Methods used

Indicators consolidation

Indicators composing the WorldRiskIndex were obtained directly from official sources, as illustrated in the respective tables, many of them already in ranges between 0 and 1 or 0 and 100. When dealing with data ranges bigger than 100, normal standardisation was applied transforming values between 0 and 1 as shown in the following equation:

$$v' = (v - min) \cdot \frac{max_{\text{norm}} - min_{\text{nom}}}{max_{\text{m}} - min} + min_{\text{norm}}$$

This transformation was only used if the measurement unit were not proportionate to the population. All values were based on a single person as a unit. Special cases of transformation were used for GDP, life expectancy at birth and expenditure on health, according to the behaviour of the variables, so they were normalised with a logarithmical transformation to achieve a normal distribution.

Data Gaps and Country Data Coverage

Statistical analysis was used to cover some of the missing data, by comparing countries with similar characteristics, according to Templ routine for Robust Imputation of Missing Values in Compositional Data (Templ et al. 2006). These values were checked afterwards by additional information and/or other indexes sources in order to verify the coherence for this application in the data base.
However there are some countries with several values imputed for their indicators, so it is important to remember that this method allows a broad understanding of the situation in general, but does represent a regional average rather than a country's exact value. Examples are Kiribati, Bahamas, Fiji, Serbia, and Tonga. A table of all imputed can be found here

Factor analysis

The factor analysis was done in order to validate the aggregation formula of the WorldRiskIndex. The results of the factor analysis give information about the choice of the mathematical aggregation of the four different aggregated indices (exposure, susceptibility, coping and adaptation). A perfect aggregation would result in a Kaiser-Meyer-Olkin (KMO) Measure Accuracy of 1, the result of the factor analysis of the used aggregation formula was 0,769. This means the choice for the used aggregation formula was reasonable.

Another result of the factor analysis is the factor loadings for each component. They represent the correlation between each component and the overall index. The factor loading for susceptibility is -0,938, for coping 0,937 and for adaptation 0,944. The fact that these three components have more or less the same factor loadings means that each component has a strong correlation with the overall index thus could be weighted equally.

Sensitivity Analysis

As suggested during the Berlin Symposium, which was held in December 2009, a sensitivity analysis was carried out in order to

> *"...increase the confidence in the model and its predictions, by providing an understanding of how the model response variables respond to changes in the inputs, be they data used to calibrate it, model structures, or factors, i.e. the model-independent variables." (Saltelli 2000: 3)*

This means that a sensitivity analysis examines the sources of variation in a model output and can therefore be used to determine input variables largely contributing to that variation or also to determine variables that do not have a significant influence on the model outputs (see Saltelli 2000).

There are many different methods to carry out such sensitivity analysis, one general classification can be done between global and local methods: Local sensitivity analysis aims at explaining the influence of one varying variable on the model output while other variables held constant (Saltelli 2000). The global sensitivity analysis takes into account the apportion of uncertainty in the output variable to the uncertainty in each input factor (Campolongo et al. 2000: 17). This means, that all factors are changed at the same time which will also be the

case for subsequent editions of the WorldRiskIndex. Thus, a global sensitivity analysis was chosen and carried out for this study.
A local sensitivity analysis could reveal complementary information that may have policy relevance, as it can show which of the variables that are policy-dependent would need foremost alteration in order to obtain better scores at the index, in other words to lower the risk towards natural hazards. Given that only one indicator is changed at a time, it could show, for example, if it would have a greater influence on the index results to change the percentage of people undernourished or people living on less than 1.25 USD/day.

Bayesian Approach

For many index approaches, a Monte Carlo method has been used for the sensitivity analysis (e.g. Environmental Performance Index, Americas Programme). The Monte Carlo analysis is a simulation of high number of cases for each value, very computer intensive, that assumes that all indicators are entirely independent (as is the best case scenario, but not very likely for social indicators).

For the sensitivity analysis of the World Risk, Vulnerability and Adaptation Index, a Bayesian approach was used explaining each variable as a function plus a Gaussian noise [$y= f(x) + \text{noise}(0, \sigma^2)$] which means that the noise is assumed as normally distributed. Such approach uses a Bayesian regression which has an advantage. In other words, this new method uses a fist step as same as Monte Carlo, but with a stratified sample, and then it calculates with less values because it uses a normal distribution with Gaussian noise and substitutes frequencies with weights.

