



Activity Report

November 18, 2014



Table of Contents

ICDRiA ACTIVITY REPORT.....	3
1. INTRODUCTION.....	3
2. FUNDING	3
3. EDUCATION PROGRAM	5
4. RESEARCH PROGRAM	6
4.1. Risks and Uncertainties in Information Systems	6
4.2. Risks in Supply Chain Management	7
4.3. Risks in Financial and Economic Systems	9
4.4. Risks and Uncertainties in Alternative Energies	10
4.5. Risks on Technical Systems	11
5. PRESENT ACTIVITIES	12
5.1. Activities in the Security in Information Systems Domain	12
5.2. Activities in the Supply Chain Domain	18
5.3. Activities in Finance and Economics	36
5.4. Activities in Alternative Energies.....	38
5.5. Activities in Risks on Technical Systems	39
6. PUBLICATIONS.....	43
7. RISK AND DECISION ANALYSIS JOURNAL.....	47
8. ICDRiA Website	51
9. ICDRiA Board	53



Naveen Jindal School of Management
Alain Bensoussan
Ashbel Smith Chair Professor
Director

**THE UNIVERSITY OF TEXAS AT DALLAS
INTERNATIONAL CENTER FOR DECISION AND RISK
ANALYSIS**

P.O. BOX 830688 SM30 RICHARDSON, TEXAS 75083-0688
(972) 883-5970 FAX (972) 883-5850



ICDRiA Activity Report 2014

1. Introduction

The International Center for Decision and Risk Analysis was created in September of 2004 as a Research Center of the School of Management. The objective of the center is to develop education and research programs in the field of Risk Analysis and Decision Making. We report in this document the accomplishments during the period 2014.

The cooperation with the Johnson School of Engineering and Computer Science, on the domains of cyber security, systems engineering and energy management is developing in a very positive manner.

On the international side, the discussions with City University Hong Kong have materialized into a MOU at the level of the two universities. This MOU is being materialized. Visits from Dean Marc Spong and the Chairman of the department Systems Engineering Steve Yurkovich to City U have occurred in June 2014. A dual degree is being prepared.

2. Funding

New funding obtained this year:

2.1 “EREN Development”

Optimization of Wind Farms and Solar Plants Facilities: Competitive Markets

Alain Bensoussan (PI)

150,000€ (\$190K) October 20, 2014 – October 19, 2017

Ongoing grants:

2.2 Mean Field Games, Mean Field Type Control and Extensions

National Science Foundation

Alain Bensoussan (PI)

\$ 339,572, October 1, 2013- September 30, 2016

2.3 RGC, General Research Fund, Hong Kong

Mean Field Theory, Stochastic Control and Systems of Partial Differential Equations

Alain Bensoussan (PI)

HK\$ 423,562, October 1, 2013-September 30, 2016

The contract with EREN is a follow up of the contract with EDF-EN, and it is thanks to the work done previously that we are happy to get this new one. EREN is a relatively new company, and not a subsidiary of EDF, as EDF-EN is. We address here some new challenging problems. We are dealing with new markets, for which there is no precedent. So far, the power providers, relying on wind and solar energy, can benefit from a privileged status, which is the consequence of the general political will to reduce environmental risks, occurring from classical power plants. Their profitability is protected by a system of subsidies or guaranteed markets. This will be changed in the near future. The providers, exploiting a park of turbines or solar plants, will compete on markets which will be open and without backing from public sources. In this context, the profitability will highly depend on the way risks are managed. In view of the fact that things can change fast, and that many players will enter these new markets, the best preparation will be an essential asset for success.

The type of problem to be faced by the provider is to guarantee a given amount of energy, for a given duration, at a given price. The contract commitment is for some future date, which can be short term or longer. The major difficulty is that the capacity of production comes from wind turbines and solar plants. Therefore, this capacity is highly dependent on the wind speed and direction, or sun availability. Consequently the capacity is highly random. The problem is to assess the risk of bidding for a contract.

3. Education Program

Risk and Decision Analysis is included in the education programs of the Jindal School of Management. The course is taught in the fall every other year and is also part of the program “Systems Engineering and Management” which is a joint venture between the School of Engineering and the School of Management. The course is now well established and almost 50 students are registered, including around 15 from the School of Engineering, for the master in systems engineering. This class will also be included in the master of finance and the master in business analytics.

The course “Introductory Mathematical Finance” has been offered as a part of the Master in Finance in fall since 2008. The class attracts motivated students and is attended by doctoral level students as well. This class attracts regularly students from the mathematics department, and occasionally from other schools.

We are preparing a new course “Stochastic Dynamic Programming and applications to Operations Management, Finance and Economics” It will be offered in the fall 2015. Stochastic Dynamic Programming is a general methodology which plays an essential role in many areas of economics and management science. It deals with decision making under uncertainty for dynamic systems, which is the situation appearing commonly in a lot of applications. Although this fact has been known for long time, it has become even more evident in view of the new problems which are presently at the forefront of research.

