Emerging Research Directions for Modeling the Impact, Short Time Recuperation and Long Term Recovery in the Case of Natural Hazards

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Abstract

The *economic impact of natural hazards, view as very low frequency but high impact events,* are difficult to model in a general approach (because hazards strike are unique in the way they impact a different place; damages are difficult to quantified especially in poor areas; the largest economic impact is on stock variables, capital and labor, while economic indicators measure flows).

Previous work in modeling strategies (Dacy and Kunreuther, *The Economics of Natural Disasters,* 1969; Sorkin, 1982; Albala-Bertrand, 1993; Kunreuther, 1978; Kunreuther, 1996; Kunreuther, Roth, 1998) are based on *classical frameworks*, but little has been dealt with *a general theory on economics of natural hazards*. Some authors proposed an analysis based on similarities with business cycles, risk aversion and insurance. In his review, Skoufias (2003) addresses some problems related to the analogies of the economic impact of natural disasters, with economic crises: the return to the previous growth path and long term consequences, the problems which arise after the natural disaster in medium term, the psychological impacts of a natural hazard). Other recent studies in the field of *economic analysis of natural hazards* (Cochrane, 2004; Cole, 2004, Okuyama, 2004) are more focused on *modeling spatial economic impacts of disasters in a regional context.*

The lack of robust theoretical development/ analyses of natural hazards impact to economy is due to the fact that *natural hazards are quite different from other economic events*, in terms of its frequency, extent and global impact, predictability. These aspects pose totally different set of impacts to economy and require a special treatment of economic behavior changes under the chaotic situation after a hazard.

The presentation is organized as follows:

- a review and a comparative analysis of the theoretical aspects in the field of natural hazards
- aspects and models for the *short-term recuperation*; the limits of the decision-making theory and laws of demand and supply from microeconomic theory
- an analysis of the models capable to estimate the *impacts of long-term recovery*; the efficiency of different growth models and valuing the macroeconomic risk
- *future research directions* in the field of economics of natural hazards: new perspectives on the REH (rational expectations hypothesis), the use of *statistical decision theory* and the *choice theory under uncertainty* (to explore the ramifications of model uncertainty and learning in environments in which historical data may be insufficient to yield acceptable probability statements), the *role of uncertainty in the exploration of hypothetical government/ public-private-partnership interventions*.

Keywords: natural hazards, vulnerability, risk, recovery

1. Introduction

The ability to measure vulnerability represents a key step toward effective risk reduction and the promotion of a culture of disaster resilience. Coping capacity represents a combination of all strengths and resources available that can reduce the level of risk, or the effects of a disaster. The research on natural hazards aim to offer a generalized framework of natural hazards analysis, but they are still oriented to investigate empirical cases/ empirical modeling frameworks The lack of robust theoretical development/ analysis of natural hazards impact to economy is due to the fact that *natural hazards are quite different from other economic events*, in terms of its frequency, extent and global impact, predictability.

These aspects pose a totally different impact and require a special treatment of economic behavior changes under the chaotic situation after a hazard. In the second section is review and analyzed the theoretical aspects in the field of natural hazards. In the third section is analyzed the value of information. The theoretical aspects of the *short term recuperation* (decision-making theory and laws of demand and supply from microeconomic theory) and an analysis of the *impacts of long-term recovery* (using growth models from macroeconomics). In the last section are presented conclusions including future research directions in the field of economics of natural hazards.

2. A Review of Economic Theory in the Field of Natural Hazards

In *"The Economics of Natural Disasters",* (Douglas C. Dacy, Howard Kunreuther, 1969) the objective was "to formulate a clear-cut case for the development of a comprehensive system of disaster insurance as an alternative to the current paternalistic Federal policy" focusing on three major aspects: a background with various economic theories (based on the general trends of natural disasters and the damages); empirical evidence for the *short-period recuperation* and *long-term recovery*; the role of the government in natural hazards and insurance programs.

2.1. The emergency response and restoration (Short-term recuperation period)

In this phase, the information about the hazard, damages, and the restoration strategy become highly *uncertain* (ICP problems).

In and immediately after a disaster, the information regarding the damages are uncertain and the principles of decision making for efficient resource allocations are difficult to use.

Dacy, Kunreuther introduced the concept of uncertainty and risk in a *resource allocation problem* of a community just struck by a catastrophic hazard, concerned with inventory related expenses (storage costs and shortage costs). It results a simple *maximization problem* with an *objective function*. Regarding the information availability the relationship between each storage cost, and the capacity constraint, depends on the types of the damages; all the other variables and the probability of usage are unknown before the hazard occurs. In this case, the objective function is impossible to solve.

Dacy, Kunreuther proposed a new *decision making model for emergency response*, based on the concept of uncertainty and risk.

The microeconomic analysis of *supply and demand relationship* in and after a hazard is based on three cases of *supply-demand changes*.