> *"…that the standard deviations that are associated with estimates are generally very much smaller, often by orders of magnitude, than those which are obtained from a Monte Carlo method with the same number of model runs. It is this that allows us to achieve useful sensitivity analyses of complex expensive models without having to make prohibitively many runs." (Oakley & O'Hagan 2004:759)*

The Bayesian approach application for global sensitivity was applied by components as well as for the entire index.

Figures 1-6 illustrate the sensitivity analysis done for each component of the WorldRiskIndex. Each figure consists of 3 parts (left, middle and right part). The left part shows each indicator displayed as a curve. Whereas the x-axis shows the original input data of each indicator scaled between -0.5 and +0.5 and the y-axis the variance of these indicators (scaled between 0 and 1). Every curve (indicator) shows the strength of influence on the index. The stronger the influence, the steeper the curves will look like. The middle part of each figure shows a *boxplot* with the different indicators on the X–axis and the sensitivity on the Y-axis. The size of the box explains how precise the indicator influences the index. The smaller the box the more precise is the influence on the index. The bold line in each box describes the median whereas high values on the y-axis explain the strength of the influence of each indicator to the overall index.
The right part of each figure shows also *boxplots* that display the influence and interaction of each indicator among each other in case of changes of one indicator. This could lead to following effects like e.g. the total sensitivity index of one indicator is zero meaning that this indicator is exchangeable whereas a large median represents a none substitutable and meaningful indicator.

Please be aware that the sensitivity analysis does not take over of the decision how to weight. There should be always logical argument to change weights.