This is particularly true for mathematical finance, whose developments have motivated many innovative techniques related to SDP (Stochastic Dynamic Programming). The consumer-investor problem of Merton is the most famous one, but option pricing, credit risk, corporate finance, optimal compensation and many others have originated substantial new effort and interest in SDP related techniques.

In operations management, the application of SDP goes back to inventory theory, with the well-known base stock and s, S policies. However, the structure of the supply chain has become very complex, and has justified new approaches, in particular the use of principal-agent methodology. For realistic situations, one has to consider dynamic systems, with moral hazard problems, asymmetric information, risk-sharing issues and incentives considerations.

A lot of interest is related to linking operations management with other management domains, like marketing and finance. The issue of pricing, traditionally a marketing question, is now considered together with capacity planning and inventory control. This new and very important topic is called revenue management. Dynamic models are essential, and lead to substantial extension of SDP.

Investment theory, growth of firms and real options are now connected and elicit new questions related to SDP methodology.

As soon as there are several decision makers, in competition, or contracting with each other, the issue of information comes naturally, with very delicate questions, for each intuition is of little help. A solid theory requiring sophisticated mathematical techniques is imperative. Even if mathematics is not the objective, it is indispensable to be comfortable with some of these techniques and concepts.

The case of a very large number of decision makers leads to the question of dynamic equilibrium, topics of strong interest in economics, but also for financial markets, and social networks. “Big data” has become the new framework, and involves new statistical problems, advanced simulation techniques and stochastic optimization with dynamic structure. All these considerations have amply modified the type of background which is indispensable to perform relevant research in the current circumstances. They all have to do with stochastic dynamic programming and its evolution.

4. Research program

The activities of the center are presented in 5 domains:

- Risks and Uncertainties in Information Systems;
- Risks in Supply Chain Management;
- Risks in Financial and Economic Systems;
- Risks and Uncertainties in alternative energies;
- Risks in Technical Systems.

4.1. Risks and Uncertainties in Information Systems

The center benefits from the activity of a group of faculty focused on security issues in information systems, a major strength of the School of Management. The center cooperates also with the Cyber-security Center of the School of Engineering, headed by Professor Bhavani Thuraisingham. Through this center, we have been associated to a MURI project, “*Assured Information Systems sharing*” supported by Air Force. Alain Bensoussan is also co-PI in a grant from ONR, of which Professor Murat Kantarcioglu is P.I. Under this grant, we are sub-contractors of Purdue University. The topic is “A Systematic Defense Framework for Combating Botnets.” Finally Alain Bensoussan is co-PI of an NSF grant: *TC: Large: Collaborative Research: Privacy-Enhanced Secure Data Provenance*, initiated in 2011, which runs till 2016.

Concerning the Assured Information Systems project, we have proposed a model of access to information based on a scoring procedure which has analogies with that of a credit score. There are some common issues in both situations; one of which is the idea of building trust. Based on a good or bad score (using the score as an indicator of trust) the access to information (as the access to credit) is more or less difficult. A publication has been submitted.

In the botnet project, the interesting aspect is that there is a market of malignant actions. An entity interested in being harmful to another entity buys the services of a botnet herder. A botnet herder has contaminated a network of computer systems without the owner’s knowledge. He can

drive these systems to perform damages on targeted systems. The problem that we have treated is the calibration of the defense effort.

One can define a criterion for the botnet herder. This criterion is itself the result of equilibrium on the market. There is a price for the malignant actions and the herder optimizes an objective based on his profit and costs (including risks). The defense can then formulate a game based on its' own criterion and that of the botnet herder. We have considered and solved completely a dynamic game based on these considerations.

We have also worked on a new problem in cyber security. This concerns ways to crack down the cybercriminal market. In the literature, it has been proposed to use the idea of "*Lemonizing the market*".

This means putting more fake products, under government control, which has the effect of shrinking the demand. Using game theory, we have considered several possibilities opposing government and cybercriminals, and defined the best strategy to significantly reduce the cybercriminal market.

We have also studied the problem of extension of cloud computing. This topic belongs to a more general question on how a new technology expands. We have been inspired by work in this domain, making use of mean field theory, an area of research which we study independently, for its own sake. The idea is that the cost of using cloud computing technology is not simply determined by the level of use, as it will be if it were a product with fixed unit price. There is a scaling effect. The unit price is not fixed, but depends on the density of users. So the extension is defined by the evolution of the density of users, and this problem can be dealt with using mean field theory.

We finally have been associated with an important proposal submitted to the Army. It took the form of a Cyber Security Collaborative Research Alliance (CRA) bringing together five academic institutions: Purdue University (Lead Research Organization), the University of Texas at Dallas (UTD), the University of California at Irvine (UCI), the Massachusetts Institute of Technology (MIT), and the University of California at Riverside (UCR). The objective is to develop multi-disciplinary approaches to solve the critical security challenges faced by the Army. Our proposal was among the three finalists. Unfortunately, our proposal did not finally win, but we are confident that this effort will allow obtaining further successes in the future.

