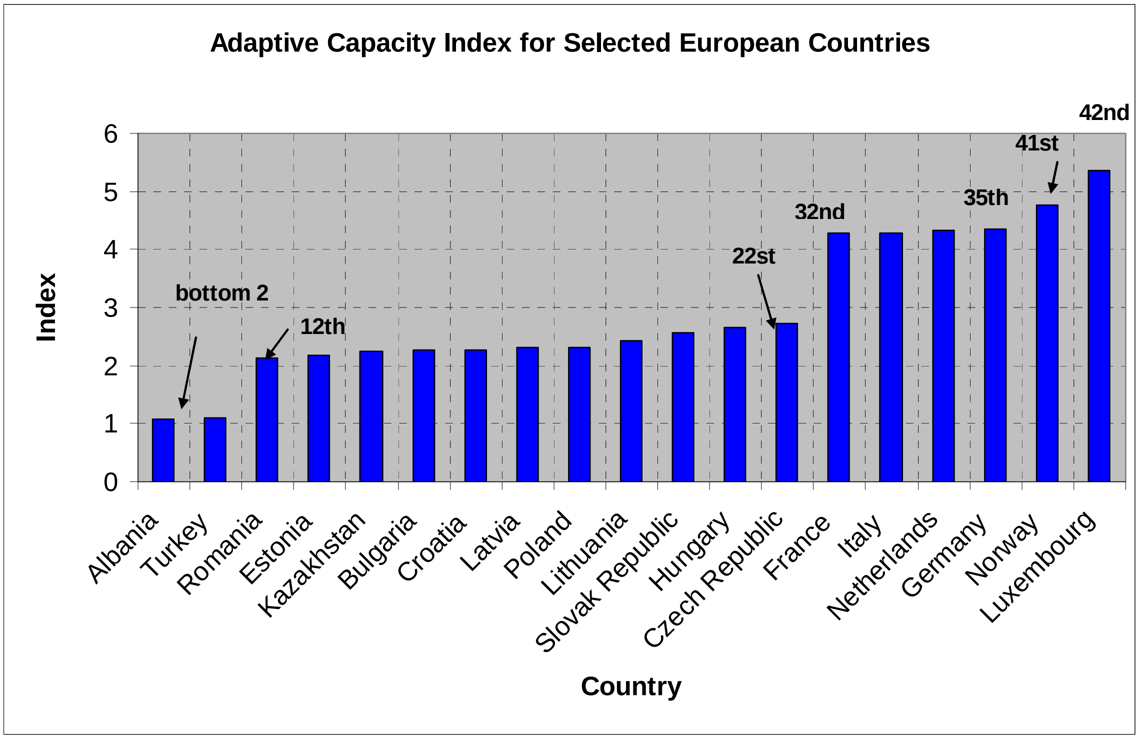
less—than one (for good measure, we chose a cutoff ratio of 0.7). Absent specific information about a country's institutional setup, we formed a prediction based on this ratio and on the 0.7 cutoff.

Figure 1. Adaptive capacity index for 42 Europe and Central Asia countries. Higher index values mean higher adaptive capacity.



Although our assumptions about what constitutes high/low inequality and high/low access to information are arbitrary, the countries' rankings in terms of adaptive capacity are generally robust to changing these assumptions. We arrived at this conclusion after experimenting with all possible combinations of (i) a more stringent definition of high inequality in the distribution of income (a country has an inequitable distribution if its Gini coefficient is greater than 0.31, the average in Europe and Central Asia),[20] and (ii)

[20] In recent decades, countries have tended to converge to a Gini coefficient of about 0.40, and indeed the average Gini coefficient for countries in Europe and Central Asia is about 0.31. Under this alternative classification, Russia is regarded as a high inequality country, whereas it was not considered so in our base calculation. The new classification widens the adaptive capacity gap between Russia (low income and high inequality) and Norway (high income and low inequality), but generally preserves the ranking of countries. The only exception is Turkey, which does poorly in our base calculation but rises dramatically through the ranks in the alternative calculations.

an alternative definition of access to information which considers a country to have high access if the number of landline and mobile phones per 1,000 residents is greater than 370, Europe's average from 1990 to 2002.

VII. Are the Experts Right?

To answer this question, we use a panel of data from over 100 countries[21] covering the years 1990-2003 and estimate the regression equation:

(10) $\ln(y_{lt}+1) = \gamma_0 + \mathbf{E}_{lt}\boldsymbol{\gamma}_1 + \mathbf{S}_{lt}\boldsymbol{\gamma}_2 + AC_{lt}\gamma_3 + (AC_{lt} \times \mathbf{S}_{lt})\boldsymbol{\gamma}_4 + \mathbf{A}_{lt}\boldsymbol{\gamma}_5 + \varepsilon_{lt}$

where y is our measure of vulnerability—country l's deaths in extreme weather events per million people in year t;[22] **E** is a vector of variables thought to capture exposure, **S** is a vector of proxies for sensitivity, *AC* is our adaptive capacity index,[23] and **A** is a vector of other proxies for adaptive capacity. The γs are vectors of unknown regression coefficients, and ε is the econometric error term.