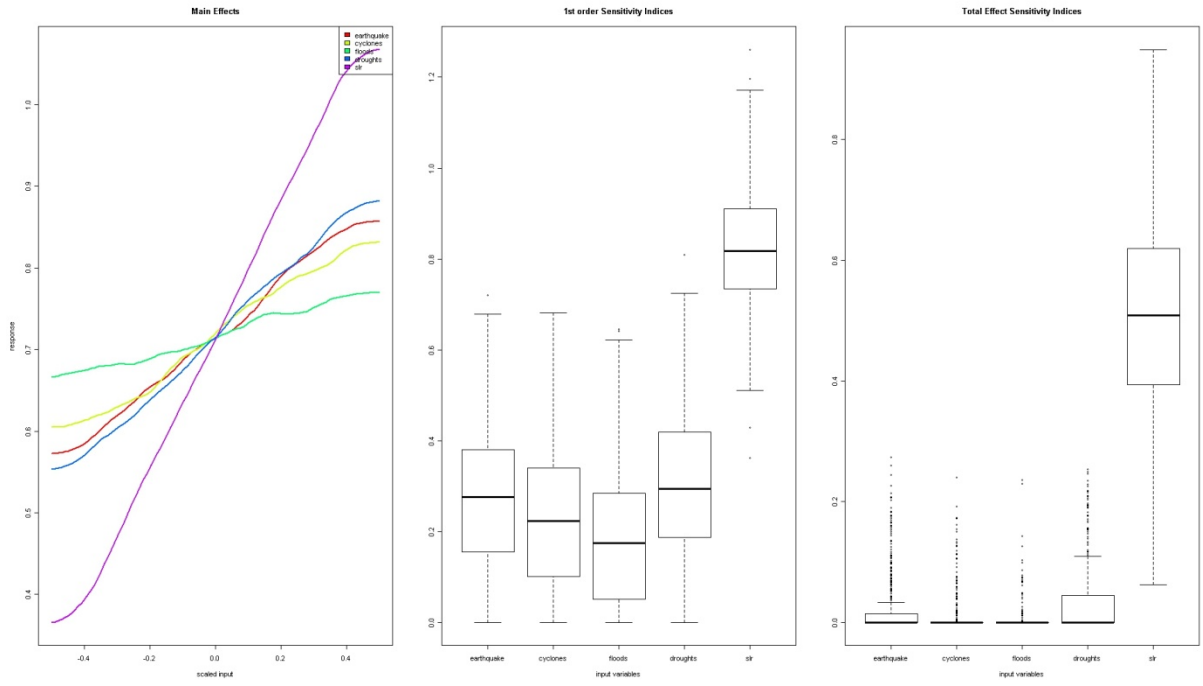

Fig. 1 Results of the Sensitivity Analysis for the exposure component

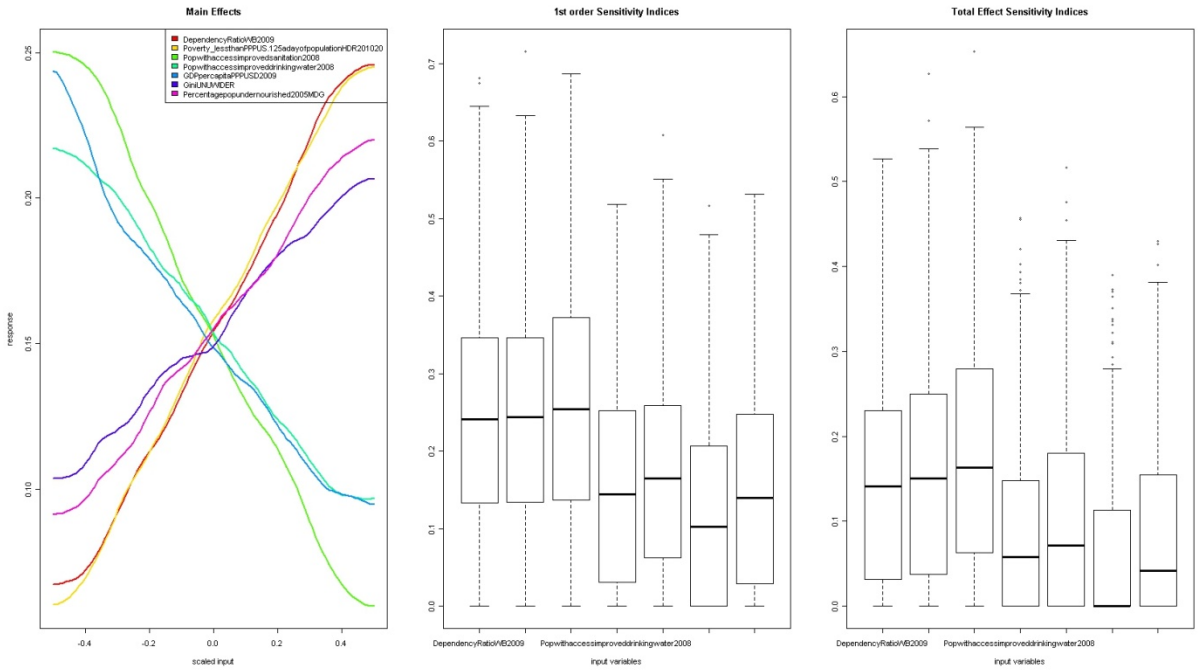

Fig. 1 Results of the Sensitivity Analysis for the susceptibility component

Figures 3 and 4 explains the sensitivity analysis of the coping component. The analysis of the first concept (carried out in 2009) revealed that the indicators "hospital beds" and "physicians" had only marginal influence on the variation of the aggregated coping index, visible in a flat slope (left part) and low values (middle and right part).