We are very happy to be associated with the center for cybersecurity, which is extremely dynamic and offers the opportunity of interesting and challenging new areas of research.

4.2. Risks in Supply Chain Management

In the "supply chain" area, the center relies mainly on the expertise of the Operations Management department. Risk arises from uncertainties at all stages of the supply chain. In particular, there are uncertainties on key variables needed to make decisions. For instance, one does not know the inventory and one must decide on the level of replenishment. Uncertainties on

inventories have been at the core of our research since many years, when we were awarded an NSF grant to support the research in this topic over a period of three years, and also a support from the State of Texas.

We have developed a general methodology which provides the optimal policy for managing inventories in the context of uncertainties. This is an original result that was not known before. It is now commonly referred in the field. We have shown numerically that this optimal policy provides a real improvement in lowering cost compared to a policy based on the best estimate of the inventory. We have also introduced efficient and easy-to-implement approximate policies based on the mean and the variance of the inventory.

The usual approach in inventory management is to reduce the uncertainty in the inventory level by using technology which provides accurate counting, like RFID technology.

Our approach follows the idea of fault tolerant systems. We do not correct the pathology, which is the uncertainty, but we incorporate it in the decision making. In practice we combine both.

We have been addressing new sources of uncertainty, in particular shrinkage, which may imply serious risks on the inventory. The Inventory Manager observes the level of sales. Our general methodology applies.

A general situation in which the methodology works well is *learning*. This is a common situation when one tries to learn about the demand. Demand is of course an essential source of risk for companies and also provides a wide diversity of modeling possibilities. As an example, we have studied in Hong Kong the situation of dynamic inventory management of nonperishable products with a Poisson demand process. We learn on the demand rate through past sales. We have compared three scenarios, no observation of the sales, full observation and partial information.

Inventory Management in the context of global supply chain is the source of numerous research problems. In fact, it is more and more connected to the definition of contracts with suppliers. Big issues concern the setting of incentives, the issue of moral hazard, the sharing of risks and the lack of information.

In these new directions, we have initiated two actions, involving new participants at UTD as well as in Hong Kong. One concerns a “Principal-Agent approach to inventory control” We propose a contractual approach between a supplier and a retailer. The inventory manager, the supplier or principal, proposes a contract to the retailer, based on a replenishment policy of base stock type. This guarantees the availability of the product to the retailer, against the payment of a premium. There is an asymmetry of information. The retailer (Agent) knows the demand better than the supplier (Principal). He provides some information to the principal. The issue for the principal is to design the contract so that it has the revealing property; the agent has no interest in distorting the information. Besides the design of the contract, the problem of the principal is to choose the time when he proposes the contract. This leads to problems of optimal stopping in inventory control with partial information, which is new and challenging.

The second direction has been initiated in Hong Kong. It concerns simultaneous inventory and pricing optimization. This is a very natural problem, considered in the literature with primitive techniques. More advanced mathematical techniques should be used to handle it. The version in continuous time is completely open, and we have proposed this topic to a PhD candidate in the mathematics department. Moreover, when prices are decision variables, we have a natural extension to games, when firms compete in pricing. This is an extremely challenging problem, offering a lot of possibilities.

4.3. Risks in Financial and Economic Systems

In the third direction, we are considering several questions. Financial Engineering is a particularly challenging domain, and the present crisis has an impact on the needs. We expect many opportunities in the mid- and long-term. More research is needed that would make stronger connections between financial decisions and risk management and between the financial world and the 'real world'.

In the context of coupling the financial world to the real world, we are particularly active in the area of "Real options," which aims at adapting techniques from financial engineering in project risk management. We have seen in particular that the pharmaceutical industry and the aeronautical industry are making use of these methods for R&D projects. We want to apply this theory to investments in energy and similar domains.

On the more theoretical side, we have been working on problems of real options when there is competition. This is an extremely interesting but challenging problem. In real options, the number of competitors is generally limited whereas in financial options the multiplicity of players allows to assume that a single player cannot alone modify significantly the market (this is of course not always true). Therefore, integrating competition in the model is important.

We have obtained significant results, with Celine Hoe, who now holds a position at Texas A&M. With another post-doc, Benoit Chevalier-Roignant, we have connected the methodology of real options to that of building capital in firms. This is a very well-known problem in economics, under the name of growth of firms. Real options are linked with management science and finance.

These questions have been considered separately in the literature. They are obviously linked; a firm builds its capital through projects. We can formulate the general problem as an impulse control problem. We have obtained new results, to characterize the optimal policy. It must be emphasized that, in spite of a huge literature, only partial results existed so far. The reason is that only special situations have been considered, without a comprehensive approach. Several publications are under way. The impulse control problems which arise in this context are quite new and challenging. We have delicate free boundary problems to solve.

