ON THE ECONOMIC APPROACH TO NATURAL HAZARDS MANAGEMENT: WHAT ECONOMICS CAN ADD TO COMMON TECHNICAL KNOWLEDGE ON HAZARD-RISK BINOMIAL IN ENGINEERING DISCIPLINES

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EXTENDED ABSTRACT

Technical knowledge has been subject to a continuous adaptation process along the last 20 years, and a lot of new issues and problems have been attracted and included in Civil Engineering paradigm in this period. Environmental issues that were marginal subjects in the sixties are nowadays part of the core knowledge developed under the umbrella of the "Common Technical knowledge" of Civil engineers. One of the most characteristic issues that have followed this path is the subject of natural hazard -risk management. While societies have reached an increasing level of awareness about the challenge we face in this area, a broad set of approaches have been involved in knowledge development. These areas go from geographic sciences (focusing on physical sources of vulnerability and measures of natural events), social sciences (focusing on economic and social sources for vulnerability and resilience), and biological sciences focusing in environmental consequences both from natural events and for human induced changes. The fragmented origins of knowledge have produced an academic literature that shows a clear lack of consensus among basic concepts, measures and indicators.

Economic disciplines have been traditionally involved in engineering analysis, through the conventional CBA approach that traditionally played an auxiliary role for engineers when huge amounts of resources were mobilized in the construction of big infrastructures. Hence this paradigm was supposed to serve as overall framework for natural hazards related technical decisions. Nevertheless two specific issues have emerged in the process, which require some reflection: The unexpected high level of risk we face, and the need to adopt sustainable strategies. These issues need to be considered to develop a general framework, as far as they should serve as a robust basis for knowledge development and assignment criteria. Hence decisions in the field of risk adaptation or mitigation will be better implemented.

There is a continuously increasing perception of hazard exposures in our society that has attracted the attention towards this subject, and unveiled the unexpected relevance of involved decisions in these areas. On the other hand, sustainability issues have emerged in parallel with economic analysis, asking for new decisions criteria in order to approximate technical issues to intergenerational equity restrictions.

The aim of this paper is to investigate the existence of a common basic knowledge that helps to efficiently decide on resource assignment, by indexing the different approaches on the literature that may serve as a common knowledge for engineering learning. The paper is organized as follows. First, we review the different risk assessment frameworks in the existing literature. Then, we compare the different conceptual approaches and clarify the assumptions yielding behind each ones. Third, we review the contribution from economic approaches to the issue. And fourth, we derive some theoretical conclusions on the role played by the different multidisciplinary contributions.

KEYWORDS

Evolutionary, Institutional, Resilience, Vulnerability

1. INTRODUCTION

Analysis of the consequences derived from natural shocks and catastrophes has always been a central issue for human concern. Specifically the analytic approach on this issue can be tracked back on economics to the early seventies, when the US Administration first introduced the term vulnerability in normative and executive documents, (OEP-EOP, 1972). From that moment on a new network of concepts emerged in literature, attempting to introduce in the discussion a broad set of ideas that have been diversely applied.

In this line interesting concepts suggesting fruitful ideas have been imported to the literature from diverse origins. Concepts as exposure were imported from health safety discipline, resilience was developed under ecology paradigm, and others were gradually adopted according to specific approaches, on social sciences such as geography, on political sciences, and on economics, following the analytical focus trend that was pointing to increasingly complex problems, and searching for explanation and proposals for correction measures. A new jargon has emerged covering suffered damages and prevention measures (mitigation, adaptation…).

This approach showed some interesting characteristics. First it was the result of an interdisciplinary work, where economists, natural scientists (geologists, ecologists…) and social scientists faced the different pieces of the question, tried to apply their model and finally assumed the need for interdisciplinary exchange of ideas. Nevertheless, the results of this process did not provide a consistent framework capable of representing all the specific problems and questions analyzed and a global framework was needed to combine them. The aim of this paper is to review what economic analysis can offer to create a consistent model, where the different concepts and ideas taken into account by the analysts are seen as part of a broad map, and where interaction among them serve to model the complex interactions yielding behind natural phenomena.

