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Contributions towards climate change vulnerability and resilience from institutional economics

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ABSTRACT: This paper analyzes the various contributions made in the economic literature that influence climate change vulnerability. We try to create conceptual order and transparence in the contributions identifying the assumptions and constraints that each school has introduced into academic debate and practical application. We analyze the conceptual framework that articulates the debate, review the theoretical approaches developed in the literature identifying the object of analysis and the basics of each theory, so that the real model implications are established in each case study. From this scheme we derive a clarifying proposal for organizing theoretical discourse. We specifically focus on the theoretical assumptions underlying each model. We conclude with some criteria for choosing the right models in each case and a general guideline for future research.

KEYWORDS: Evolutionary, institutional, resilience, vulnerability.

JEL classification: Q12, C23.

Contribuciones a la vulnerabilidad hacia el cambio climático desde la economía institucional

RESUMEN: Este trabajo analiza las diversas contribuciones hechas en la literatura económica que influyen en los análisis sobre vulnerabilidad frente al cambio climático. Tratamos de dotar de orden conceptual y transparencia a las contribuciones sobre la identificación de los supuestos y las limitaciones que cada escuela ha introducido en el debate académico y la aplicación práctica. Se analiza el marco conceptual que articula el debate, se revisan los enfoques teóricos desarrollados en la literatura que identifican el objeto de análisis y los conceptos básicos que constituyen el marco de cada teoría, de forma que se establecen en cada caso de estudio consecuencias para el modelo práctico. De este esquema se deriva una propuesta de clarificación para la organización de un discurso teórico. En especial, se analizan los supuestos teóricos que subyacen a cada modelo. Concluimos con algunos criterios para elegir los modelos adecuados en cada caso y una guía general para la investigación futura.

PALABRAS CLAVES: Evolución, Institución, resiliencia, vulnerabilidad.

Clasificación JEL: Q12, C23.

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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 followed 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, although powerful and rich, 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 as geography, political sciences, and 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 (geologist, ecologist…) 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.

Simultaneously, economic theory had evolved introducing new fresh trends challenging marginal paradigm. In 1989 Ecological Economic 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. Discussions about the systemic approach to model human-nature mutual exchanges and pressures where typical at this moment, and were not far from hazard risk environmental debate. Under a different scope institutional economics had emerged as a result of a long tradition as a new paradigmatic approach to explain both social structures behavior as a whole, and incentives on individuals as a single subject of analysis. Once again the analysis of the institutions created by society to assign resources, distribute costs and benefits and solve conflicts, result to be a key issue to understand the consequences of a certain environmental damage, seen under risk analysis scope or catastrophes study analysis.

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 will propose a consistent model where to include and 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 leaded 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. From that point the institutional approach in economics has offered a new perspective on how to create a robust framework to include the broad set of concepts, parameters and indicators emerging from the literature.

TABLE 1

Proposals for analysis

LAYERS	Focus point	Structure
Framework	Identify Relevant Phenomena	Flows, Stocks, Controls, Attributes
Theoretical Approaches	Identify Assumptions and relative priorities	Evolutionary economics, Institutional economics, Entitlement theories, Ecological Economics, Risk Management, Natural hazards and Catastrophes analysis.
Models	Specific applications	

According with Costanza *et al.* (2001), a distinction has to be made between a) framework, that is, the inventory of basic elements included in the analysis, who serve as a reference for theoretical debates, b) theories that identify and sets priorities among relevant elements to solve specific questions and fixes proposal for assumptions, and c) specific models introduced to represent each case study. This produces a parametric approach where interactions and data are again connected through a set of assumptions that help us to quantify the specific issues we face in each case. Hence the first step is to clarify that we are working under a clear framework assumed everywhere. Second we need to express clearly which is the theory that yields behind each of the proposals, and third we need to justify which is the model applied in the analysis.

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). And these are not trivial issues, any proposal focusing in the situation of certain ecosystem that is elaborated based on aggregate data, might be confusing as far as it can be elaborated following two different trends: 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. The Ecosystem web can be treated as a single organic unit when its behavior has to be considered as a different item than the sum of its parts, and if it shows to be partitionable, what fortunately happens very often, it can be divide in autonomous subsystem (Allen *et al.,* 1982). The same is also true when social system are under study.

