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Uncertainty in adaptive capacity

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Abstract

The capacity to adapt is a critical element of the process of adaptation: it is the vector of resources that represent the asset base from which adaptation actions can be made. Adaptive capacity can in theory be identified and measured at various scales, from the individual to the nation. The assessment of uncertainty within such measures comes from the contested knowledge domain and theories surrounding the nature of the determinants of adaptive capacity and the human action of adaptation. While generic adaptive capacity at the national level, for example, is often postulated as being dependent on health, governance and political rights, and literacy, and economic well-being, the determinants of these variables at national levels are not widely understood. We outline the nature of this uncertainty for the major elements of adaptive capacity and illustrate these issues with the example of a social vulnerability index for countries in Africa. ***To cite this article: W.N. Adger, K. Vincent, C. R. Geoscience 337 (2005).***

Résumé

Incertitudes dans la capacité d'adaptation. L'aptitude à s'adapter est un élément critique du processus d'adaptation : elle est le vecteur des ressources qui constituent les atouts de base aux actions d'adaptation. La capacité d'adaptation peut être théoriquement identifiée à des échelles diverses, allant du niveau individuel à celui de la nation. L'évaluation de l'incertitude affectant de telles mesures fait appel à l'étendue des connaissances et aux théories contestées relatives aux déterminants de la capacité d'adaptation et des actions humaines d'adaptation. Alors qu'on estime souvent que la capacité d'adaptation générique, au niveau national par exemple, dépend de la santé, de la gouvernance et des droits politiques, les déterminants de ces variables au niveau national demeurent largement incompris. Nous soulignons la nature de cette incertitude pour les éléments majeurs de la capacité d'adaptation et illustrons ces points par l'exemple de l'indice de vulnérabilité sociale pour des pays africains. ***Pour citer cet article : W.N. Adger, K. Vincent, C. R. Geoscience 337 (2005).***

Keywords: Climate change; Adaptive capacity; Vulnerability; Uncertainties

Mots-clés : Changement climatique ; Capacité d'adaptation ; Vulnérabilité ; Incertitudes

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1. Framing adaptation to climate change

There are many apparent paradoxes at the heart of debates on adaptation to climate change. Clearly human societies have adapted to changing climate throughout history, yet it is commonly asserted that future climate changes will push beyond the limits of adaptation. Similarly it is frequently assumed that the capacity of societies to adapt to climate risks is based on their level of economic development: the more economically 'developed' a society, the greater the access to technology and resources to invest in adaptation. Yet evidence from traditional societies demonstrates that the capacity to adapt in many senses depends more on experience, knowledge and dependency on weather-sensitive resources. Pastoralists in Sahel have adapted to significant depletion of rainfall and resource availability in the course of the 20th century without apparently having major reserves or resources to invest in new livelihood sources.

In this area of research, then, it is apparent that uncertainty in the science of adaptation stems more from contested underlying theories of behaviour, politics, and risk than of data and observation. Hence adaptive capacity is a scale-dependent concept and adaptation itself can best be conceptualized as a characteristic of an adapting system [45]. The challenge for emerging insights into adaptation is how to characterize this adaptive capacity in a meaningful sense and to find generic determinants of adaptive capacity at various scales to build predictive models of its evolution into the future.

Adaptive capacity is a vector of resources and assets that represent the asset base from which adaptation actions and investments can be made. Within the IPCC Third Assessment Report, it is recognized that this capacity may be latent and be important only when sectors or systems are exposed to the actual or expected climate stimuli [49]. Vulnerability to climate change is therefore made up of a number of components including exposure to impacts, sensitivity, and the capacity to adapt. Adaptive capacity is, therefore, a component of vulnerability [34,48]. Adaptive capacity has diverse elements encompassing the capacity to modify exposure to risks associated with climate change, absorb and recover from losses stemming from climate impacts, and exploit new opportunities that arise in the process of adaptation.

Adaptation decisions taken by individuals (e.g., to use insurance, relocation away from threats, or changing technologies) and taking place within an institutional context can act to facilitate or constrain adaptation. It is clear that individuals and societies will adapt and have been adapting to climate change over the course of human history – climate is part of the wider geographical and historical landscape of human habitation. Thus individuals and societies are vulnerable to climate risks and other factors and this vulnerability can act as a driver for adaptive resource management. There are various geographic scales and social agents involved in adaptation. Some adaptation by individuals is undertaken in response to climate threats, often triggered by individual extreme events [46]. Other adaptation is undertaken by governments on behalf of society, sometimes in anticipation of change but again, often in response to individual events. Government policies and individual adaptations are not independent of each other – they are embedded in governance processes that reflect the relationship between individuals, their capabilities and social capital, and the government. A previously hypothesised distinction between planned and autonomous adaptation [49] fails to account for the nested nature of decision-making – each individual adaptation action is constrained by antecedent development and regulatory decisions. Indeed all adaptation decisions and policies have socially differentiated impacts and equity implications. This emerging set of insights into how adaptation occurs is likely to be planned for the future, and on the nature of the capacity to adapt (see [6] for a review), pose significant challenges for the description and incorporation of uncertainty into its assessment.