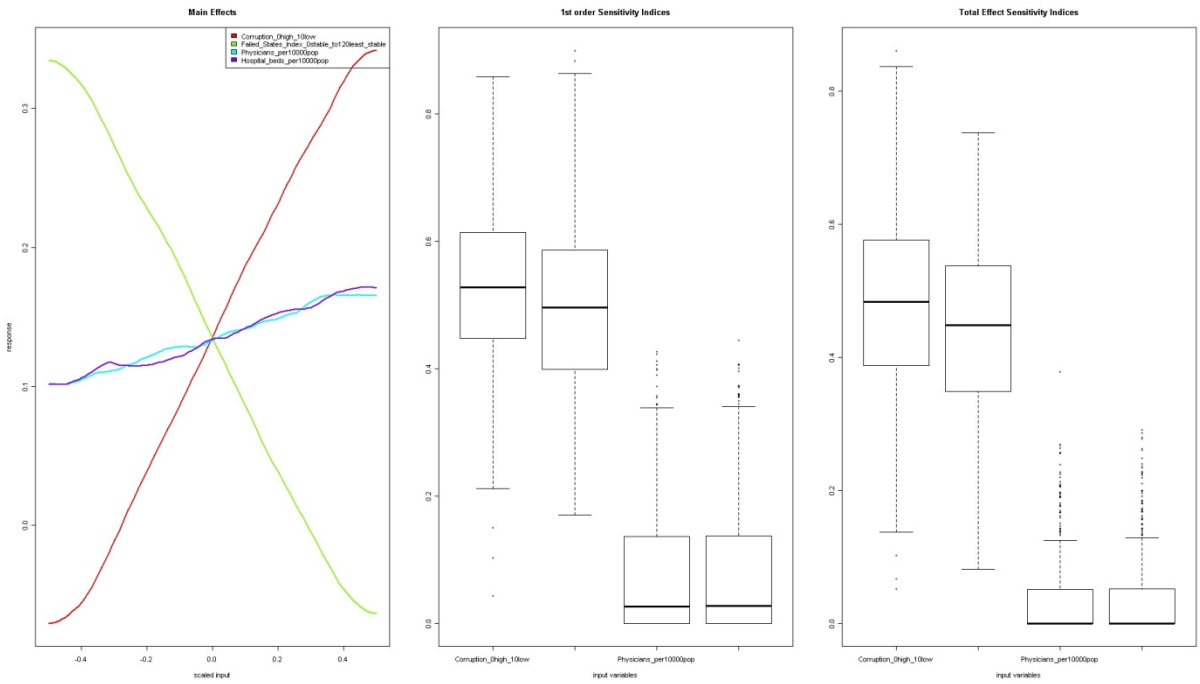

Fig. 3 Initial results of the Sensitivity Analysis for the coping capacity component, showing little influence of the "Health" indicators ("health" data from 1990-2007, Failed States and Corruption Perceptions Index of 2009)

Based on this result, the initial assumptions of the health indicators (hospital beds per inhabitant and physicians per inhabitant) have to be changed. While the target values were defined initially as 1/10 hospital bed per inhabitant and 1/20 physician per inhabitant according to the maximum values that occurred in the sample, they were changed by a factor 5 (i.e. 1/50 hospital bed and 1/100 physician per inhabitant) now being closer to the OECD mean for the respective indicators (Simoens & Hurst, 2006). Figure 4 illustrates the results of the sensitivity analysis with modified assumptions and the most recent data ("health" indicator data from 2000-2009 and Failed States and Corruption Perceptions Index 2010). It shows that the change in the assumption improved the sensitivity for the coping component, as the four indicators are now responsible for a similar proportion of the variation.