Under the previous assumptions we shall select among different frameworks to explain how interactions between social and natural areas are produced. If we assume a situation where we can split the system in independent subsystem and we adopt Costanza´s proposal, the following issues are to be considered as basic elements of the system:

1.- Stocks: That include any elements that are 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. Under the first one we include all service sources that can be derived ultimately from the sun, and provides both ecological services, and harvesting production. A second category of natural capital can be defined under a different scope according to the role played for the self-functioning of the global system, biodiversity and biomass, both as individual and species and genetic information and biological networks distribution can clearly be identified in this group. We propose this division where capital is divided according to its final destination rather than an alternative where the essential nature of the asset is considered.

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. One additional flow or transfer under analysis emerges from the catastrophic interaction between natural and social environment as are global warming, that manipulates the energy balance from the sun, and earthquakes that liberate a sudden energy shock are included in the external category of flows.

3.- Controls: The ecological-social system is equipped with a complex structure of limits, restrictions, and feedback loops that represent per se a new element to analyze in all the developments derived from our framework, in order to accurately represent the system. Under this category we include physical and biological laws that regulate physical processes and biological behavior, and 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. Under this family of institutional controls, formal political rules dealing with collective decisions coexist with informal agreements on communal issues. The strengthening process of this rules to cope with new situations, moving towards evolved societies, was already cited as one the consequences from social capital investment.

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 focus on the diversity of positions, interests and characteristics of the affected elements, decomposability focus 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 with 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 to the analysis 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 (Schumpeter, 1950). For this school of thought the system should not be decomposed and rebuilt from the pieces according with a set of rules and conditions but to be divided in self-organized subsystems that, with a short set of rules and linkages, incorporates 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, at a prize of limiting the ability to survive, 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, system shows lack of capacity to cope with shocks, due to the rigidity generated in this process, what 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 on 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.

Deepening in the intellectual building, different theoretical approaches can be made according with assumptions made and objectives of the analysis. A lot of approaches are possible, and so a lot of theories have been posed in the discussion, and each one has obviously produced detailed models where to include the final proposal for indicators. We are not focusing here in the inventory of available theories. A small group of them will be discussed further on in this document. The important point here is to understand that if we explicit the general framework invoked in each theory, we are moving a few steps ahead towards comparability of models results data, variables…

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 etc.) (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. Two initial conclusions can be derived, first the splitting process, inherently included in any partial model focusing on a specific issue has to be understood as a concrete development of a more general framework under a theoretical approach, and both have to be taken into account when actual data are collected and integrated in an indicator, it is not a pure index computing what matters. Second what we are measuring is not a static phenomenon, changed through climate change pressure whatever the origin is, but a dynamic evolution that is continuously adapting to new circumstances.

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 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.

At a previous item we argued that although complexity, evolutionary and institutional economics as disciplines have done a big effort to create a general framework capable to deal with climate change the practical approach has been developed without paying enough attention to the issues of comparability and academic conceptual consensus.

We have recovered from Costanza *et al.* (2001) a proposal to define the three levels of the intellectual structure that we shall follow here: framework as general items to be considered, theories as specific proposals of functioning, and models as actual quantification.

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 for our system. Our present situation can hardly be understood without these ideas. The question is that being the problem so complex, we have attacked it with partial approaches that, according to our previous experiences, were expected to recombine in a more general spontaneous integrating theories, and part of the complexity of the problem may be lost in the process of aggregation.

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[1] (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 2.

TABLE 2

Comparative Frameworks for Risk Management (based on Constanza *et al.* (2001) and Wadekker *et al.* (2009)

	DPSIR		**PSR**
FLOWS STOCKS	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 5.- Responses: recombination of the system		1.- Shock will exist 2.- Different pathways 3.-Final consequences on each receptor.
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 first couple, flows and stocks, the differences can be observed easily from the very beginning of the proposal, there is an obvious simplification. The first one (DPSIR) focuses on: a) the different drivers that direct the elements on the system towards coping specific needs, b) pressures defined as the demands raised to the environment by the agents act 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

[1] OCDE State of the Environmental Group has developed a more simplified framework named with the same acronym PSR that may drive to confusion (Pressure State Response) that is actually a simplified version of DPSIR.

to adapt to the impacts both environmental or social, this 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.

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 to include 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. Long discussions can be made in academic forums but the relevant point here is that both models are internally consistent, the only problem comes from the fact that, as they focus to a different subject, they require different instruments, they build different models and hence different indicators are needed for similar problems.