Nevertheless, there is a parallel emerging literature that focuses on the conceptual dilemma between the consideration of “natural hazards” either as pure natural risk (e.g. derived from volcanism) or human induced risk both as new causal effects derived from environmental consequences from development [Martin (2007)], or as institutional weakness derived from the lack of resources to immediate response, carrying and recovering capacity and financial responses. [Benson and Clay (2004)].

Simultaneously, economic theory had evolved introducing new fresh trends challenging marginal paradigm. In 1989 Ecological Economics Society was founded and the Ecological Economics Journal started to be published, promoting a new approach to environmental problems, where interdisciplinary experiences were perfectly suitable.

The paper is organized as follows, first we will review the general approaches to environmental and climate change risks, then we will analyze the institutional framework produced by economics to explain the complex natural human system and attempt to identify the main questions under discussion and the sources of this lack of consensus, second we will review the main concepts that have been produced to capture the diverse implications of environmental risks on society. Then we combine the relevant works in the literature in this area. We finish with some conclusions on the result of the question.

2. INSTITUTIONAL APPROACH TO HUMAN-ECOLOGICAL SYSTEM

Environmental science has always lead the research in the field of climate change. The determination of the scenarios to be considered in climate change has required a systematic analysis of environmental variables and relations among them. Nevertheless,

when sustainability emerged in social science debates as a central issue, both in theoretical analysis and in the political practice, institutional, evolutionary and complexity economics emerged as new actors in the show. At that point the evidence showed that complex problems as climate change require more than the analysis of the parts, that is the individual sub-models. When we are coping with nonlinear complex systems, their overall behaviour will result from the interaction among the pieces and not from the pieces themselves, and from the internal evolutionary mechanisms included in it.

According to Costanza et al (2001), a distinction has to be made between a) framework, that is, the inventory of basic elements included in the analysis, which serves as a reference for theoretical debates, b) theories, that identify and set priorities among relevant elements, that try to solve specific questions and that fix proposals for assumptions and, c) Specific models introduced to represent each case study. Furthermore hierarchy and scale have to be considered as basic explanations of the proposals, [O'Neill and Rust, 1979 and O'Neill et al 1989]. On one hand individuals affected by the pressure under study, considered as study subject per se, will show their individual behaviors, and on the other the overall ecosystem might initiate an evolutionary path that will drive the system to a different stable state that can be preferred even at the cost of individuals or species destruction. [Allen et al (1982)].The same is also true when social systems are under study.

Adopting Costanza´s scope, we can identify as basic elements in the theoretical framework:
1.- Stocks: They include any element that is susceptible of accumulation. Under this category different assets can be considered, human made capital be it physical (industrial equipment, infrastructure, human (knowledge and culture), or social or institutional capital capturing the value generated by the complex infrastructures created by societies in order to provide them regulations, buffers and protection [Coleman, (1988)]. On the other hand natural capital is also included in this category and again we can identify different families, in one group we can find assets assimilated to conventional economic capital as renewable and non renewable natural capital.

2.- Flows. Under this issue we include all the interactions among elements listed under the stock issue in the previous point. Several flow categories can again be identified, external flows, that arise from the sun, and interchange flows, that can be identified again as internal for each stock, when can be considered as pure exchange among assets under the same stock category, or inter-stock when a transfer between the two spheres can be observed. In the first group we can find the internal flows of biomass in the ecosystem, and the process of accumulation of human made capital, through physical investment, knowledge accumulation and learning and institutional strengthening. In this last case, all the institutional agreements developed on natural resources management play a key role in our framework. In the second group we can include all the extractive activities, from non renewable resources, and harvesting, in the broad sense, to the renewables; in both cases we found the externalities generated from socioeconomic activities as pollution or environmental protection and reconstruction, and finally any recreational services.