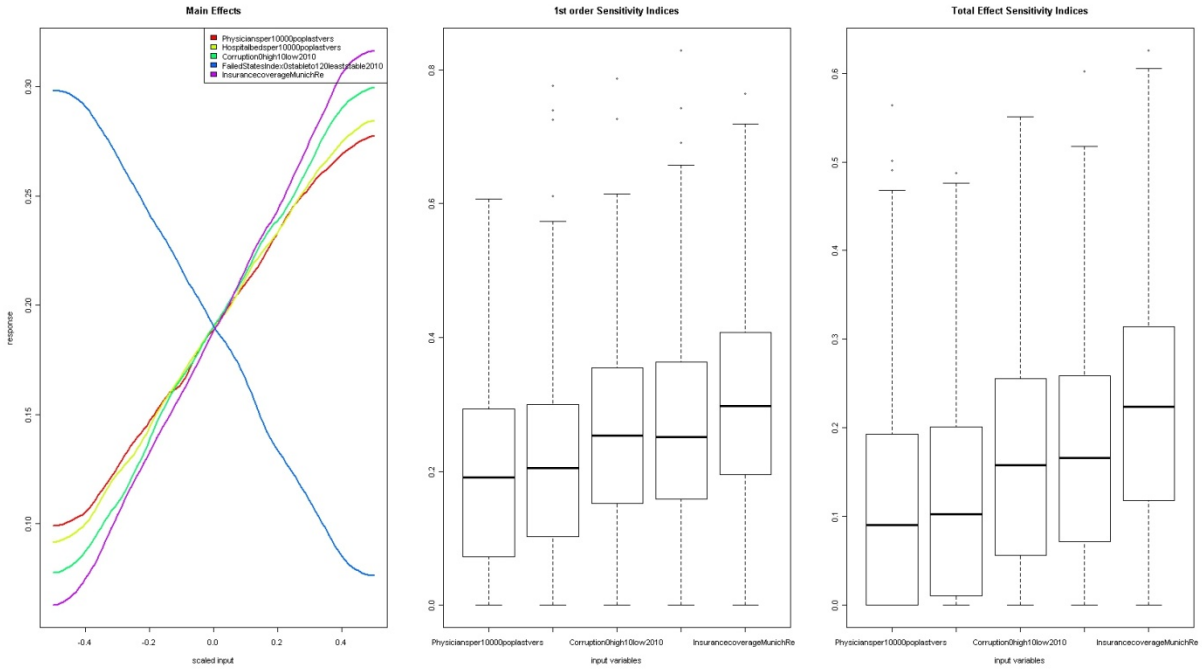

Fig. 4 Results of the Sensitivity Analysis for the coping capacity component after the adjustment of the "Health" indicators

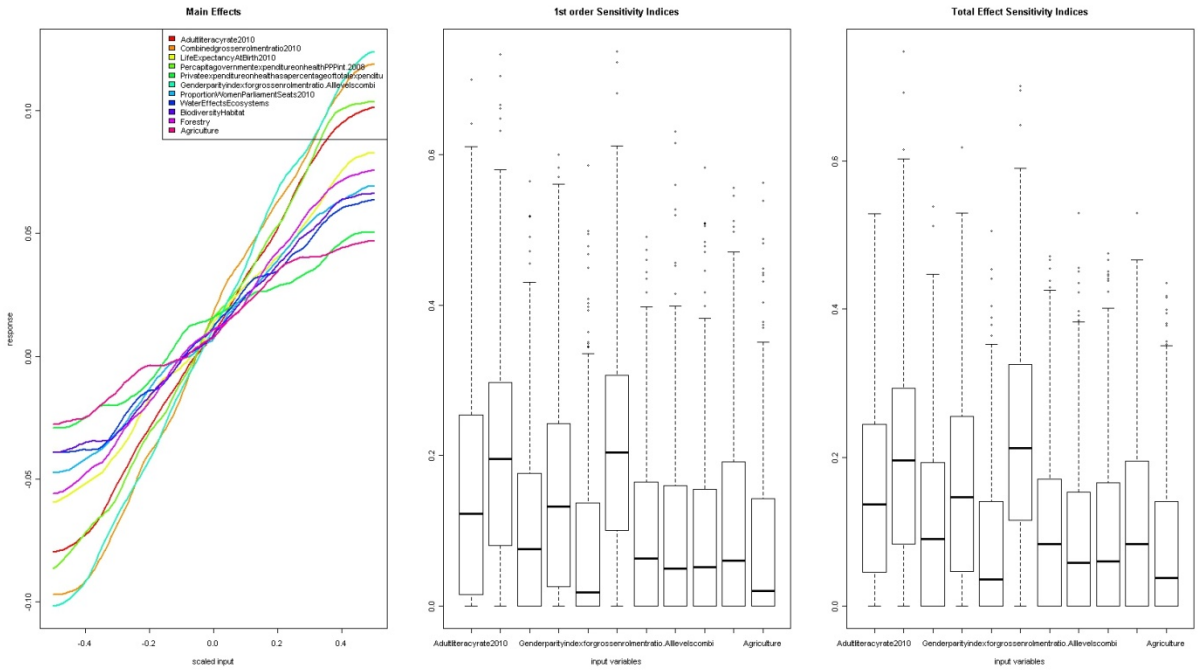

Fig. 5 Results of the Sensitivity Analysis for the adaptive capacity component, showing that the indicator on gender parity in school enrolment has least relevance for the component's results