2. Elements of uncertainty

The IPCC conceptualizes vulnerability within a systems perspective. It judges a system to be vulnerable if it is exposed to climate change impacts, if it is sensitive to those impacts, and if it has a low capacity to cope with those impacts. Moss and Schneider [39] show an explosion of uncertainty towards the 'range of possible impacts' (upper part of Fig. 1). Along with Jones [27] and others, they argue that aggregating impacts of climate change is an uncertain science since moving from biogeochemical cycling through to im-

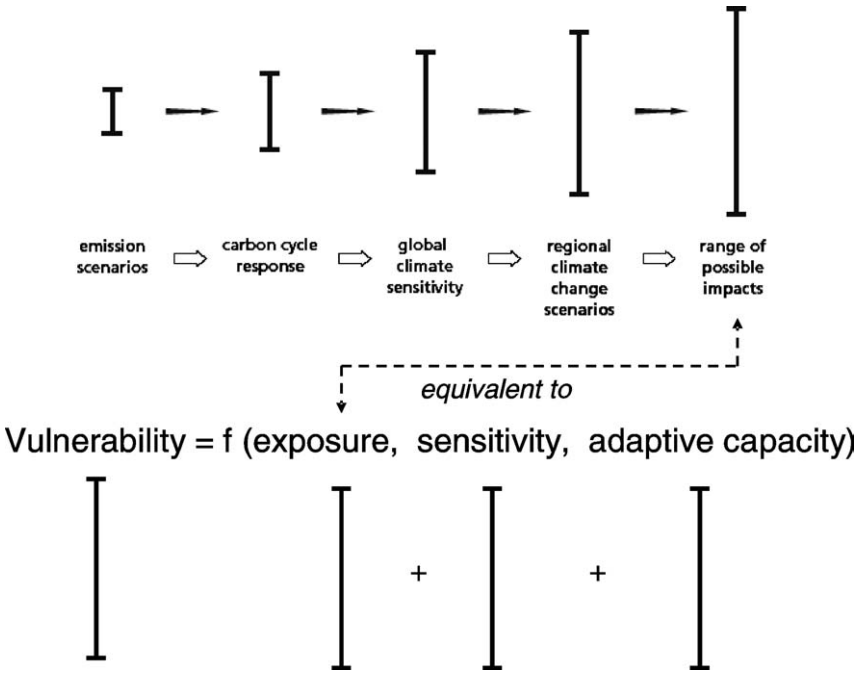

Fig. 1. Range of uncertainty associated with climate change impact assessment (upper panel) and with elements of vulnerability and adaptive capacity (lower panel). Upper panel adapted from [39].

Fig. 1. Étendue de l'incertitude relative à l'estimation des conséquences du réchauffement climatique (partie supérieure) et aux éléments de la vulnérabilité et de la capacité d'adaptation (partie inférieure). La partie supérieure est tirée de la référence [39], à une adaptation près.

pact assessment involves a complex set of links in the chain of causality [27]. Thus the range of uncertainty associated with impacts 'are multiplied to encompass a comprehensive range of future consequences, including physical, economic, social and political impacts and policy responses' [39, p. 39].

The uncertainties in impacts depicted in the upper panel of Fig. 1 represent the 'exposure' elements of vulnerability. In the lower panel of Fig. 1, we illustrate how uncertainty in adaptation and adaptive capacity are related to this prior cascade of uncertainty in other parts of the climate science system. The range of possible impacts is effectively the range of exposure. The ranges of uncertainty associated with sensitivity to change and with the capacity to adapt are shown in Fig. 1 as having equal ranges to that of exposure. Both sensitivity and adaptive capacity have complex causal chains. While there is mixed evidence that sensitivity to underlying climate is correlated with indicators of development for a region [37], there are diverse specific mechanisms, technologies and pathways by which sensitivity to climate change may be altered. In the sections below we emphasise the nature and determinants of the third element in the vulnerability chain, that of adaptive capacity.