Also, with colleagues from Ajou University we have been considering interesting questions related to credit risk. We solved a problem of defining the relation between a loan and its

reimbursement taking into account the possibility of default. In this context, we have solved Dynamic Programming equation with innovative techniques, using the martingale approach.

In Korea, problems related to optimal retirement policies have been also considered. These problems become more and more popular, in view of the uncertainties linked with health and active life duration. We have worked on the incomplete market case and obtain solutions when the incompleteness is sufficiently small.

A new and important development in this line of research is *Mean Field Theory*. This is a direction of research initiated a few years ago, which has become extremely popular in many countries. The general idea is to apply concepts well known in Physics, and deemed very useful, to social and economic sciences. The objective is to study the systemic risk, and more generally the influence on decisions of a large community of agents, with characteristics similar to the decision-maker. This impact is in general discarded, because of its complexity. Note that this is different from equilibrium theory in economics.

In equilibrium theory, one takes decisions based on market prices. These prices reflect the interactions between all players, but they remain external for the agent, unlike in the mean field theory, in which the effect of the large community is endogenous. This theory is becoming popular in many other domains, like traffic congestion, consumer behavior, or information technology.

Our efforts in this domain are supported by an NSF grant and RGC-GRF grant. We support a post-doc who joined the center last summer.

4.4. Risks and Uncertainties in Alternative Energies

We have completed our work under the grant from Electricité de France. It concerns forecasting wind energy production.

There are many forecasting situations in this context. In particular, one must differentiate the investment phase from the operational phase. In the investment phase, the situation is to decide whether or not to install a wind farm in a specific region. This is typically a situation where the methodology of real options applies. However, we are not at this phase yet. Besides, it will involve confidential information, which is not accessible. We are at the forecasting phase. There are government and industry data that can easily be made anonymous so that confidentiality of data is not a real problem. We have obtained data from EDF and CPL (China Power Limited) in Hong Kong, so we are in a comfortable situation to calibrate our methods.

The problem at the investment phase is to forecast accurately the annual production. It is important not only to forecast its mean but also quantities to assess the risk. We have developed a methodology for that purpose which has been well received by EDF. We have shown that a substantial amount of risk is presently overlooked in the literature and by practitioners.

This structural risk, so far neglected, is important because of the correlation, between periods. Although the correlation disappears after 48 hours, this period plays a significant role in increasing the volatility. So it is important to model accurately the correlation. We have finalized our study of the impact of seasonality. Since seasonality leads to an improvement of accuracy, we can obtain formulas which reduce the structural uncertainty. Our numerical calculations show significant results in that extent. It is comforting to see that more complex modeling is rewarded by a significant reduction of structural risk.

At the operational level the problem is to make an accurate short-term forecast. Indeed, wind energy is most commonly coupled with another energy source, and it is important to assess how much is needed. In addition, the potential surplus of wind energy is a problem since a storage facility has to be available; these questions are related to smart grid management, which is a huge area of research. This domain is more and more popular. We are very happy that the new contract with EREN will provide the opportunity to develop expertise in this important topic.

4.5. Risks on Technical Systems

In the fifth domain, we work on technical risk management. This research was initiated by a contract with the French Atomic Energy Agency (CEA) to study the effect of vibrations on mechanical structures. This potentially leads to assessing the risk of collapse of buildings subject to seismic vibrations. We have developed new methods and new mathematical tools which were sufficiently promising to justify a proposal to NSF which was awarded in July 2007.

The CEA has also increased its support to our group. This research is done in cooperation with Professor Janos Turi from the Mathematics Department. In relation with the NSF contract, we have obtained an international supplement to cooperate with the Hungarian Academy of Sciences. The NSF grant has been closed at the end of 2011. Although CEA has extended its support, we have failed to obtain an extension from NSF. This is very unfortunate, since the research has progressed greatly. We have supported 2 PhD students, 2 post-doc. One of the doctoral students has received the award of the best dissertation in applied mathematics from the French Academy of Sciences, in 2011. He is presently Professor at the University of Nice.

Among the major results of this research, we have obtained explicit formulas for the fatigue of a material which goes from elastic to plastic stages. These formulas are very much appreciated by practitioners, which rely mainly on simulation to obtain them. From the theoretical point of view, we have introduced new random processes and have studied their ergodic properties. This provides the mathematical framework to perform the calculations of quantities of interest to engineers, like fatigue of materials, which otherwise are accessible only through simulation. Unfortunately, the support from CEA has arrived to an end. In spite of the interest in our results and in view of the significant budgetary cuts, the support will not be renewed at its present level. We are hopeful to get a relatively symbolic support, to prepare new proposals.