- Case I (no outside aid/ no sympathy), a theorist view
- Case II (adds the aid from the outside), indicate the changes in demand side that anticipate the aid from the outside.
- Case III (mutual aid in a chaotic situation)

In a chaotic situation, the decisions are somewhat differently as usual, creating further complicated economic activities after a hazard.

2.2 The long-term capital recovery aspects

It refers to the *rebuilding process that brings the community back to its pre-disaster economic level*; in the definition, it is assumed that *residents desire to be in at least the same position following the disaster as they were before*.

The long-term recovery of the damaged community can be influenced from many other factors like macroeconomic influences and business cycle. Most *economic models for disaster* are *flow model type*, measuring the impacts on economic flows rather than *stock model type* focused on the damages and the recovery (Rose, 2004).

Many *economic impact studies* of hazards have dealt with the medium term recovery aspects and not considering the capital (stock) recovery analysis after a hazard (Rose, 2004).

Even that the *disturbances* to economic flows caused by a disaster are relatively easy to model (using the conventional modeling frameworks, such as input/ output analysis) *the capital recovery* *analysis* should consider that the investment decisions to capital are very complex and different from the usual ones.

The impact of damages from a catastrophic hazard and recovery analysis depends on the type of the nation and the regional context.

The *long-term recovery model* is inspired from *Solow-Swan growth model* with the capital stock, *K*, divided into three-fold in terms of its use: public capital, K_p, business capital, K_b, and residential capital, K_r. Assuming that the levels of labor and outside aid for capital recovery are fixed at *L* and *K*, respectively, the production function during the recovery is:

$$Y = f(K_p, K_b, K_r, L, K) \quad (1)$$

In this formulation, the *optimum path of recovery* (resources will be utilized in restoring the facilities whose contributions to overall productivity are the greatest) can be analyzed directly from the marginal productivity conditions.

The uncertainty of the damages to capital stocks during the emergency response period becomes less significant, since the information become available in the long-run. It is useful to introduce relationships of productivity between the different types of capital (public capital, K_p, have a significant influence on the productivity of undamaged business capital, K_b, and to the *recovery of both* K_b *and* K_r.

2.3 The endogenous technological progress in long run g, under catastrophic disturbances.

Some authors (Barro, Sala-I-Martin, 1995; Aghion, Howitt, 1998) indicate the efficiency of using *technological progress* in long-run growth and in an equilibrium. If capital stocks are damaged in a disaster, the decision making to replacement, or recovery, of the damaged capital can be quite different. Empirical studies indicate that older facilities are more prone to receive severe damages and they will be replaced. This replacement, can be considered as *a positive jump in technology level* for production (Okuyama, 2004), and may have sizeable *impacts on the growth path after a hazard*. This process is view as an exogenous shock to technological progress.

3. The Value of Information: Risk and Uncertainty

The critical information about the damages is very important, especially for the resource allocation in emergency response period.

This *uncertainty of information* may create further disturbances in economic activities and decision makings. There are only few studies in the literature that have explicitly dealt with this uncertainty of information asymmetry and its effects.

3.1. The concepts of risk and uncertainty in natural hazards literature:

The literature on risk and uncertainty is based on the following schools: a)Frank H. Knight's (1921)- the distinction between risk and uncertainty: *risk* refers to situations where the decision-maker can assign probabilities; *uncertainty* refers to situations when the randomness cannot be expressed in terms of probabilities; b) von Neumann and Morgenstern (1944)- the modern 'risk' school; Arrow (1953) and Debreu (1959) – the 'uncertainty' school; Savage's (1954) expected utility with subjective probabilities theory. Davidson (1991) reconsidered the Knightian uncertainty, as the only relevant form of randomness for economics, while Knightian risk is only possible in very controlled scenarios with very clear alternatives.

In classical disaster literature, it is used a *risk model with objective probability* without an explicitly discuss about the probabilities.

The term *risk* is used for probability of a disaster occurrence or of the damages from a disaster (Oppenheim, 1980; Nordenson, 1997; Johnson, Eguchi, 1998); *uncertainty* is used for describing the situation created by a disaster and represents a broader definition of *risk*. Some authors (Howe, Cochrane, 1976; Brookshire, 1985; Boisvert, 1992; Kunreuther, Roth, 1998) use the probabilistic occurrence of a disaster as risk in order to derive the expected utility for decision-makings against disasters giving more attention to pre-disaster analysis, such as risk management and disaster insurance, rather than toward the uncertainty created after a disaster.

With the Knightian distinction, the research was focused on the concept of *risk*, but not *uncertainty*. It can be assumed that '*risk*' refers to the *occurrence of disasters or damages where decision-makers can assign probabilities for the randomness in a pre-disaster context* whereas '*uncertainty*' refers to the *situations in the aftermath of a hazard* where the situations/ consequences cannot be expressed in terms of probabilities in a *post-disaster context*.