The range of uncertainties associated with adaptive capacity is that relating to the determinants of adaptive capacity as well as to uncertainty in projecting those determinants into the future. Adaptive capacity in the IPCC assessments is determined by the 'characteristics of communities, countries, and regions that influence their propensity or ability to adapt' [25, p. 18]. There are, therefore, generic features of adaptive capacity of societies to climate variability and change as well as to other types of stress. These are to do with the resources available to cope with exposure, the distribution of these resources across the landscape and between groups within a population, and the institutions which mediate both resources and coping with risk. If institutions fail to plan for changing environmental conditions and risks, adaptive capacity is constrained, and vulnerability increases.

Since the Third Assessment Report, there have been a number of research efforts aimed at outlin-

ing generic and specific adaptive capacities at various scales [6,21,40,55]. Many of these aim to elaborate country-level adaptive capacity, primarily with a view of assisting international decision-making around investments in adaptation coming from the mechanisms of the Framework Convention on Climate Change. All have encountered data and conceptual problems in characterizing adaptive capacity quantitatively or in characterizing uncertainty. Yohe and Tol [55] suggest eight determinants of adaptive capacity including the range of available technological options for adaptation, the availability of resources and their distribution, the structure of critical institutions, the stocks of human and social capital, access to risk spreading mechanisms, the ability of decision-makers to manage risks and information and the public's perceived attribution of the source of the stress and the significance of exposure to its local manifestations. They conclude, however, that 'many of these variables cannot be quantified, and many of the component functions can only be qualitatively described' [55, p. 27].

Adaptive capacity in effect gives a picture of the adaptation space within which adaptation decisions are feasible. It is therefore more meaningful and tractable to develop scenarios of adaptive capacity than scenarios of adaptation per se. Predicting adaptation requires adopting a model that describes the processes of adaptation. This is difficult because adaptation comes through markets, civil society and government action and complex interactions between them.

Berkhout and colleagues [8], for example, show empirically that it is not meaningful to describe a single adaptation path of a climate-sensitive sector of the economy [8]. They demonstrate that in the house-building sector in the UK faced with expected changes in risk from flooding, a fragmented picture appears of niche markets and diverse strategies, the diversity of strategies being defined by the adaptation space and the capacity of the sector.

Where climate change involves primarily market impacts, adjustments may be quicker and less costly than other sectors of society [36]. Timber markets or markets for irrigation technology, for example, may minimize private adaptation costs [50]. But market adjustments represent only a subset of adaptation costs: many of the impacts on economic well-being are so-called social costs rather than private costs. The social costs of impacts on agriculture, for example, are food insecurity and vulnerability: while international markets for food commodities may clear, the welfare costs of food insecurity in terms of health, nutrition and conflict may be the most significant of the costs. Thus distribution of adaptation costs between private and public agents are both uncertain and a crucial element in the creation of vulnerability [2].

Developing scenarios of adaptive capacity at various scales highlights the nature of uncertainty in this area. Clearly adaptive capacity is dependent on a range of socio-economic variables for which there are specific uncertainties. Many of these relate to discussions on uncertainty in mitigation. Rates and patterns of demographic change, the development and diffusion of technologies for adaptation, and the distribution of economic well-being are all elements of adaptive capacity that are also driving emissions and the capacity to mitigate [53].

There is an increasing need to develop indicators of both vulnerability and adaptive capacity both to determine the robustness of response strategies over time and to understand better the underlying processes. The climate change policy process has increasingly focussed on the potential for adaptation. National level indicators of vulnerability or adaptive capacity directed towards the allocation of resources to support financial mechanisms of the UNFCCC, for example, will only find acceptance if based on agreed criteria that are as transparent and robust. While it is possible to compare the vulnerability of people and places across time and space at different scales, it is less meaningful to aggregate vulnerability across scales since the processes that cause vulnerability are different at each scale [6].

National-level assessments of adaptive capacity are appropriate for providing information utilised by central government in determination of policy. Comparing adaptive capacity across countries can identify leverage points in reducing vulnerability to climate variability and, by inference, to climate change, which is likely to be manifest through changes in the frequency and severity of existing hazards at least in the short- to medium-term. Identification of nations with low specific adaptive capacity can act as an entry point for both understanding and addressing the processes that cause and exacerbate vulnerability. A common critique of work at this scale is that the sub-national

spatial and social differentiation of vulnerability and local conditions mediate the capacity to adapt [55]. Published studies of national-level vulnerability have generally been based on assumptions about the factors and processes leading to vulnerability, informed by intuitive understandings of human-environment interaction.