5. Present Activities

5.1. Activities in the Information Systems Domain

5.1.1. Predictive Analytics for Readmission of Patients with Congestive Heart Failure

Participants: Indranil Bardhan, Cath Oh, Eric Zheng, Kirk, Kirksey

Mitigating preventable readmissions, where patients are readmitted for the same primary diagnosis within thirty days, poses a significant challenge in the delivery of high quality healthcare. Toward this end, we seek to understand whether health information technologies (IT) can help lower readmission risks. We develop a novel, predictive readmission model, termed as the beta geometric Erlang-2 (BG/EG) hurdle model, which predicts the propensity, frequency, and timing of readmissions of patients diagnosed with congestive heart failure (CHF). This unified model enables us to study the role of health IT applications, as well as patient demographics and clinical factors, in terms of their association with the risk of patient readmissions. The BG/EG Hurdle model provides superior prediction performance compared to extant models such as the logit, BG/NBD hurdle, and EG hurdle models. We test our model using a unique dataset that tracks patient demographic, clinical, and administrative data across 67 hospitals in North Texas over a four-year period. We find that health IT, patient demographics, visit characteristics, payer type, and hospital characteristics are significantly associated with readmission risk. We observe that implementation of cardiology information systems is associated with a reduction in the propensity and frequency of future readmissions, while administrative IT is correlated with a lower frequency of future readmissions. Our results indicate that patient profiles derived from our model can serve as building blocks for a clinical decision support system to identify CHF patients with high readmission risk.

Bardhan, I., Cath Oh, Z. Zheng, K. Kirksey. "Predictive analytics for readmission of patients with congestive heart failure: analysis across multiple hospitals", forthcoming at *Information Systems Research*, 2014.

5.1.2. Know Yourself and Know Your Enemy: An Analysis of Firm Recommendations and Consumer Reviews in a Competitive Environment

Participants: Jabar Wale and Eric Zheng

Reviews and product recommendations at online stores have successfully enabled customers to readily evaluate alternative products prior to any purchase. In this context, firms generate recommendations to refer customers to a wider variety of products. They also display customer-generated online reviews to facilitate evaluation of those recommended products. This study integrates these two IT artifacts in order to investigate consumer choice vis-à-vis competing products. We use a dataset collected from Amazon.com consisting of books, sales ranks, recommendations, reviews, and reviewers. We derive the granular impact of reviews, product referrals, and reviewer

opinions on the dynamics of product sales within a competitive market using comprehensive econometric analyses.

Jabar, W. and Z. Zheng. "Know Yourself and Know Your Enemy: An Analysis of Firm Recommendations and Consumer Reviews in a Competitive Environment" *MIS Quarterly* 38 (3), 2014, 635-654.

5.1.3. The Power of Silence: An Analysis of the Aggregation and Reporting Biases in User-Generated Contents

Participants: Eric Zheng

Working paper.

User-generated contents (UGC) such as online reviews are inherently incomplete since we do not capture the opinions of users who do not write a review. These silent users may be systematically different than those who speak up. Such differences can be driven by users' differing sentiments towards their shopping experiences as well as their disposition to generate UGC. Indiscriminately aggregating UGC across different sentiment levels can lead to an aggregation bias and overlooking the silent users' opinions can result in a reporting bias. We develop a method to model users' UGC generating process and then rectify these two biases simultaneously through an inverse probability weighting (IPW) approach. In the context of users' movie review activities at Blockbuster.com, we found that the average probability for a customer to post a review is 0.06 when the customer is unsatisfied with a movie, 0.23 when indifferent, and 0.32 when satisfied. A user's reporting probability with positive experience first order stochastically dominates the one with negative experience. We then adjust common UGC measures such as review volume and sentiment using these estimated reporting probabilities as weights. We show that these rectified measures yield superior predictive power, as opposed to the raw ones. Our proposed approach provides a realistic solution for business managers to properly utilize incomplete UGC.

5.1.4. Protecting Privacy against Record Linkage Disclosure: A Bounded Swapping Approach for Numeric Data

Participants: Xiao-Bai Li and Sumit Sarkar

Record linkage techniques have been widely used in areas such as anti-terrorism, crime analysis, epidemiologic research, and database marketing. On the other hand, such techniques are also being increasingly used for identity matching that leads to the disclosure of private information. Such a technique can be used to effectively re-identify records even in de-identified data. Consequently, the use of such a technique can lead to individual privacy being severely eroded.

This study addresses this important issue and provides a solution to resolve the conflict between privacy protection and data utility. We propose a data masking method for protecting private information against record linkage disclosure, while preserving the statistical properties of the data for legitimate analysis. Our method recursively partitions a dataset into smaller subsets such that data records within each subset are more homogeneous after each partition. The partition is made orthogonal to the maximum variance dimension represented by the first principal component in each partitioned set. The attribute values of a record in a subset are then masked using a double-bounded swapping method. The proposed method, which we call multivariate swapping trees, is nonparametric in nature and does not require any assumptions about statistical distributions of the original data. Experiments conducted on real-world datasets demonstrate that the proposed approach significantly outperforms existing methods in terms of both preventing identity disclosure and preserving data quality.

Li, Xiao-Bai and S. Sarkar. Protecting Privacy against Record Linkage Disclosure: A Bounded Swapping Approach for Numeric Data. *Information Systems Research*. Forthcoming.