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. Resilience 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. As one can notice we are not making differences between social adaptation measures or biological survival mechanisms, and so it is the researcher´s role to identify the phenomena where these loops are located and quantify how robust (resilient) the system becomes because of them. These can be clearly seen in coastal areas where the increase in pressure immediately generates morphological changes in the geometry allowing or not the survival of the beaches (conditioned to the presence of sand rerserves), but also in areas where the fragility of the situation is solved because of the direct connection between pressures and impacts, in an adequate incentive framework, against an area with weak incentives mechanisms ready to self-destroy. 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. This source of resilience can be easily identified when we discuss about the critical dependence of economic activity on one single input (eventually the only source of wealth in one area) compared with another economic network that has different available and independent alternatives to survive, if one of them is affected. Pure economic indicators may hide that dependency if only it introduces a GDP contribution estimate. 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. Wealthy societies full of financial resources and human capital involved in a never ending search of economic opportunities can be compared with areas of greater potential whose development or survival is blocked by the lack of self-generated resources to assign to new uses. 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. Conservative static societies with an overburden of normative and restrictions show good examples of non-resilient areas that result not to be capable to adopt new strategies due to their institutional inertias, even if such solutions exist. e) Buffering is another source to focus in 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 suggest a single-causal single-driver and linear process.

Under the DPSIR approach, theories based on ecology, economic and social science have focused in different issues, as resilience, biodiversity and ecological services, social resilience strengthen 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. Specifically in the coastal effects of climate change geologist, ecologist and oceanographic and coastal engineers have centered the work (Hinkel, 2010).

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 (Intergovernmental Panel on Climate Change – IPPC) 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 towards capturing the concept.

Institutional economics (a) has broaden 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 on 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) has 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 on 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 3).

TABLE 3

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.- Equity in the distribution of wealth, 3.- Governance and transparence, 4.- Quality of social and human capital		1.- Biodiversity 2.- Resilience 3.- Evolutionary paths 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)

On the first question related to 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 to the increasing exposure to hazard by poorer groups in societies, second on social dependency 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 points to the lack of controls a society has, due to 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, 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. The adaptive capacity model points to long term results of global change as the key problem to focus on, and so is the natural capacity to jump to a new stable state, and the comparative of the new situation with the previous are the relevant issues. Ecological schools focus on pressures generated on ecological systems both by preexistent human generated evolutionary process and from new global change processes. The second area of research sees the problem from a different point of view, the natural hazards and the risk created on societies are the relevant issues to focus in, as far as this approach has been developed by engineers trying to quantify the new infrastructure and technical solutions needed, a quantitative approach and a single source analysis methodologies have attract major attention (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.

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 its 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 (Méndez *et al.,* 2008; Menéndez *et al.,* 2008).

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). It is still pending from environmental and ecological economics schools to develop a synthetic formula that combines human produced assets and natural assets values although work has been done in order to include natural assets in National Accounts, to identify interactions among human and natural subsystem through Input-Output analysis, and to obtain social perception of values. About social vulnerability issues global indexes as Human Development Index suggest the idea of using multi-criteria weights to combine them, as far as they are pointing to diverse consequences of the same problems. 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

This is neither the place nor the moment to generate a definitive solution to the vulnerability index we need, but some conclusions can be expressed:

First: 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 to identify the relevant phenomena to analyze, where two approaches have been identified (DPSIR and PSR), theoretical approaches that introduce parameters, priorities, and behavioral assumptions for variables; and models to present specific applications to case studies.

Second: 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. No robust analysis can be made without this measure, but reducing the work to measure this as final result will produce a myopic view of the situation.

Third: There is a binomial approach to the measure of vulnerability one 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.

Fourth: The overall consequences of global change have to be thought from an evolutionary point of view, and hence we need to estimate future scenarios of the situation we are approaching to capture the overall phenomena, the prognosis of future adaptation and mitigation measures emerge as a relevant issue, reflecting our availability to assume the damage and protect from it. And that is essentially a social and political issue of the highest importance. The social economic and institutional factors are critical to understand possible consequences of a certain source of change and so have to be considered as part of the sources of vulnerability.

Fifth: There are at least six theoretical approaches from economics to the problem of vulnerability that contributes from different assumptions, at different scales and with different priorities. Evolutionary economics focus on adaptation mechanisms and its effects in long term, trying to draw a future map of the situation. Institutional economics focuses 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 dependency of nature, an issue that we have pompously ignored in a 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.

Each one represents a different layer in a complex framework, mutually reinforced, and hence no piece can substitute the whole image. There is a long way ahead until consensus is reached on a synthetic conceptual framework and for the moment we can only have a clear map of concepts and assumptions and goals. One can expect that, as research in the described areas produce more robust individual approaches, some clarifying proposals are going to be needed.

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