The processes that shape vulnerability operate on different geographic scales. While decreasing labour availability, for example, manifests itself on a community level, a national level indicator may aim to capture the processes that shape local level decrease in labour availability, such as urbanisation and de-agrarianisation. The nation-state functions as a broker between global and local scales for example as a conduit for external funding for climate change adaptation or as an enforcer of international agreements on emission reduction. Yet the experience of climate change is finely resolved in spatial scales and the challenges of adaptation in markets, networks and communities may be largely invisible to many aspects of national governments. Assuming that the nation state has the interests of all its citizens in mind introduces greater levels of uncertainty in adaptive capacity: there is deep uncertainty concerning the role of governments in creating vulnerability or in ignoring intractable problems [4].

The contextual nature of vulnerability, the difficulties of validating indicators, and considerations of timescale, provide challenges to the development of robust indicators. Brooks and colleagues [12] attempt to account for the hazard-specific and context-specific nature of vulnerability and adaptive capacity in developing national level indicators that explicitly addresses the issue of timescale [12]. They find that on multi-year and decadal timescales, the capacity of a country to cope with and adapt to extreme events associated with climate variability is associated predominantly with health, governance and political rights, and literacy. Eleven key indicators exhibit a strong relationship with decadally-aggregated mortality associated with climate-related disasters. Validation of indicators using mortality outcome data goes some way towards addressing the issue of subjectivity in the choice of indicators. Expert judgment data, collected through a focus group exercise, identifies the most important indicators through consideration of processes and contexts. Perhaps not surprisingly, governance plays a key role: the Brooks et al. [12] results indicate that the most vulnerable nations are those situated in sub-Saharan Africa and those that have recently experienced conflict [12].

Governance is an uncertain area. Not only is it difficult to project scenarios of governance into the future or to predict their change, but the very notion of governance indicators is problematic. Some theories suggest, for example, that the presence of civil society groups lobbying for interest groups is a drain on effective governance, while other theories suggest exactly the opposite – that membership of formal groups is an indicator of the vibrancy and effectiveness of government and themselves promote trust in government. These competing notions of governance and the role of social capital have been empirically tested to elicit the relationships between trust, civic action and economic performance [32,33] with mixed results. Knack and Keefer [33] find that high levels of general 'trust' in society (trust in property, and law enforcement) are positively correlated with economic performance; they do not find that higher trust means greater direct involvement of individuals in civil society [33]. This latter variable, the engagement of individuals in networks, is hypothesized by Putnam et al. [44] to be significant for economic development, the strength of institutions and other factors that may represent generic adaptive capacity [44]. Based on empirical experience in adapting to present day weather extremes, Adger [2] argues that associations, networks and capital form a vital element in adaptive capacity [2]. Clearly elements of governance such as trust are important in adaptive capacity but its determinants and its evolution in the future remain obscure.

Governance creates other dimensions of uncertainty in adaptive capacity. It may seem intuitively obvious what direction of change of key indicators enhances adaptive capacity at the national level (e.g., greater wealth represents enhanced capacity to adapt). But the objectives of government across different areas of adaptive capacity are not given. Rather they are a function of the underlying objectives of governance. There are inevitably discrepancies between governments whose aspirations are to maximize the welfare of its citizens, compared to those governments which seek to maintain control of their citizens, or those that seek to reduce the vulnerability of the most vulnerable groups. These different aspirations lead to

different weightings of the elements of adaptive capacity – seeking to reduce vulnerability would likely lead to investment in short term hazardous impacts more than in coping with long term changes for example. Haddad [24] has shown empirically that the ranking of adaptive capacity of nations is significantly altered when governmental aspirations are taken into account [24]. But government aspirations change, often with revolutionary zeal.

3. An illustration: uncertainty in adaptive capacity for African nation states

The contested knowledge domain of adaptive capacity discussed above retains its fundamental uncertainty whether it is analysed through theory and hypothesis testing or through normative research on indicators of capacity. Indicators and indices are used to describe the determinants of vulnerability and allow comparison of adaptive capacity at different scales. They are used for the purposes of allocating resources and determining priorities. Lessons from this research are that adaptive capacity is scale-dependent and that different indicators are required to capture elements of adaptive capacity at different scales. In other words, the determinants of adaptive capacity are specific to the system undertaking the adaptation and its characteristics [45]. A number of indicators and indices of national level vulnerability have been attempted, particularly for small island developing states [10,19,22, 29] as well as for adaptive capacity and vulnerability to climate change. However, the process of developing indicators involves uncertainty at several levels. In this section we present a social vulnerability index (SVI) (detailed in [51]), to illustrate the issues of uncertainty in adaptive capacity raised above. The SVI is an aggregate index of human vulnerability to climate change-induced changes in water availability that is formed from the weighted average of five composite sub-indices: economic well-being and stability, demographic structure, institutional stability and strength of public infrastructure, global interconnectivity and dependence on natural resources sensitive to water stress and water availability. We illustrate the application of the SVI for countries in Africa. Fig. 2 outlines the structure of the SVI, showing the composite sub-indices and their component indicators.