5.1.5. Data Clustering and Micro-Perturbation for Privacy-Preserving Data Sharing and Analysis

Participants: Xiao-Bai Li and Sumit Sarkar

Clustering-based data masking approaches are widely used for privacy-preserving data sharing and data mining. Existing approaches, however, cannot cope with the situation where confidential attributes are categorical. For numeric data, these approaches are also unable to preserve important statistical properties such as variance and covariance of the data. We propose a new approach that handles these problems effectively. The proposed approach adopts a minimum spanning tree technique for clustering data and a micro-perturbation method for masking data. Our approach is novel in that it (i) incorporates an entropy-based measure, which represents the disclosure risk of the categorical confidential attribute, into the traditional distance measure used for clustering in an innovative way; and (ii) introduces the notion of cluster-level micro-perturbation (as opposed to conventional micro-aggregation) for masking data, to preserve the statistical properties of the data. We provide both analytical and empirical justification for the proposed methodology.

Awarded Second Runner-Up Award for the Best Conference Paper at the *International Conference on Information Systems*, Dec 2011

Li, Xiao-Bai and Sumit Sarkar. "Data Clustering and Micro-Perturbation with Confidential Class Restriction," *Management Science*, 796-812, **59** (4), April 2013 .

5.1.6. Digression and Value-Concatenation to Enable Privacy-Preserving Regression.

Participants: Xiao-Bai Li and Sumit Sarkar

Regression techniques can be used not only for legitimate data analysis, but also to infer private information about individuals. In this paper, we demonstrate that regression trees, a popular data-analysis and data-mining technique, can be used to effectively reveal individuals' sensitive data. This problem, which we call a "regression attack," has not been addressed in the data privacy literature, and existing privacy-preserving techniques are not appropriate in coping with this problem. We propose a new approach to counter regression attacks. To protect against privacy disclosure, our approach introduces a novel measure, called *digression*, which assesses the sensitive value disclosure risk in the process of building a regression tree model. Specifically, we develop an algorithm that uses the measure for pruning the tree to limit disclosure of sensitive data. We also propose a dynamic value-concatenation method for anonymizing data, which better preserves data utility than a user-defined generalization scheme commonly used in existing approaches. Our approach can be used for anonymizing both numeric and categorical data. An experimental study is conducted using real-world financial, economic and healthcare data. The results of the experiments demonstrate that the proposed approach is very effective in protecting data privacy while preserving data quality for research and analysis.

X. Li and S. Sarkar "Digression and Value-Concatenation to Enable Privacy-Preserving Regression," forthcoming in *MIS Quarterly*.

5.1.7. Managing Hot Lists in Intrusion Detection and Prevention Systems

Participants: Vijay Mookerjee, Radha Mookerjee, and Subodha Kumar

We study the problem of minimizing total cost for an Intrusion Detection and prevention Systems (IDPS). The IDPS system monitors the items that are possible courses of attacks. The objective of the monitoring problem is to minimize the sum of attack costs and the monitoring cost. The key tradeoff in our model is that as more items are monitored, the attack costs should reduce. However, the monitoring cost would likely increase with the number of items being monitored. We use a stochastic differential equation model to describe the dynamics of the monitoring process. A key step in solving the problem is to derive the probability density of a system with n items being monitored with specified elapsed times. Once this probability density is derived, we are able to determine the average attack rate from the hot-list. We next optimize the number of items being monitored by trading off the attack cost saved with the cost of monitoring.

Mookerjee, R., Kumar, S., and Mookerjee, V., "Managing Hot-Lists in Intrusion Detection and Prevention Systems," Conference on Information Systems and Technologies, 2013.

5.1.8. Optimal Information Security Investment under Uncertainty

Participants: Vijay Mookerjee, Monica, Johar and Jing Zhou

This paper presents a control theoretic model to manage a firm's information security level over time in a given planning horizon. Most of the previous literature on information security investment is based on a deterministic analysis, where the security level is managed as a function of the maintenance effort over a given time period. In reality, however, firms need to maintain information security in a situation where the efforts made to improve the security have a non-deterministic impact on the level security. We study the problem of determining the optimal amount of effort that should be exercised so as to minimize the expected total cost (cost of effort plus vulnerability cost) over a planning horizon. Our findings can help firms decide on how to manage IT security given the characteristics of the security environment and the efficiency of maintenance effort.