3.- Controls: The ecological-social system is equipped with a complex structure of limits, restrictions, and feedback loops. These elements represent per se a new issue to analyze in all the developments derived from our framework, to accurately represent the system. Under this category we include physical and biological laws that regulate first physical processes and biological behavior and second, ecological interaction both between individuals and aggregates, if focusing in internal nature controls, and another set of control rules when focusing on human societies. In this second group obviously we

still find biological behavior, but also primary institutions as families, social aggregates and political institutions, and a set of rules adopted in order to clarify assignments and solve conflicts among different agents and assets.

4.- Attributes: these are the characteristics of the previous elements that have to be considered in the analysis for a comprehensive approach to the actual situation. A broad set of attributes can be included in this category of elements, but when sustainability is under analysis the main attributes are heterogeneity, decomposability, predictability, extent in space and time, resilience and productivity. All of them help to improve the accuracy of the approach. Heterogeneity focuses on the diversity of positions, interests and characteristics of the affected elements, decomposability focuses on our ability to break down study subjects and predictability clarifies the degree of uncertainty in each of the observed phenomena, extent of space and time puts a limit to the temporal or geographical unit of study needed, productivity relates to intrinsic wealth associated with assets and resilience is included as attribute to capture the ability to absorb shocks without changing to a different equilibrium state [Holling, (1973)]. When natural risks are under analysis a new broad set of attributes emerge: vulnerability, susceptibility, exposure to certain risks and again resilience. This attributes will be our subject of analysis further on in this paper.

Another approach for the analysis of the ecological social system is derived from complexity literature. Holling (1973) proposes a different framework based on the idea that the different elements of the system are subject to a never ending cycle of adaptation and creative destruction. For this school of thought the system should not be decomposed and rebuilt from the pieces according to a set of rules and conditions but to be divided in self-organized subsystems that, with a short set of rules and linkages, incorporate their own logic into the global explanation and facilitates mutual reinforce. These units created decomposing the global systems show three properties, wealth, internal controllability and adaptive capacity [Holling, (1973)]. The first one, wealth, quantifies the possible alternatives that can be reached by the system. The second one, internal controllability, focuses on the number and strength of internal connections and hence the susceptibility of the system when external pressures are present, its capacity for self-governing. The third, adaptive capacity, offers a view of the capacity of the system to absorb pressures without suffering irreparable damage, incorporating once again the elusive concepts of vulnerability and its contrary, resilience.

Following this path, systems evolve from an initial phase where at a certain point the process of exploitation of resources starts. In this phase an initial social group, be it human or strictly animals, after several attempts, discovers a path to growth and stability, strengthening system resilience. The Darwinian selection or the economic competition can both explain the launching of the process, and in any case an accumulation of resources starts, be it directed towards biological accumulation or economic capitalization. As the process matures, an increasing set of self-controlling measures are created in order to solve conflicts and avoid the less profitable horizons to happen. This phenomenon occurs at the prize of limiting the ability to survive, of limiting heterogeneity and diversity, and inexorably approaching destruction through a process of assets accumulation and limiting degrees of freedom, and hence lowering resilience (increasing vulnerability). When the process is mature enough in this new conservation phase, the system shows lack of capacity to cope with shocks, due to the rigidity generated in this process, and this generates an inexorably and sudden collapse. The accumulated resources are suddenly freed and a new release phase starts. In this situation the previous game seems to be over and new opportunities are opened to all the agents in an unpredictable way. A race starts to take control of the organization and the winner establishes himself reorganizing the system according to its interest and paths, creating a

new reorganization phase. In this phase a continuous increase in stability allows to reproduce another cycle moving again to exploitation phase.

The third level of the analytical framework is manifested in individual models focusing on the specific issues to be covered selecting and quantifying variables (drivers) different models have been created around the different focus point of the project (DIVA for coasts…) [Hinkel and Klein, (2009)]. As a result of this review we have a clear view of two theoretical frameworks where we can integrate the existent proposal on vulnerability resilience and related concepts.