Many indicators and index studies in the environmental area are, in effect, constrained by data availability. They adopt an inductive rather than a theory-driven or deductive approach [41]. Data-driven approaches to indicator development generally develop a wide range of indicators and select from these using either expert judgment [28–30], principal component analysis [22], or correlation with past disaster events [12] to determine those that account for the largest proportion of vulnerability. The weakness of data-driven indicator studies is that a proxy variable for vulnerability must be chosen as the benchmark against which indicators are tested. This is somewhat paradoxical since the very need for vulnerability indicators is because there is no such tangible element of vulnerability. Insight into the nature and causes of vulnerability can, alternatively, be used to select variables for inclusion, although in practice this necessarily occurs within the constraints of data availability [10].

In theory, historical indicators can be used to test hypotheses concerning the nature of the relationships implicit in the aggregated indices. Brooks and colleagues [12] undertake such an analysis of vulnerability indicators by examining national level data on mortality and economic costs of weather-related disasters from 1970 to 2000. They analyse multivariate correlations of particular indicators with observed outcomes. They find that the characteristics of the resource system are an important determinant of disaster outcome. Thus indicator studies can, with some development, shed light on the underlying processes of adaptation as well as being simply descriptors of arbitrarily picked proxy indicators.

The SVI outlined here uses a theory-driven approach where we deduce relevant indicators based on hypothesized links between development, environment and resilience. Hence the major uncertainty issue is that of construct validity. The key challenge is to derive simple and easily comprehensible indicators or proxy indicators from these hypothesized links. In some cases the indicators are fairly uncontroversial in capturing the underlying determinant of vulnerability. In the case of the economic well-being and stability sub-index for example, many have cautioned against assuming a direct relationship between GDP and vulnerability [1,10,19,31]. However, whilst there is widespread acceptance of the complexity and contested nature of the relationship, there is still consensus that a

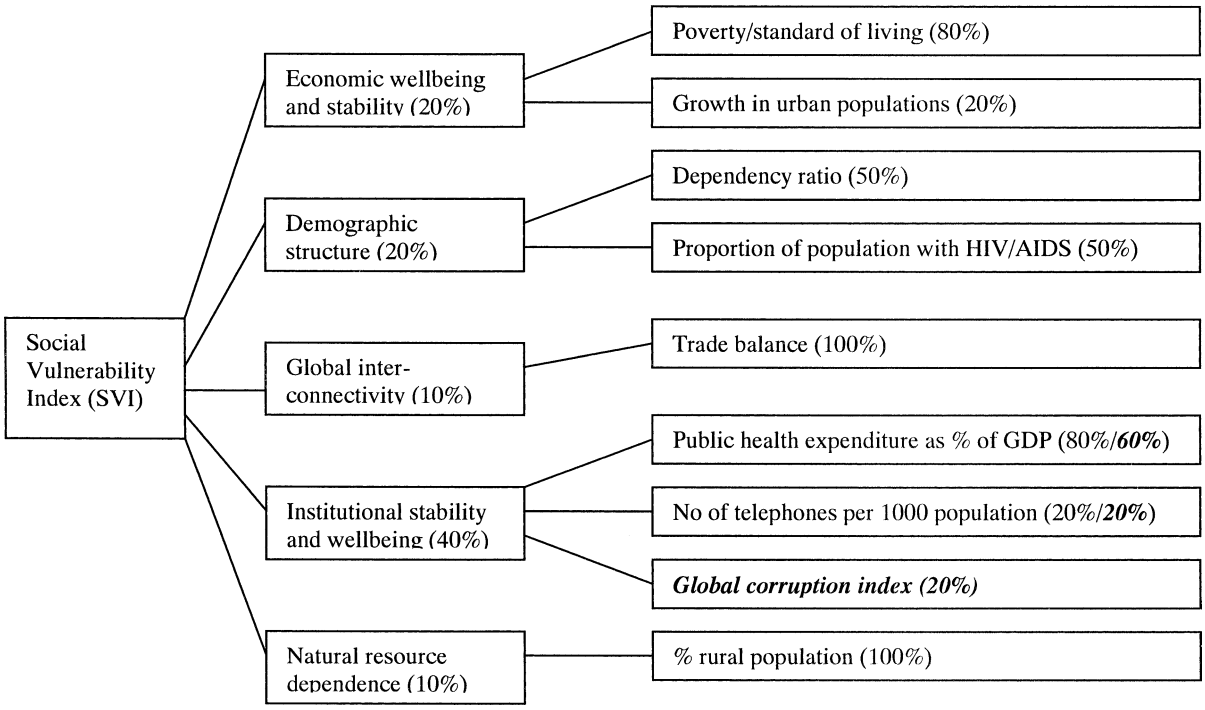

Fig. 2. Structure of the aggregate Social Vulnerability Index, composite sub-indices, and components indicators. Text in bold represents the alternative structure of the institutional stability and well-being sub-index used in version B of the SVI.