The degree and extent of *'uncertainty'* after a disaster is not fixed, as emergency response and recovery starts, more information regarding the damages and recovery plan will become available; thus, the degree and extent of '*uncertainty*' is variable (Fig 1). At the time of disaster, the degree of uncertainty jumps up to a high level (no information

available about the extent of the damages).
After a short period, with very high uncertainty, confusion and depression under this chaotic situation, the information regarding the level and extent of damages become available and uncertainty may start declining with a speed influenced by: the release timing of recovery plan, the priority of recovery, the damages to the other regions. All these uncertainties are difficult to be quantified with mathematical probabilities, or measured.

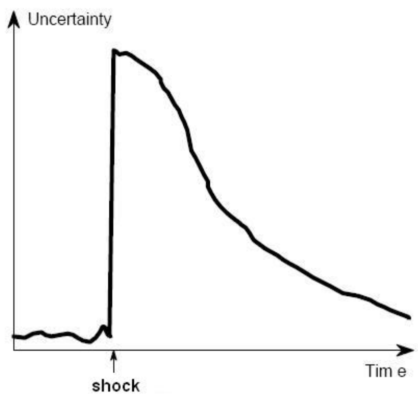

Fig 1. Degree of Uncertainty in and after a Disaster

The uncertainty create disturbances and influences in decision-making for economic activities and recovery with serious impacts (Okuyama*.,* 2004). Dacy, Kunrauther introduce *the value of information* useful to promote pre-disaster preparedness.

During this extreme uncertainty period there are *behavioral factors* (*sympathy*, Dacy , Kunreuther, 1969; *postdisaster cooperation*, De Alessi, 1975), and severe *changes in consumption behavior* (Okuyama*,* 1999), that should be modeled to understand t*he full spectrum of impacts and the recovery process and path after a natural hazard.*

3.2. Vulnerability and the coping capacity

Vulnerability (defined as the likelihood of injury, loss and disruption of livelihood in extreme events) and *coping capacity*, manifest after the exposure to a hazard. There are different conceptual models:
a)Bohle (2001) double structure: in the internal side, coping relates to the capability to anticipate, cope, resist and recover; the external side involves exposure to risks and shocks
b)The 5 elements(natural, human, financial, social, physical capital) *sustainable livelihood framework*: vulnerability is view as shocks, trends, seasonality
c)Vulnerability in the risk-hazard framework (Bohlin, 2003): the preexisting conditions that make infrastructure, processes and efficiency more sensitive
d)Turner (2003)global environmental change community; a definition which encompasse exposure, sensitivity, resilience, adaptation in the context of man in the loop
e)Bogardi- Birkmann (2004) "onion" framework: the impact of hazards is related to the economic sphere and the social sphere, focusing on the potential losses
f)The PAR (pressure- release)model: underlines how disasters occur when risk events affect vulnerable people (Wisner, 2004)
g)Cardona (2001) holistic approach: vulnerability is characterized by physical exposure and susceptibility, fragility of socio-economic system, lack of resilience to cope/ recover
h)The BBC framework (Bogardi, Birkman,Cardona): stress that vulnerability goes beyond the estimation of deficiencies and assessment of impacts in 3D (economic, social, environmental).
The models for vulnerability, based on a vision or goals, should be closer to decision making (the knowledge for action). A forward- looking approach is a challenge. For practical reasons, vulnerability indicators take into account damage occurred in the past and a separation between damage, impact and vulnerability is less rigid in the course of practical application.

4. Effects on long-term in the growth theory context

The basic neo-classical model of the Solow-Swan (1956). Let express the production function without technological progress, in intensive form y=f(k). Let saving rate, s, capital depreciation, δ *and* population growth rate, n constants. The change in per capita capital stock over time becomes as follows:

$$k = dk/dt = s\text{-}f(k)\text{-}(n+\delta)\,k \qquad (2)$$

Let a steady state economy and a catastrophic shock without casualties in labor population; the per capita capital level decreases from the steady state level, y^*, to the damaged level, y_d. The economy goes out of its steady state, and results a space (B-C) for the recovery. Because the extra-output allocated toward the reconstruction of damaged capital stocks, the recovery saving rate, s_r may *accelerate the speed of recovery*, (D-C> B-C). As the economy recovers, the recovery saving rate return to the normal rate, s (D goes to A).