3. THE ACTUAL DEVELOPMENT USED IN POLICY AND STUDIES

Although at present a demand of order and internal consistence is generally accepted in literature, [Adger (2006)], there is a huge amount of rigorous work that has already been developed that will be better understood if we try to unveil and consistently structure the basic assumptions yielding behind it. With this purpose we present a parallel view of the practical developments following the same structure we have previously used to describe the theoretical proposals.

An interesting reflection on the semantic confusion built around the term vulnerability can be seen in Mc-Fadden et al (2007) that points to the role played by language as an instrument to categorize knowledge, and hence points to the exogenous origin of the different concepts built around colloquial terms. The concept behind the word vulnerability is built mixing several assumptions: weakness, exogenous attack, and subject suffering this attack, so natural thinking process drives to identify a receptor, a source, and to assume a balance between shock size and carrying capacity.

3.1 The general framework

At the first level the general framework is not discussed in depth because there is not discussion about it in the literature, nobody explicitly objects to the idea that climate models are complex, uncertain, and full of non-explicitly observed feedback loops that makes the process to respond dynamically. The same can be argued about evolutionary ideas, it is generally assumed that long term consequences drive the system to new states, and there is no reason to omit adaptation capacity and systemic evolution of our system.

Specifically two definitions can be observed: the first one following Costanza´s approach has provided an intellectual basis for the so called DPSIR (Drivers, Pressures, States, Impact, Responses) theoretical proposal emerging from environmental disciplines, and the second has given birth to the PSR (Pathway Source Receptor) emerging from risk analysis disciplines. There are basic differences among them and we can easily understand them according to the answer given to the four questions the model suggests: flows, stocks, controls and attributes. See Table 1.

About Flows and stocks clear difference exists between both approaches. The first one (DPSIR) focuses on: a) the different drivers that direct the elements of the system towards coping specific needs, b) pressures defined as the demands raised to the environment by the active agents in the system, c) states both as pollution externalities or harvesting of resources, and on the states or levels of services reached by the different elements whom the demands are raised, d) impacts as loss of quality states created by the shocks, and e) responses to capture the recombination of the system to adapt to the impacts, both environmental or social, these responses are then included in variables as adaptation, mitigation damage… The second one (PSR) offers a narrower view of the situation, the model assumes that a certain shock will exist, and then identifies the

different pathways to be followed in order to determine the final consequences on each receptor. The quantitative and probabilistic aim in the model can easily be seen and no second step responses are internally considered.

Table 1 Comparative Frameworks for Risk Management (based on Costanza *et al.* (2001), and Wadekker *et al* (2009) Diaz Simal and Torres (2011)

	DPSIR		PSR
FLOWS	1.- Drivers: different drivers towards Specific needs 2.- Pressures: demands raised to the environment 3.- States: pollution externalities and levels of services reached 4.- Impacts: loss of quality		1.- Shock will exist 2.- Different pathways 3.-Final consequences on each receptor.
STOCKS	5.- Responses: recombination of the system		
CONTROLS	1.- General system of feedbacks 2.- Reassignment of resources and functions		1.-Physical process 2.-Probabilistic impact - response
ATTRIBUTES	1.- Heterogeneity 2.-Decomposability 3.- Predictability 4.- Extent in space and time 5.- Resilience-vulnerability 6.-Productivity	Resilience Vulnerability: 1.- Homeostasis 2.- Omnivory 3.- High Flux 4.- Flatness 5.- Buffering 6.- Redundancy	1.- Hazard – Exposure 2.- Susceptibility 3.- Vulnerability 4.- Resilience 5.- Adaptive capacity

About the controls that connect all the different elements, again both frameworks provide a different solution, the DPSIR approach includes a general system of feedbacks that allows all sort of realignment of paths, reassignment of resources and functions, and the second offers a more static view. The physical process analysis is the critical issue and there is only one final response to the probabilistic impact that has to be anchored in the real system in order to estimate the consequences of the shock for the different affected agents.