Johar, M., Zhou, J., Mookerjee, V. "*Optimal information Security Investment Under Uncertainty*," Conference on Information Systems and Technologies, 2014

5.1.9. Studying Dynamic Equilibrium of Cloud Computing Adoption with Application of Mean Field Games

Participants: Alain Bensoussan, Celine Hoe, Murat Kantarcioglu

Computing is undergoing a substantial shift from client/server to the cloud. The enthusiasm for cloud infrastructures is not only present in the business world, but also extends to government agencies. Managers of both segments thus need to have a clear view of how this new era will evolve in the coming years, in order to appropriately react to a changing economic and technological environment. In this study, we explore the dynamic equilibrium of cloud computing adoption through the application of Mean Field Games. In our formulation, each agent (i.e., each firm or government agency) arbitrates between "continuing to implement the traditional on-site computing paradigm" and "moving to adopt the cloud computing paradigm". To decide on his level of moving to the cloud computing paradigm, each agent will optimize a total cost that consists of two components: the effort cost of moving to the cloud computing paradigm and the adoption cost of implementing the cloud computing paradigm. In the formulation, the adoption cost is linked to the general trend of decisions on the computing paradigm adoption. Thus, an agent's optimal level of transition to the cloud computing paradigm is not only dependent on his own effort and adoption costs but also affected by the general trend of adoption decisions. The problem is solved by a system of partial differential equations (PDEs), that is, mean field games PDEs, which consists of a backward PDE, the Hamilton Jacobi Bellman equation for a controlled problem, and a forward Fokker-Planck equation transported by the optimal control from the backward HJB equation. Thus, the solution to the forward Fokker-Planck equation enables us to study the dynamic evolution of the density of the cloud computing adoption. It therefore allows us to investigate the impact of the general trend of technology adoption decisions on a firm's optimal decision of technology transition.

Bensoussan, A., S. Hoe and M. Kantarcioglu. Studying Dynamic Equilibrium of Cloud Computing Adoption with Application of Mean Field Games, *Proceedings of Fifty Annual Allerton Conference, 2012*.

5.1.10. A Game Theoretical Analysis of Lemonizing Cybercriminal Black Markets

Participants: Alain Bensoussan, Celine Hoe, Murat Kantarcioglu

It is known that cybercriminal black markets that trade in illicit digital goods and services belong to markets for lemons due to the information asymmetry of quality of goods and services between sellers and buyers. Based on the seminal work of Akerlof [1], Franklin et al. [3] suggests that “Lemonizing the Market” be an effective way to crack down the well-developed cybercriminal underground market. In our work, we provide a game theoretical framework to analyze whether cybercriminal black markets can be effectively lemonized. First, we investigate if signaling quality through an extra provision, such as the offer of trial periods or a money-back guarantee, observed in this marketplace (see the Panda security report [6]) provides cybercriminals selling real illicit data (i.e., the peach group) with a solution to address the lemon market problem. We also study the relation between the market lemonization and the cost constraint on seller’s implementation of signaling of quality. We find that, because of the effectiveness of resolving quality uncertainty through perfect signaling of quality, law enforcement cannot clamp down the operation of this underground economy through “Lemonizing the Market” by joining the group of “pure lemons”, that is, joining the group of sellers with no crime products offered to sell (i.e., rip-off sellers). If no information of quality is disclosed, the market demand shrinks increasingly as lemons in the market increases. However, to secure the market demand, cybercriminals with real illicit data for sale always attempt to implement quality signaling to single out their quality products, accepting a higher amount of cost constraints on applying quality signaling as the portion of lemons in the market escalates. Recognizing that lemonizing the market through magnifying the group of ripoff sellers could not effectively shut down these underground economic activities, we extend our model to consider that law enforcement: (1) joins the “peach group” to add “noisiness” to quality signals, and (2) takes advantage of transactions with buyers of crime products to locate these cybercriminals for arrest. To make quality signaling noisy, law enforcement produces quality fake data with the same extra provision, such as trial periods, offered by cybercriminals selling real illicit data to lure buyers; however, once the deal proceeds further, buyers get nothing. We call law enforcement playing “fake peaches” in this scenario. We find that the presence of “fake peaches” makes quality signaling imperfect, which in turn disincentives sellers’ use of quality signaling to secure demand for staying in business. When incorporating the possibility of arresting buyers of crime products, we find that the market demand decreases as a result of buyers’ fear of getting arrested, leading to declines in sellers’ profits. Therefore, playing “fake peaches” coupled with effectively tracing buyers for arrest is the most efficient way for law enforcement to make the signaling strategy ineffective for sellers of crime products, leading the market to resort to markets for lemons.

Bensoussan, A., S. Hoe and M. Kantarcioglu. A Game Theoretical Analysis of Lemonizing Cybercriminal Black Markets, *GamSec 2012, Jen Grossklags and Jean Warland (Eds)*.

5.1.11. Online Rating Games

Participants: Alain Bensoussan, Celine Hoe, Murat Kantarcioglu

Traditionally, consumer purchase decisions were based on advertisements or product information provided by vendors. With the proliferation of e-commerce and increasing number of Internet review forums, it has been found that consumers have increasingly relied on online reviews for their search of information related to a variety of products. Realizing that online reviews can be a powerful and cheap promotional tool, marketers and vendors have used this medium to reach their customers. Reports have shown that promotional chat has infiltrated the online review forums, and reviews manipulation is known to exist widely in popular websites related to e-commerce, travel, and music. Existing literature focuses on the detection of online manipulative reviews and the impact of online reviews on consumers' purchase decision. We extend the exploration to incorporate the discussion of (1) Can online sellers such as Amazon be incentivized to adopt appropriate tools to provide objective ratings, and if so, what is their optimal spending, and (2) How can manipulative ratings be discouraged and (3) What is the dynamic equilibrium of online rating environment with manipulation potential from the attacked and the preventive measures taken from the online sellers.