Data sources and a description of the regressors are provided in table 6. Briefly, we account for exposure using geographical dummies and the CUMDISASTERS, the count of extreme weather events normalized by area from 1960 to 1989.[24] CUMDISASTERS

[21] We assembled data on losses of lives in extreme weather events for 218 countries, but due to missing values for the regressors the specifications of table 7 rely on 143 and 119 countries, respectively.

[22] We use the log of (y+1) because about 53% of the observations on the counts of fatalities are equal to zero. Because of the large share of zero in the sample, we initially fitted a tobit model. The tobit model gives qualitatively similar results to the linear regression we report in this paper, but does not fit the data as well as the semilog model.

[23] In this equation, we rely on a more parsimonious specification of the probit model than the one shown in table 5. Specifically, we omit physicians per 100,000, the percentage of the elderly in the population, and life expectancy at birth, which were not significant determinants of the experts' choices between countries. For the purpose of creating the adaptive capacity index, we regress the country selected by the respondents on an intercept, GDP per capita, the inequality dummy, the universal health care coverage dummy, and the high access to information dummies. The probit coefficients are -0.117346, 0.0000502, -0.190206, 0.724698, and 0.746632, respectively.

[24] Skidmore and Toya (2002) find a positive correlation between this measure and 1960-90 growth in GDP per capita, after controlling for initial level of development, initial education, fertility, government consumption spending, and change in trade flows. They reason that propensity to experience climatic

may, however, also pick up adaptive capacity, if those countries that are hit by extreme weather frequently have increased their preparedness for such events. We proxy sensitivity with density, share of the population that lives in urban areas (URBAN), and share of the elderly in the population (POP65). Possible proxies for adaptive capacity are log income per capita, our adaptive capacity index, and POLITY2, a variable that captures institutions, political processes, social capital,[25] and possibly even the government's willingness to provide assistance in the event of disasters.

We report the results of two alternative specifications for regression (10) in table 7. The two specifications differ solely for the regressors used to capture adaptive capacity: specification A uses log GDP per capita and POLITY2, whereas specification B drops the latter and replaces it with the adaptive capacity index based on expert judgment, plus its interaction with the share of the elderly in the population.[26] The purpose of including interactions in the right-hand side of the model is to better capture the dependence of sensitivity (and exposure) on adaptive capacity shown in equation (1).

disasters may lower the returns on physical capital, thus discouraging investment in this type of capital and increasing the attractiveness of investment in human capital, which in turn increases growth in the long run. Disasters may also provide opportunities to adopt new technologies. The association between growth and *geological* disasters (e.g., earthquakes) is negative and insignificant.

[25] See Pelling and High (in press) for a discussion of social capital and its role in contributing to adaptive capacity.

[26] POLITY2 is highly correlated with our adaptive capacity index (correlation coefficient 0.51), which implies that the latter does a good job of capturing institutions, social capital, etc. Since POLICY2 is correlated with both income per capita (correlation coefficient 0.4) and the adaptive capacity index, we omit it from specification B to reduce the problem of collinearity among regressors.

Table 6. Variables used in the regression.

Category	Description	Data source
Dependent variable	Log(ndeaths+1), where Ndeaths=fatalities in extreme weather events (floods, windstorms, extreme temperature, slides, wildfires, wave surges) per million residents in year t	Emergency Events Database (EMDAT), Center for Research on the Epidemiology of Disasters (CRED), University of Louvain.*
E (exposure)	Geographical dummies; CUMDISASTERS (number of extreme event disasters 1960-1989 per 1000 square km)	 EMDAT
S (sensitivity)	Density (population per square kilometre); Urban (percentage of the population that lives in urban areas); Pop65 (percentage population older than 65)	World Development Indicators (WDI)
A (other determinants of other capacity)	GDP per capita (1995 constant dollars); POLITY2 (variable that ranges from -10 to 10, where -10=high autocracy and 10=perfect democracy)	WDI Center for International Development and Conflict Management, University of Maryland

* The events documented in EMDAT are disasters with 10 or more people reported killed, 100 or more people affected, a call for international assistance, or a declaration of a state of emergency.

Table 7. Vulnerability regression results. Dependent variable: log(ndeaths+1).