On the attributes we will find again a different family of concepts emerging in each of the parallel lines, on one hand on the DPSIR approach, we build the discourse based on attributes as previously stated: heterogeneity, decomposability, predictability, extent in space and time, resilience-vulnerability and productivity. A brief analysis has previously been made in this document, but it is important to review here the relevant issue of resilience [see Holling (1973)]. Although this concept is invoked in both frameworks as a relevant attribute its scope is clearly more adapted to DPSIR approach. Resillience has been in use for years by ecologists and social scientists in a continuous process of scope broadening, expanding from pure biological concepts to social behavior strength sources [Folke, (2006)] and has been recently parameterized by Wardekker et al (2010) around six explanation components that might guide the research for modeling resilient behavior systems. These components point to the relevant sources of resiliency where research has to focus, and so became a useful guideline in the applied field work. The set is formed by: a) Homeostasis that refers to the existence of control loops, previously defined as a component of the system, and suggests that a mature system gains resilience when multiple feedback loops generate stabilization processes helping to assume and survive to external shocks. b) Omnivory is again a multi-disciplinary concept suggesting that resilience is gained through the availability of alternatives to fulfill needs, and lost when we are playing with only one card be it as high as ace or a two. c) High flux has to do with the dynamic “speed” observed in the system, the abundance of resources for the agents to try new solutions in the adaptation process. As dynamic and rich as the system is, as quickly it can adopt new strategies, and thinking in terms of adaptive cycles, this ability to give quick response is a critical issue for survival. d) Flatness focuses on the hierarchical structure of the system. Again social environment with absence or excess of

administrative levels producing institutional paralysis does not look very different from ecological systems, where new adaptive strategies can be adopted spontaneously by single species or through a global coordinated change adopted by all the species of the system. e) Buffering is another source to focus on that qualifies any social or environmental system, once again the abundance of resources, acting as safety ratios, produce different possibilities available and allows to qualify system´s strength. Typical buffers as aquifers, sand deposit, food deposits that help biological systems to survive to extreme conditions, can be mirrored in the socioeconomic systems through social guarantees, financial deposits, insurances… that should be considered as resilience sources. The final item f) redundancy introduces a new source of resilience that identifies systems where no critical resource or mechanism exists, as far as it can be substituted or reproduced. Examples for this can be seen from living organisms full of redundant genetic information, to advanced societies ready to replicate their institutional arrangements, or in a different sense in network structures where no one is critical and the destruction of any component is solved just by displacing the activity to the next available alternative.

Two additional comments have to be made, first vulnerability seen as a loss in resilience of a system can be decomposed in individual attributes as has been showed, and second all those attributes suit with Holling (1973) schema proposal for a system adaptive cycle: wealth, internal controllability and adaptive capacity.

On the other hand, the alternative SPR approach has developed different attributes according to the basic scope adopted: Hazard measuring the probability of a source to shock the system, exposure reflecting the probability that a shock consequence reaches a certain receptor, susceptibility and vulnerability to reflect the gravity of the consequences of such a phenomenon, extent of time and space, delimitating the receptor under analysis and resilience (also critical in DPSIR model) and adaptation acting as second step reaction by the system. [Adger, (2006)]

3.2 The Theoretical approaches

In this step it has already been clarified that two separate theories have been developed, the first one around DPSIR approach suggests a complex, multi-effect and multi-driver, evolutionary behavior, heavily compromised with non-linearity relations, and focusing in the adaptive reaction of the system, and the second one around SPR approach, suggests a single-causal single-driver and linear process.
Under the DPSIR approach, theories based on ecology, economic and social science have focused on different issues, as resilience, biodiversity and ecological services, social resilience and entitlement theories among others [Villagrán, (2006)]. Under the SPR framework, theories based on engineering knowledge applied to specific receptor have been the usual case.

4. A REVIEW OF THE DIFFERENT APPROACHES FOR MEASURING VULNERABILITY

As can be derived from the contents of this paper, vulnerability as a variable has attracted attention from different theoretical developments, under the umbrella of different conceptual frameworks derived from institutional agreements or from academic proposals. Adger (2006), Fussel (2007), Fussel and Klein (2006), Villagrán (2006) and Gallopín (2006), have developed a systematic analysis of the diverse contributions and solutions. As has been defined previously a broad set of origins have produced parallel paths to the concept. [Diaz Simal et Torres (2011)].