Fig. 2. Structure de l'indice de vulnérabilité sociale agrégé, des sous-indices composites et des indicateurs constitutifs. Le texte en gras correspond à la version de la structure institutionnelle et des sous-indices de bien-être utilisés dans la version B de l'indice de vulnérabilité sociale.

strong economy acts as a safety net in the case of environmental risk and hazard exposure, both pre-event through enabling anticipatory coping strategies, and post-event in responding to a shock [14,15].

The use of other indicators in the index is more contested: for example, that relating to natural resource dependence. While all human populations have a physiological demand for water, for example, this generally does not suggest how water scarcity and quality can be captured in a definitive relationship. One way of differentiating between different levels of dependence on water resources is to examine the proportion of the population dependent on water for their productive livelihoods. The constraint of only using internationally-reputable data sources means that percentage rural population is the most suitable proxy (Fig. 2). This choice of indicator assumes that rural populations largely rely on primary industries that are natural resource-dependent and hence are directly linked to water availability, such as agriculture. Whilst once widely accepted that substantial proportions of rural African income was derived from the land, up to 60% [23], this is now a contested area. Diversification and 'de-agrarianisation' of the rural economy have occurred concurrently. De-agrarianisation is defined in this context as 'a long term process of occupational adjustment, income-earning reorientation, social identification and spatial relocation of rural dwellers away from strictly agriculturally-based modes of livelihoods' [13, p. 726]. Nothing in these debates on the changing nature of livelihoods in rural Africa suggests, however, that populations are any less exposed or sensitive to climate change impacts over time.

As discussed in the section above, there is, for the most contested areas, in addition to uncertainty in the construct validity, uncertainty about even the direction of the functional relationship of each indicator with vulnerability. With the 'global interconnectivity' sub-index in Fig. 2, for example, the indicator is the trade

balance of a country. Globalisation scholars argue that, while experiences are diverse, economic liberalization and integration into the global economy tend to exploit particular sectors of society and in turn reinforce existing inequalities in the global economy, creating winners and losers at a variety of scales [38,42], and has left Africa largely marginalised [7,16,17].

The poor performance of African economies and the relationship to external factors or domestic policy is a controversial area [18]. The debate comes down to the relative importance of geography and institutions in explaining recent growth patterns. Collier and Gunning [18] and others argue that while external policy issues associated with globalization are important, so too are the internal policy variables relating to public service delivery, corruption and democratic governance. An alternative explanation focuses on so-called 'destiny' factors – external exogenous factors such as whether a country is land-locked and can access global markets and the waves of globalization and domestic destiny associated with disease incidence, unreliable rainfall and related factors [47]. Wealth arises from social, physical and human capital – hence both geography and institutions play a part. Diamond [20] and others argue that more fundamentally even the nature of institutions has historical and geographical explanations (e.g., complex and stable institutions of governance emerge in response to the need for sedentary agriculture [9]). Thus, deriving relevant indicators on adaptive capacity related to integration into the world economy involves collapsing complex causal chains into single variables. The uncertainty involved in these indicators is, as shown in Fig. 1, significant but indeterminate.

As a way forward, the SVI in Table 1 assumes that those national economies with a negative trade balance are locked into external market forces on unfavourable terms, and thus are more vulnerable. However, the US has the largest negative trade balance, but is unlikely to be considered the most vulnerable country in the world. It might be possible that the better integrated a country is into the global economy, the more opportunities it might have to diversify and thus in fact is increasing its resilience. Leichenko and O'Brien [35] studied the "double exposure" of some sectors to both climate change and economic globalization, and found at the sub-national level that sectors such as agriculture are likely to have a variable distribution of winners and losers [35].

Standardisation and aggregation of the indices in Table 1 utilises a variety of methods that lead to uncertainty in the adaptive capacity measure. Jollands and Paterson [26] make the distinction between aggregate indices, where the constituent parts are not recognisable, and composite indices, where they are. The SVI combines both approaches, by having a scalar function within the theoretical background to create a single aggregate score, but also with a commitment to transparency in the composite make-up of that score. Weights are applied to the indicators in forming the sub-indices, and then when aggregating the sub-indices to form the aggregate index, in keeping with the theory-driven nature of the index, and based on expert judgment.