Description	A		B	
	Coefficient	t stat	Coefficient	T stat
Intercept	1.45159	6.13	1.22029	4.47
Sub-Saharan Africa	-0.56487	-3.16	-0.53871	-3.21
East Asia and Pacific	0.17329	0.97	0.27335	1.68
Europe and Central Asia	-0.26857	-1.58	-0.20336	-1.32
Middle East North Africa	-0.25054	-1.41	-0.18697	-1.12
Latin Am and Carib	-0.05225	-0.3	0.02389	0.14
South Asia	0.2868	1.37	0.56191	2.74
Cumdisasters	-0.06263	-1.43	-0.02854	-2.45
Population density	0.000747	3.69	0.00051	2.59
URBAN--Share of the population living in urban areas	0.000222	0.14	0.00179	1
POP65--Share of the population older than 65	-0.01901	-2.06	-0.02252	-2.16
POLITY2	0.01468	4.5		
Log GDP per capita (constant 1995 dollars)	-0.09611	-3.55	-0.08011	-2.04
AC--adaptive capacity index			-0.52875	-3.03
AC × pop65			0.04011	3.75
Number of countries	143		119	
Number of observations	1915		1657	
R square	0.1299		0.1337	

In both regressions (A) and (B) of table 7, fatalities in extreme weather events vary across regions,[27] increase significantly with population density, and are only weakly associated with the degree of urbanization. Previous climatic disasters are negatively associated with fatality rates, suggesting that this variable probably captures increased preparedness, and not just increased exposure. This effect is significant at the 1% level only in specification (B).

We had expected the share of the elderly in the population to enter in the regression with a positive coefficient, assuming that this variable captures sensitivity. Instead, the

[27] A likelihood ratio test rejects the null hypothesis that the coefficients on the regional dummies are jointly equal to zero (LR statistic=25.90, p-value<0.0001).

coefficient on this variable is negative and significant in both runs, probably because the share of the elderly in the population tends to be greater in wealthier countries, which tend to be less vulnerable. As expected, the coefficient on log GDP per capita is negative and significant. Resources reduce vulnerability, although the effect is less than proportionate: the model predicts that for the average South Asian country, for example, a 10% growth in GDP per capita income reduces the mortality rate in by 3.3 percent.

Surprisingly, in specification (A) the coefficient on POLITY2 is positive. This is the "wrong" sign, and the possible result of collinearity between this variable and other demographic and economic variables in the regression.

Moving to specification (B), the adaptive capacity index based on the experts' judgements works well, in the sense that higher adaptive capacity significantly reduces fatalities, and that this variable has additional explanatory power even after one controls for income, sensitivity and exposure. Adaptive capacity remains a significant predictor of fatalities even after one excludes log GDP from the regression, and accounts for a relatively large share of the explanatory power of the regression.[28] [29]

Because adaptive capacity is truly meaningful in the presence of elevated sensitivity and exposure to climatic disasters, we experimented with several interactions between the adaptive capacity index and CUMDISASTERS, POP65, and DENSITY. In the end, we found that only one of them enters significantly in the regression—that with POP65, which, as shown in specification (B), is positive (we had expected it to be

[28] If log GDP per capita is excluded from the regression, the R^2 of the regression is almost unchanged and still around 0.13. However, if adaptive capacity is excluded, the R^2 of the regression drops to only about 0.08.

[29] The coefficients of table 7, column (B), can also be used to illustrate the consequence of unrealistic assumptions about the adaptive capacity of less developed countries: if somehow a South Asian country

negative, and we had expected the coefficient on POP65 to be positive). In spite of this, we conclude that the adaptive capacity index does show the expected relationship with vulnerability.

VIII. Discussion and Conclusions

In this paper, we have developed a somewhat novel approach to eliciting expert judgments about adaptive capacity to climate change. The approach is based on conjoint choice questions. Specifically, we ask experts to look at pairs of hypothetical countries that differ from one another in the level of attributes (resources, distribution of resources, health status and age of the population, health care, access to information) previously identified as potential determinants of adaptive capacity, and to choose the one they believe to have the higher adaptive capacity. We focus on adaptive capacity for the effects on human health caused by extreme weather events, heat waves, and vector-borne illnesses.

We interpret the responses to these choice questions within a random adaptive capacity framework and statistically model them as a probit equation. We infer from our experts' choice responses that the resources available to a country and the level of inequality in the distribution of income are judged to be important determinants of the distribution of income, as are the type of health care system coverage (universal coverage or a system based on private insurance), and access to information. A more equitable distribution of income is judged equivalent to $4,600 in per capita income, while

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were able to achieve, all else the same, a level of adaptive capacity similar to that of the average European/Central Asian country, it would be able to reduce mortality rates in climatic disasters by 49%.

universal health care coverage and high access to information are judged equivalent to $12,000-$14,000 in per capita income.