Institutional economics (a) have broadened the scope towards social and political contributions both to vulnerability and its opposite concept, resilience. Entitlement Theories (b) proposed by Amartya Sen (1979) have focused in the analysis of poverty as a key factor towards vulnerability seen from development and welfare economics schools. Evolutionary economics (c) disciplines have focused on the adaptive process that rules human and natural evolution as subject of the analysis. Ecological economics (d) have focused on the role of nature as provider of services as part of the available capital. In a different sense, from an opposite point of view from these global vulnerability schools, Risk management (e) and risk-hazard natural disaster analysis (f) disciplines have focused the analysis to quantification of risk.

As a conclusion of all this literature we can assume that again two parallel approaches can be identified subject to a different initial framework that might be misguiding the analysts, but that have to live together as they are essentially studying the same problem through different scopes. The first approach with a more systemic view groups Entitlement theory, Institutional Economics, Evolutionary Economics and Ecological Schools, and the second, with more quantitative focus is organized among risk theories and natural hazards analysis areas.

Essentially there is a set of questions that have to be answered together although they have received independent answers. The first question is about the sources of vulnerability we are facing, the second question is related with the scale and temporal path of the analysis, the third question is related with the available information to compare vulnerable situations and the fourth is related with the capacity to produce a synthetic indicator. (See Table 2)

On the first question related with the sources of vulnerability, we find different suggestions according with the diverse priorities across societies. Entitlement theory focuses on poverty as key issue (famine insecurity health…) pointing, first on the increasing exposure to hazard by poorer groups in societies, second on social dependence on critical assets, third on the lack of recovery capacity and finally on the contribution of poverty to new social and political hazards. Institutional economics focus on the low level of controls a society has, due to the weakness of the decision framework, the perception of the problems they face, and the quality of its governance structure: that on one hand deals with certain problems. And on the other omits the needed regulations for others, hence clearly defining specific incentives in both cases. Again the ability of societies to self-protect themselves, their capacity to experiment shocks with less critical damage, and their social recovery capacity are the key problems to characterize societies. [Birkmann (2006)].

The second question that has to be solved is related with the scale and temporal path of the analysis. Again there are different answers. In a first group, Entitlement Theories, Institutional Economics, and Evolutionary Economics schools have to combine a high scale resolution to identify vulnerable areas, with aggregate indicators that include global characteristics of a society, seen as a single complex individual, when facing a crisis, and of course they have to adopt a long term temporal scale. Nevertheless evolutionary schools need to focus on micro-scale to identify individual incentives and behaviors behind paths. The ecological schools are tied to the spatial distribution of ecosystems and individuals within them. And from a different view risk and hazards literature adapts its scale to their probability prediction, and so work in long term periods for capturing trends in natural events, and high space resolution to capture spatial differences.

Table 2 Theoretical contributions to the concept of vulnerability

	Evolutionary economics	**Institutional economics**	**Entitlement theories**	**Ecological economics**	**Risk Management**	**Natural hazard and Catastrophes analysis**
Sources of vulnerability	1. Evolutionary paths 2.- Long Term States	1.- Weakness of the decision framework 2.- Perception of the problems and risk 3.- Quality of the governance structure	1.- Poverty 2.- Ability to choose	1. Anthropic pressures. 2.-Carrying Capacity	1.- Risk management decisions (adaptation mitigation, assumed damage…)	1.- Risk hazard probability quantification. 2.-Expected damage
Scale and temporal path of the analysis	1.- Long Term scale 2.- Social micro-scale (Incentives)	1.- High scale resolution to identify vulnerable areas. 2.- Low scale indicators to include aggregate characteristics of a society 3.- Long term temporal scale.		1.- High scale resolution to identify ecosystem units	1.-Long term periods for capturing trends in natural events. 2.-High space resolution to capture spatial differences.	
Available information	Qualitative information on evolutionary and adaptive capacity.	1.- Aggregate economic data, 2.- Distributive equity, 3.- Governance and transparence, 4.- Quality of social and human capital		1.- Biodiversity 2.-Resilience 3.- Evolutionary 4.- Primary production	1.- Physical data on the present functions 2.- Previsions on path evolution of climate parameters	
Capacity to produce a synthetic indicator.	Projected trends	1.- GDP 2.- Wealth Distribution. 3.- Governance indicators 4.- HDI	1.- Sen´s Poverty Index	1.- National Accounts environmentally adjusted 2.- Happiness indexes	Expected damage ($)	Level of risk (probability)