As Table 1 demonstrates, the country with the highest level of social vulnerability is Niger, followed by other sub-Saharan countries such as Sierra Leone, Burundi, Madagascar, Burkina Faso, Uganda, Ethiopia and Mauritania. The countries at the bottom end of the range are the North African states of Egypt, Morocco, Libya, Tunisia and Algeria, along with the relatively developed southern African countries of Namibia and South Africa, the Indian Ocean island of Mauritius and Senegal in the west. Perhaps most surprising is that Djibouti scores relatively well. Taking corruption into account in index B does not have much effect on the overall ranking, with Madagascar, Uganda, Tanzania, Cameroon and Ethiopia exhibiting the highest levels of social vulnerability, and the north African states, Mauritius, Senegal, South Africa and Namibia better off. It is difficult to draw too many conclusions about changing ranks given the different sizes of the samples. In terms of actual scores, the largest changes between indices A and B are Zambia (+0.034), Kenya (+0.025), Namibia (+0.024), Angola (+0.022) and Zimbabwe (+0.022), highlighting the relative importance of corruption in their vulnerability profiles. However, in both versions of the SVI index it is important to remember that the indicators have been standardized across the range of data for Africa, not across a normative range with theoretical high and low values. Therefore the countries with scores nearest to '0' are not necessarily resilient, just less vulnerable than other countries in Africa.

Table 1
Score and ranking of African countries by the Social Vulnerability Index (SVI) under two definitions of the index. Index A refers to the main index, whilst index B represents a variation that could only be created for a limited number of countries due to data constraints on corruption

Tableau 1
Performance et rang des pays africains au regard de l'indice de vulnérabilité sociale, pour deux définitions de cet indice ; l'indice A est l'indice principal, l'indice B correspondant à une variante qui n'a pu être construite que pour un nombre limité de pays, à cause des contraintes sur les données relatives à la corruption

Country	Vulnerability index A	
	score	**rank**
Niger	0.725	**1**
Sierra Leone	0.705	**2**
Burundi	0.703	**3**
Madagascar	0.691	**4**
Burkina Faso*	0.658	**5**
Uganda	0.657	**6**
Ethiopia*	0.655	**7**
Mauritania	0.654	**8**
Lesotho	0.649	**9**
Tanzania	0.646	**10**
Cameroon	0.640	**11**
Togo*	0.633	**12**
Rwanda	0.627	**13**
Ghana	0.624	**14**
Nigeria	0.621	**15**
Chad	0.618	**16**
Angola	0.612	**17**
Eritrea	0.601	**18**
Swaziland	0.599	**19**
Zambia	0.597	**20**
Guinea Bissau	0.591	**22**
Dem. Rep. Congo	0.591	**22**
Malawi	0.591	**22**
Botswana*	0.586	**24**
Mali*	0.585	**25**
Ivory Coast	0.584	**27**
Central Africa Republic*	0.584	**27**
Benin	0.584	**27**
Comoros*	0.581	**29**
Kenya	0.578	**30**
Rep. Congo*	0.576	**31**
The Gambia	0.567	**32**
Guinea	0.562	**33**
Equatorial Guinea	0.561	**34**
Mozambique*	0.557	**35**
Sudan*	0.556	**36**
Morocco*	0.550	**37**
Gabon	0.547	**38**
Zimbabwe	0.545	**39**
Cape Verde*	0.543	**40**
Namibia*	0.522	**41**
Egypt	0.493	**42**
Senegal	0.481	**43**
Libya*	0.405	**44**
South Africa*	0.390	**45**
Tunisia	0.368	**46**
Algeria	0.360	**47**
Mauritius	0.329	**48**
Djibouti	0.303	**49**

(*continued on the next column*)

Table 1 (*Continued*)

Country	Vulnerability index B	
	score	**rank**
Madagascar	0.697	**1**
Uganda	0.670	**2**
Tanzania	0.640	**3**
Cameroon	0.637	**4**
Ethiopia*	0.635	**5**
Angola	0.634	**6**
Zambia	0.631	**7**
Nigeria	0.624	**8**
Malawi	0.606	**9**
Ghana	0.604	**10**
Kenya	0.603	**11**
Ivory Coast	0.576	**12**
Zimbabwe	0.567	**13**
Botswana*	0.537	**14**
Morocco*	0.525	**15**
Namibia*	0.498	**16**
Senegal	0.489	**17**
Egypt	0.487	**18**
South Africa*	0.381	**19**
Tunisia	0.341	**20**
Mauritius	0.300	**21**

* Represents countries where missing value analysis has been applied for an indicator.