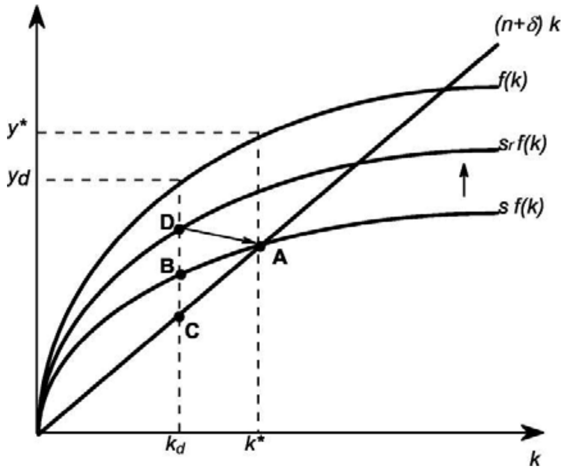

Figure 2 Solow-Swan Model and the dynamics of recovery after hazard

The dynamics of recovery can be expressed by introducing the growth rate of *k*, γ_k

At the steady state, *k**, the growth rate becomes zero due to the intersection of two lines,

s f(k)/k = (n + δ). (3)

In a hazard, the level of per capita capital becomes k_d and the growth rate of k (B-C) becomes positive. Because in reconstruction phase the saving rate becomes higher (to s_r), the growth rate of k increases (D-C). As the reconstruction progresses, the saving rate gradually returns to *s,* and the growth rate of *k* to the steady state level of zero (from D to A). In conclusion, the more resources are allocated for the recovery, the faster the speed of recovery (capital re-accumulation).

4.1 An analysis of the transitional dynamics with technological progress

Let introduce the *effective labor, L = L(t),the* labor population multiplied by its efficiency, *A (t)* and the quantity of capital per unit of effective labor, *k*.

The intensive form of the model $\hat{y} = f(\hat{k})$ with technological progress becomes:

$$\hat{k} = s \cdot f(\hat{k}) - (x + n + \delta) \cdot \hat{k} \qquad (4)$$

and the growth rate:

$$\gamma_{\hat{k}} = s \cdot f(\hat{k}) / \hat{k} - (x + n + \delta) \qquad (5)$$

The steady state condition is

$$s \cdot f(\hat{k}^*) / \hat{k}^* = (x + n + \delta) \qquad (6)$$

The technological replacement can increase the rate of technological progress during the recovery period. Because of the faster technological progress it results a faster growth of effective labor, thus, slightly slower growth (recovery) rate of *k*.

4.2 Long term policy implications

- the rate of recovery depends on the resource allocation to the recovery activities;
- the degree of mixture between old and new capital stocks in an economy can influence the recovery rate.

4.3. Future work

The analysis with classical long term growth theory should be completed with:

-further theoretical investigation of uncertainty created by a disaster will provide insights to these studies.

-the model needs to be stretched to employ the framework of endogenous growth models to compare different policies of technological progress and the impacts on disaster recovery.

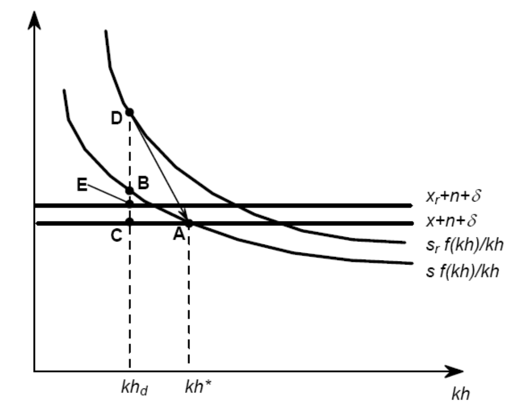

Fig 3 Transitional Dynamics with technological Progress

5. Conclusions

Natural hazards are low probability- high impact phenomena and the damages vary considerably from one disaster to another and from one region to another. The generalized analysis of the hazards is important to advance our *knowledge for* the *impacts, consequences and management* and can assist empirical analysis of disasters.

The effects of uncertainty after a disaster need to be incorporated in the analysis of economic impacts of the hazards since the decision-making and response to supply- demand changes are noticeably different. Computable General Equilibrium (CGE) models, should take into account this uncertainty and behavioral changes. Uncertainty create also severe influences to the production planning and bring additional impacts on inventory management and production scheduling (Okuyama, 2004).

The theoretical analysis of hazards impacts will offer some new perspectives to the disaster related research.

The analysis of long-term growth technological progress after a hazard proposed the issues of *technological replacement and optimal saving rate*. While technological replacement resulted from the reconstruction is different from usual technological progress, in terms of its exogenous nature of shock, but is similar about the endogenous level of technology available for replacement. The speed of recovery depends on the extra amount of savings allocated to reconstruction. This concept is also related to the issue of hazard insurance that should incorporate this type of consumption-saving optimization analysis for the long-run implications.

The interest in future applications is related to:

-a better selection (some indicators show a high correlation with one another)

-a better definition of weighting factors for each indicator (Saisana- Tarantola, 2002)

-a better representation of the quickly change of structural characteristics of the population as a result of extreme events

-new models for relevant assessments (disaster management capacities, risk perception).

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