For the third question related with the available information to compare vulnerable situations, again we have different scopes. A first group is formed with schools concerned on societies, human settlements, and wealth and hence the indicators produced focus on the measure and combination of attributes derived from aggregate economic data, equity in the distribution of wealth, governance and transparence, and quality of social and human capital, (education level, social security, retirement funds, assistance networks…). The ecological schools try to capture their own defined indicators as biodiversity, resilience, evolutionary paths, primary production… About the risk-hazard literature, there are two main sources of information, first physical data on the present functions of affected dynamics, and second previsions on path evolution of climate parameters behavior.

The fourth question is related with the quantification of the synthetic indicator to capture the information, and consequently builds a vulnerability function based on this data, and again different responses are available at this point. The first possibility is to keep different vulnerability sources separate and not trying to combine them in any expression, at a risk of describing the same problems several times, and the second is to move towards a single synthetic indicator.

Different attempts have been made in this area that require further explanation, in risk analysis, some work has been done trying to determine the expected damage derived from a hazard, combining hazard, exposure to it, fragility of the exposed assets and valuation of the damage, identifying probability of occurrence of an event with percentage of damage expected [Alexander, (2000)]. Other analysts have focused on the pure probability risk [Dilley et al (2005)]. Finally economic attributes of a society are based on conventional economic statistics (GDP) and equity comparative indexes as Gini Indexes

on wealth distribution and Sen´s (1976) poverty indexes that compare the expected economic impact of the hazard with the poverty threshold and consequently weight-relative impacts on poor and rich. Hahn (2003) suggests a set of conditions to verify in order to obtain robust indexes: validity, verifying when it points to the core of the phenomena, sensitivity to the differences among them, availability of data in space and time at the needed scale, consistence along series of measures, and objectivity.

According to the answers to these questions we can justify a lot of different models according to Costanza´s proposal, each one justified by a different framework, and a different theoretical view. The problem at the moment is to select the one we need to solve our questions, and to be prepared to consistently merge different contributions.

5. CONCLUSIONS

There are different approaches to the problem of defining vulnerable situations each one pointing to a different factor of the problem of global change, and derived from different conceptual framework and theoretical approaches. To guarantee a solvent approach three layers have to be clearly stated: Framework, theoretical approaches that introduce parameters, priorities and behavioral assumptions for variables; and models. In any case, hazard quantifications are essential in any analysis, and have to be measured in probabilistic terms that compute both probability of events and value of affected assets. There is a binomial approach to the measure of vulnerability focusing on the potential losses through vulnerability measures itself, and the other focusing on the carrying capacity or resilience. These two concepts play different roles, the first one reviews the pressure and the second marks the threshold pressure that the system can assume, be it by natural factor of resilience, by economic wealth or by social strength.

There are at least six theoretical approaches from economics to the nature of vulnerability as a concept that contribute from different assumptions, at different scales and with different priorities. Evolutionary economics focus on adaptation mechanisms and their effects in the long term, trying to draw a future map of the situation. Institutional economics focus on the arrangements made in our societies as a condition and requirement to understand the distribution of effects of change. Development and welfare economics try to contextualize the effects in different social conditions. Ecological economics focus on our dependence on nature, an issue that we have pompously ignored in our monetized world. Risk management and Nature and Catastrophes analysis have focused on identifying sources of risk (pressures), drivers towards societies and quantification of effects both in terms of risk and expected damage. All of them have to be included in technical paradigm in order to create a common knowledge area.

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