The SVI essentially comprises predictive indicators of vulnerability based on existing insights, but as shown above a number of subjective decisions and assumptions are embodied in the methodology. One of the main reasons for this uncertainty is not being able to validate the effectiveness of the indicators in representing determinants of vulnerability, as indeed the whole objective of indicators is to capture intangible processes. A common method for assessing the validity of vulnerability and risk measures involves looking at correlations with past disasters data [11,19,22,43]. This method is less than ideal as it is working across

timescales, linking current adaptive capacity to past events.

The timescale element is a particular cause of uncertainty when trying to determine adaptive capacity. The SVI index, as many other indicators, provides a snapshot in time of a potential state that is dynamic and multidimensional, being embedded in a variety of different processes [52]. The way in which globalization will unfold in the future, for example, is very difficult to predict, and this can have implications for a country's scores in many of the sub-indices. To take a hypothetical example, if there were to be a change in government in a country, and a new leader were to be successful in a drive to benefit from globalization through increasing involvement in the global economy, arguably the vulnerability would potentially decline in a number of the indicators: poverty, rate of urbanization, trade balance, dependence on agriculture. There is, therefore, a contradiction in using a current measure when looking at climate change in the future. Adger and Kelly [3] suggest that current vulnerability is the best proxy, and is appropriate for identifying the means of increasing adaptive capacity [5]. Moss et al. [40] have embraced the use of socio-economic scenarios in an attempt to capture how adaptive capacity might change over time, but the results of this merely compound uncertainty in climate projections to give an unwieldy range which has little practical application.

It is therefore clear that the degree of uncertainty inherent in determining vulnerability and adaptive capacity, as potential future states, is of similar scope and dimension to the uncertainty involved in future climate projections. In an attempt to quantify vulnerability and adaptive capacity, indicators and indices have been developed, but there are a number of uncertainties embodied in their creation, which require critical evaluation of the methodology and results. These indicators and indices often measure the current nature of vulnerability or adaptive capacity, when what is ideally required is the future nature to use in conjunction with projections of climate change. The issue of timescale is a major element of uncertainty that can be addressed only through monitoring and the development of time series data (see [12]). The evolution of the social and economic determinants of vulnerability and adaptive capacity into the future are as difficult to predict as the nature of climate change. As a final note of caution, adaptive capacity relates to the potential for adaptation to take place, for example, having appropriately-designed institutions in place. Even if adaptive capacity exists or has been developed, there is still uncertainty as to whether individuals, communities or countries will use that capacity to adapt to the projected impacts of climate change.

4. Conclusions

In summary, there are pertinent and critical issues of uncertainty in determining adaptive capacity at many different scales, from that of individuals through to that of nations. This paper has examined some of the uncertainties with reference to an index of social vulnerability for cross-country comparison in Africa. The Social Vulnerability Index presented for illustrative purposes in this paper, and related initiatives on indices of adaptive capacity and vulnerability have important policy implications in highlighting priority areas for aid and building adaptive capacity. These are both critical elements enshrined in the UNFCCC. But without consideration of the nature of uncertainty, use of such indices can be highly misleading in the same manner as probability statements of attribution of individuals events to climate change can be misleading. A single aggregate index representation of vulnerability can be appealing, but the limits stem from various uncertainties and can be traced to necessary decisions made at various stages of the index construction.

In this paper, we illustrate the uncertainty issues in adaptive capacity by using indicator research to exemplify the dilemmas and sources of contestation. The issues we highlight, of the reliance on qualitative data, the unclear nature of processes of adaptation and vulnerability, and the contested theories of social and economic change, are common to all approaches in this area. Positive analysis of the determinants of adaptive capacity through to investment-oriented normative analysis of plans and programmes all face the same uncertainty challenges. Yohe and Schlesinger [54], among others, argue that to reduce this uncertainty, adaptation strategies should focus on no-regrets options, primarily because adaptive capacity is constrained by its weakest component. There are clearly policies for which it is useful to identify these weak links, but the research community has yet

to identify robust metrics of vulnerability or adaptive capacity.

A second issue is the relationship between adaptive capacity, the object of much public policy discussion, and the processes by which adaptation takes place. Adaptive capacity highlights only the resources available for adaptation rather than the most likely or most desirable adaptation decisions to be taken. Adaptation, constrained by the capacity to adapt, involves a further set of uncertainties in decision-making processes. Uncertainties in adaptive capacity are profound: the direction of change and causality in many of the key functional variables are contested. There are, in other words, no Newtonian laws guiding understanding of adaptation processes or elements. Theories of economic growth, democratization, globalization and institutional change all point in differing directions. But recognition of the nature of this uncertainty, portrayed through a traceable theoretical account, is an essential starting point for use of information for decision-making in this area.

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