

Optimal Statistical Decisions with Catastrophic Risks (AFOSR FA9550-09-1-0467)

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Abstract

Introduced and analyzed new axioms for samples with *catastrophic risks*, defined as rare events with unknown frequencies which can cause devastating losses and discontinuous system change (Posner). Based on these axioms the research provided (1) New forms of likelihood analysis that extend the foundations of probability and statistics & Bayesian analysis; (2) Characterization of new forms of risk assessment and of decision criteria appropriate for situations involving both standard and catastrophic risks, (3) Foundations for jump –diffusion statistical processes, and (4) Practical applications for the assessment and decisions of catastrophic risks – both natural and human made. Examples are asteroid impacts, climate change, which the Pentagon identifies as a national security risk, and risks of disruption of energy supplies including catastrophic incidents in oil pipelines. The research has led to a number of theoretical, experimental and empirical publications by the PI and co-authors in collaborating institutions, the preparation of a book outline on the basis of the research completed and a Workshop on Catastrophic Risks by June 2012.

Catastrophic Risks (Graciela Chichilnisky)

Objective:

New Mathematical Algorithms, Updated Statistical Decisions, including Bayesian and Group Decisions for Assessment of Catastrophic Risks in natural and human systems including climate change, Asteroids and the disruption of energy supplies

DoD Benefits:

Recent Pentagon report finds that catastrophic events such as climate change and disruption in energy supplies – eg pipeline accidents - over the next 20 years can cost millions of lives in wars and natural disasters, hundreds of \$US billions in losses, and are a priority for national security. This research provides the DOD mathematical and applied approaches and algorithms for the anticipation, assessment, measurement and management of catastrophic risks, both natural and human made. New statistical decision tools, and practical applications are provided concerning disruption of natural systems and energy supplies.

Technical Approach:

New axiomatic treatment of the foundation of probability and statistics, Bayesian analysis, and the attendant optimal statistical decisions, including algorithms for individual and group statistical decisions.

Budget: Planned \$K

Actual/ Planned \$K	6/15/09- 11/30/09	12/1/09- 11/30/10	12/1/10 -11/30/11	12/1/11- 6/14/12
	\$100,000	\$150,000	\$150,000	\$36,796

Annual Progress Report Submitted? Y Y Y N

Project Start Date: June 14th, 2009

Project End Date: June 14th. 2012

New Axioms for Likelihood with Black Swans

- **Axiom 1:** Sensitive to rare events
 - **Axiom 2:** Sensitive to frequent events
 - **Axiom 3:** Additive and continuous in the sup norm
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- Parallel axioms for decision making under uncertainty with standard and catastrophic risks
 - Based on continuous decision criteria & bounded utility

Likelihood Sensitive to Rare Events

The negation of insensitivity to rare events

Definition: A likelihood \succ is *insensitive to rare events* when, for every two events, $a \succ b$
 \iff there is an $\varepsilon = \varepsilon(a,b)$ such that $a^* \succ b^*$
for every a^* and b^* satisfying $a^* = a$ and $b = b^*$ outside a set of Lebesgue measure less than ε .

Project Goals

1. Show how standard statistical analysis based on existing relative likelihood axioms underestimate the incidence of catastrophes, and unnecessarily increase losses after the fact (1996, 1999, 2000, 2009, 2010, 2011)
2. Develop new axioms for the foundations of Probability and Statistics that correct this bias (1996, 2000, 2009, 2010, 2011)
3. Obtain a representation theorem that characterizes all the relative likelihoods or subjective probabilities, as well as all the decisions criteria, that the new axioms imply (1996, 2000, 2009, 2010)
4. Develop Optimal Statistical Decisions tools – including Non Parametric Estimation in Hilbert Spaces, Bayesian Updating and Group Decision tools (2009, 2010, 2011)
5. Develop Group Decision tools for situations involving Rare and Catastrophic Events including Crowd-Think, Cost - Benefit and Market Approaches (1996, 2000, 2010-12)
6. Introduce New Algorithms to study numerical approximations of the new types of decision rules – both for individual and groups - when rare and catastrophic events are at stake (2010 - 12)
7. Develop and apply to practical applications including (i) Bayesian analysis and Nonparametric Econometrics for (i) The Assessment of climate change risks; (ii) disruption of energy supplies and other natural resources, (v) economic decisions involving national security: water supplies, climate change and catastrophic accidents in oil pipelines (vi) experimental tests and empirical applications

Progress Towards Goals

Progress has been made towards goals (1) (2) (3) (4) and (5) based on earlier work by the PI since 1996 – in recent publications attributed to this grant, as follows:

1. “The Topology of Fear” **J. Mathematical Economics**, 2009,

Necessary and Sufficient (Topological) Conditions for Optimal Statistical Decisions that are Sensitive to Catastrophic Risks

2. “The Limits of Econometrics: Non-Parametric Estimation in Hilbert Spaces without Sample Bounds”, **Econometric Theory**, 2010

Necessary and Sufficient Conditions for extending NP Econometrics in problems with arbitrary Sample Size.

Progress Towards Goals

3. "The Influence of Fear in Decisions: Experimental Evidence" (with Olivier Chanel), **Journal of Risk and Uncertainty**, Vol. 39, No. 3, December 2009:

Experimental Evidence supporting the New Axioms for Probability and Statistics and Decisions with Rare and Catastrophic Events

4. "Catastrophic Risks", **International Journal of Green Economics**, Vol. 3, No. 2, 2009:

Survey of existing results with the new Axioms for Statistics with Catastrophic Events.