We use the probit coefficient and our random capacity framework to calculate an index of adaptive capacity for several countries around the world. The index confirms that wealthy Western countries, including most European Union nations and the United States, have high adaptive capacity. These nations are trailed by transition economies and countries that recently joined the European Union (they have lower incomes), whereas former Soviet Republics do considerably worse, due to their low incomes, high inequality in the distribution of income, and, in many cases, failure to provide universal health care coverage. These problems are even more severe in many Asian, African and Latin American countries.

Worldwide, we indeed find that the countries with the lowest adaptive capacity are predominantly in Africa (e.g., Mozambique, Malawi, Sierra Leone, Guinea-Bissau, Tanzania, Niger, Burkina Faso). Some of the poorest Asian and central Asian countries are also predicted to have low adaptive capacity. Many of the countries we find to have extremely low adaptive capacity also appear on the lists of the most and of moderately-to-highly *vulnerable* countries developed by Brooks et al. (2005), who elicit rankings from a panel of seven experts to examine how their summary measure of vulnerability varies with the weights assigned to the 11 indicators it is formed with. This overlap provides empirical support for the notion that communities and countries with least resources have the least capacity to adapt and are thus the most vulnerable (Haddad, 2005).

Subsequent regression using panel data from many countries for 1990-2003 indeed shows that our adaptive capacity index is negative correlated with vulnerability, where vulnerability is the log of deaths in climatic disasters in country *l* in year *t*, normalized by population. Although explaining climatic disaster fatalities is generally difficult (the R^2 of the regression generally do not exceed 0.13), the adaptive capacity index account for a relatively large share of the explanatory power of the regression, even controlling for the country's GDP per capita.

Based on these results, we conclude that conjoint choice questions like the ones proposed and applied in this paper in the context of adaptive capacity work well as an approach for eliciting expert opinions. They could be applied as an alternative to, or in conjunction with, other expert elicitation techniques, such as ratings and rankings (Brooks et al., 2005[30]), to study other aspects of climate change (Nordhaus, 1994; Granger Morgan et al., 2001), and/or mitigation or adaptation policies.

[30] The Brooks et al. approach and ours are nicely complementary. Brooks et al. first develop a list of factors thought to be associated with vulnerability, and compute pairwise correlations between country-level proxies for the former and mortality rates in extreme weather events for each of the last three decades of the twentieth century. They then pare down the original list to 11 indicators (those for which the pairwise correlation is significant at the 10% level or better), and form a summary vulnerability index measure based on the quintile a country falls in for each indicator. Since this summary index assumes an equal weight for each of the 11 indicators, Brooks et al. use the indicator rankings provided by a panel of seven experts to assess the sensitivity of the vulnerability index to changing the weights. Clearly, the primary focus of the Brooks et al. is on vulnerability, although they recognize that vulnerability depends crucially on adaptive capacity. Another difference between their work and ours is the role played by expert judgments: it is the starting point of our research (we elicit expert opinions, form an index based on them and check it against actual mortality figures in multiple regressions) whereas it is used for sensitivity analysis purposes in theirs (they perform a series of bivariate analyses to select indicators of vulnerability and then validate their index using expert opinions). Since our adaptive capacity index is formed directly from the experts' responses to the choice questions, it implicitly subsumes the weights that they assign to the various country attributes.

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Appendix. Example of a conjoint choice question.

C1. Let us begin with two hypothetical countries, A and B. Both countries

- have a relatively high population density (400 people per square km.),
- have experienced a significant amount of deforestation in the past,
- have significant amounts of coastline and mountains,
- are moderately susceptible to floods and landslides, and
- have a mild, Mediterranean-type climate.

In addition, they have the following characteristics:

Characteristic	**Country A**	**Country B**
Income:		
Per capita income (in US dollars)	20,000	27,000
Inequality in the distribution of income	High	Low
Population:		
Percentage of population older than 65 years	18%	12%
Health:		
Life expectancy at birth	70 years	70 years
Physicians per 100,000	400	250
Health care system coverage	Based on private health insurance	Based on private health insurance
Technology and Infrastructure:		
Access to information via newspaper, television, radio, internet	Low	High

In your opinion, which country has higher adaptive capacity?

1. A ❑ **2. B** ❑

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(lxv) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications” organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003

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(lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003

(lxviii) This paper was presented at the ENGIME Workshop on “Governance and Policies in Multicultural Cities”, Rome, June 5-6, 2003

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(lxxiv) This paper was presented at the ENGIME Workshop on “Trust and social capital in multicultural cities” Athens, January 19-20, 2004

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(lxxvii) This paper was presented at the Workshop on Infectious Diseases: Ecological and Economic Approaches held in Trieste on 13-15 April 2005 and organised by the Ecological and Environmental Economics - EEE Programme, a joint three-year programme of ICTP - The Abdus Salam International Centre for Theoretical Physics, FEEM - Fondazione Eni Enrico Mattei, and The Beijer International Institute of Ecological Economics.

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