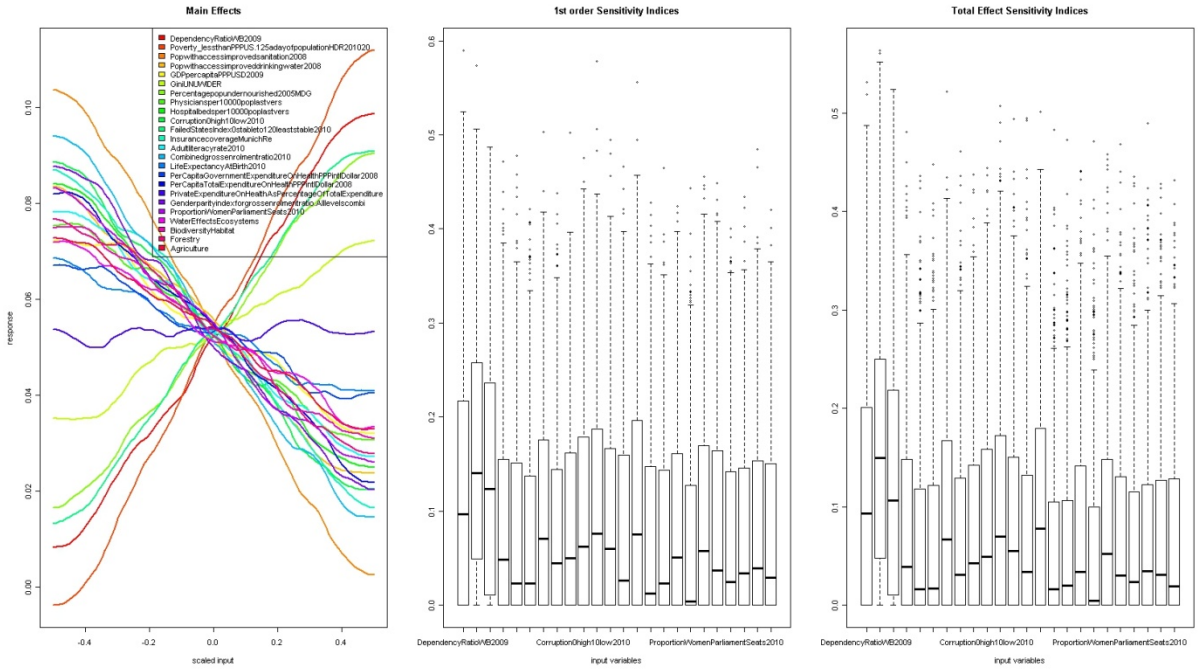

Fig. 6 Results of the Sensitivity Analysis for the entire vulnerability component of the index.

Homogeneity

Homogeneity describes the properties of data, or several datasets, and relates to the validity of the often convenient assumption that the statistical properties of

any part of an overall dataset are the same as any other part. In our case, for example, we start with the assumption that all measurable indicators of the individual countries will be homogeneous across all countries. But in reality countries differ among each other, especially large countries compared with small countries e.g. in terms of population density, culture or administrative structures, thus China is more heterogenous than Luxembourg. We are aware of this problem and could start to calculate the homogeneity but have to point out that the results are dependent on the data quality on sub-national level that –like it was mentioned before- is an overall problem since such data is often not available and therefore have to be computed based on other available data. It is possibly foreseen to calculate the homogeneity within the next report.

Expert Evaluation and Weighting

In the process of indicator selection, a questionnaire on the relevance of suggested indicators was distributed to several experts and practitioners with different backgrounds and working experience in various countries. Apart from two scientists consulted to review the conceptual approach, the professional background of the respondents lies within the field of development cooperation, so that they are familiar with topics of risk and vulnerability from a more applied vantage point (e.g. disaster relief operations). In addition to judgement on importance of single indicators, respondents had the opportunity to suggest new potential indicators or relevant criteria that were missing in the provided list. This feedback ensured the relevance of proposed indicators not only from a theoretical but also from a praxis-oriented viewpoint.

The respondents evaluated none of the suggested variables as irrelevant but some were, of course, judged more important than others. The population exposed to sea level rise, for example, was judged as less important – for the calculation of the Index - than the population exposed to other hazard types. Also, the GDP per capita in purchasing power parity received lower values than other indicators suggested for susceptibility (e.g. extreme poverty, dependency ratio).

However, the expert weights relating different indicators to each other were, for most cases, not significantly different from equal weights. It was hence decided to use equal weights in many of the components at the moment and to reassess

the weighting of the indicators at a potential later project stage, within the process of fully testing the proposed index.

Reliability analysis using Cronbach's Alpha showed very good reliability results (.94), which means the information of the single indicators is adequately represented in the final index.

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