Progress Towards Goals

5. "The Foundations of Statistics with Black Swans", **Mathematical Social Sciences**, Volume 59, Issue 2, March 2010:

New Axiomatic Foundations and the Development of Statistical Analysis with Rare Events

6. "Subjective Probability with Black Swans", **Journal of Probability and Statistics**, 2011, Special Issue on Actuarial and Financial Risks: Models, Statistical Inference,

New Axiomatic Foundations of Subjective Probability and Characterization of all Subjective Probabilities that Satisfy new Axioms and are Sensitive to Rare Events ("Black Swans")

Progress Towards Goals

7. “Sustainable Markets with Short Sales” **Econ Theory, 2011**

Existence of Group Decisions including Market Equilibrium when Traders conform to the New Axioms defining Sustainable Preferences

Case Studies:

8. "Asteroids: Assessing Catastrophic Risks" (with Peter Eisenberger), **International Journal of Green Economics**, 2010, and LAMETA, Working Paper DR 2009-13

Progress Towards Goals

9. "The Value of Life: Theory and Experimental Observations" (with Olivier Chanel), *Ecological Economics*, 2012.

Experimental results confirming the validity of the new axioms for catastrophic risks involving loss of life

10. "Catastrophic Accidents in Oil Pipelines" Working Paper Columbia University New York (2012)

How to assess the risks of catastrophic accidents with unknown frequencies and devastating effects in Calgary's oil pipelines

Progress Towards goals

- “Valuing life: experimental evidence using sensitivity to rare events”
(with o. Chanel) **Ecological Economics** March 5 2012

Experimental evidence agrees with the predictions axiom of sensitivity to rare events

- “Catastrophic Risks with Finite or Infinite States” **International Journal of Economics & Statistics** Vol 23 2011

Extending the results to finitely many states.

Collaboration

- Towards goals (1), (4) and (5) and in developing decision making policies that are useful for national security situations involving catastrophic risks – such as the disruption of energy supplies and climate change -- we collaborated with several organizations to identify specific national and international climate and energy policies from the above theoretical results on catastrophic risks: (1) Alliance of Small Island States (AOSIS), (2) Intergovernmental Renewable Energy Organization (IREO), (3) Research on Water with Institute for Advanced International Studies, University of Geneva, (4) Experimental work with; Groupement de Recherche en Economie Quantitative d'Aix Marseille (GREQAM) & Institut d'Economie Publique (IDEP), and (5) Department of Economics East Carolina University, and (6) SRI, UCI, Stanford in California, Madrid Spain, and CUNY NY: Workshop on Catastrophic Risks 2012.

Interaction with Organizations

- Columbia Consortium for Risk Management (CCRM) Columbia University NY
- Alliance of Small Island States (AOSIS) United Nations New York
- Intergovernmental Renewable Energy Organization (IREO)
- Groupement de Recherche en Economie Quantitative d'Aix Marseille (GREQAM) Marseille France
- Institut D'Economie Publique (IDEP) Paris, France
- Universite de Montpellier, Montpellier, France
- Institute for Advanced International Studies, Geneva Switzerland
- University of California Irvine
- East Carolina University
- Stanford University
- SRI International Menlo Park California

List of Publications Attributed to the Grant (2009 - 2012)

1. G. Chichilnisky: "The Limits of Econometrics: Non Parametric Estimation in Hilbert Spaces without Sample Bounds", **Econometric Theory** (2010)
2. G. Chichilnisky: "The Topology of Fear" **J. Mathematical Economics**, (2009) 45: 807-816.
3. O. Chanel and G. Chichilnisky: "The Influence of Fear in Decisions: Experimental Evidence" **Journal of Risk and Uncertainty**, (2009) Vol. 39, No. 3.
3. G. Chichilnisky "The Foundations of Statistics with Black Swans" **Mathematical Social Sciences**, Volume 59, Issue 2, March 2010.
4. G. Chichilnisky: "The Foundations of Probability with Black Swans" **J. of Probability and Statistics**, (2010) Special Issue on Actuarial and Financial Risks: Models, Statistical Inference, and Case Studies.
6. G. Chichilnisky and P. Eisenberger: "Asteroids: Assessing Catastrophic Risks", **J. of Probability and Statistics**, (2010) Special Issue on Actuarial and Financial Risks: Models, Statistical Inference, and Case Studies.

List of Publications Attributed to the Grant (2009 - 2012)

7. G. Chichilnisky: "Catastrophic Risks" **International Journal of Green Economics**, (2009) Vol. 3, No. 2.
8. G. Chichilnisky: "Breaking the Dynamics of Rationality in Conflict and Reconstruction" (with Professor Urs Luterbacher, Graduate Institute of International and Development Studies, Switzerland (2012)
10. G. Chichilnisky: "Sustainable Markets with Short Sales" **Economic Theory**, (2011).
11. G. Chichilnisky and O. Chanel: "Valuing Life: Theory and Experimental Observations" (with Olivier Chanel), **Ecological Economics**, (2012).
12. G. Chichilnisky "Catastrophic Risks with Finite or Infinite States" **International Journal of Economics & Statistics** Vol 23, (2011)
12. G. Chichilnisky: "Catastrophic Accidents in Oil Pipelines" Working Paper, Columbia University, New York, (2012).
13. G. Chichilnisky: "Markets with Black Swans" (2012)
14. G. Chichilnisky: "Statistical Processes with Black Swans"