5.2. Activities in the Supply Chain Domain

In some inventory control contexts, such as vendor managed inventories, inventory with spoilage, misplacement, or theft, inventory levels may not always be observable to the decision makers. However, shortages, delayed inventory/demand observations are observable and are called signals. The signals provide partial information. We study such inventory control problems, where orders must be decided on the basis of partial information to minimize costs.

5.2.1. Inventory Control with a Cash Register: Sales Recorded but Not Demand or Shrinkage

Participants: Alain Bensoussan, Metin Çakanyildirim, Meng Li, Suresh Sethi

Inventory inaccuracy is common at retailers. At many retailers, a cash register records incoming orders and outgoing sales, but not the demand or the shrinkage. The shrinkage refers to spoilage or pilferage of inventory. The demand differs from the sales in the periodic-review lost-sales inventory model presented in this paper. The inventory is subject to an unobserved shrinkage which happens both before and after the demand. When the remaining inventory exceeds the

demand, the unmet demand is lost and unobserved. Our objective is to minimize the expected discounted cost related to inventory holding and shortage over an infinite horizon. We use dynamic programming along with the concept of unnormalized probability, and prove the existence of an optimal feedback policy and that the value function is the solution of the dynamic programming equation. We obtain a theoretical lower bound for the cost via the formulation of a fictitious inventory problem. We develop an iterative algorithm, and compare its solution to a myopic solution and a lower bound. We identify many cases of parameter values for which the solution of the iterative algorithm performs significantly better than the myopic solution. Moreover, the achieved cost is close to the lower bound.

Bensoussan, A., Çakanyildirim, M., Li, M and Sethi, S.P. Existence and Uniqueness of Solutions for a Partially Observed Stochastic Control Problem, in *Stochastic Processes, Finance and Control*, A Festschrift in honor Of Robert J. Elliot, Samuel N. Cohen, Dilip Madan, Tak Kuen Siu and Hailiang Yang, (Eds.) World Scientific, 2012 393-43

Bensoussan, A., Çakanyildirim, M., Li, M and Sethi, S.P., “Optimal Inventory Control with Shrinkage and Observed Sales,” *Stochastics: An International Journal of Probability & Stochastic Processes*, Taksar Memorial Issue, 2013, 85(4), 589-603

Bensoussan, A., Çakanyildirim, M., Li, M and Sethi, S.P. “Managing Inventory with Cash Register Information: Sales Recorded but Not Demands,” *Production and Operations Management*, August 2014.

5.2.2. “An Analysis of Trust, Employee Trustworthiness, Fraud, and Internal Controls”

Participants: Sanjay Kumar, Ashutosh Deshmukh, Kathryn Stecke and Jiangxia Liu

We analyze important strategic relationships among trust, employee trustworthiness, fraud, and internal controls. A game is modeled between a manager and an employee, two rational decision makers. The manager makes control decisions based on the strength of controls and on employee trustworthiness, which are modeled as functions of monetary and psychic costs and benefits of committing and not committing fraud. We propose a rich definition of trustworthiness that incorporates an employee’s propensity to commit fraud and sensitivity to controls. Equilibrium strategies are identified that could be used to determine the best strategy and the optimum strength of controls to use by identifying trustworthy, untrustworthy, and opportunistically trustworthy employees.

A relationship of trustworthiness with a probabilistic choice of controls by the manager is established. As the strength of controls increases, the trustworthiness of the employees also increases, but a minimum critical level of trustworthiness is required to make controls effective. A high level of control may be needed to deter fraud. Also, this increase in trustworthiness does not translate to a proportional reduction of controls by the manager. We caution against excessive investments in internal controls. A low strength control with high probability of

controls may be a cost effective way to deter fraud. We also explore the interaction of controls strength with the losses to the manager when fraud is committed. We find that control is not always a viable strategy. Optimal payoffs indicate that, unlike simultaneous decision making, under sequential decision making, the manager's best strategy is to choose controls and auditing an employee. Policy implications and managerial insights of these findings are discussed.

“An Analysis of Trust, Employee Trustworthiness, Fraud and Internal Controls,” K. Strecke, Sanjay Kumar, Ashutosh Deshmukh and Jiangzia Liu, *International Journal of Strategic Decision Sciences*, Vol 4, No. 3, pp 66-89 (2013)

5.2.3 In-Season Transshipments Among Competitive Retailers

Participants: Nagihan Çömez, Kathryn E. Stecke, Metin Çakanyıldırım

A decentralized system of competing retailers that order and sell the same product in a sales season is studied. When a customer demand occurs at a stocked-out retailer, that retailer requests a unit to be transshipped from another retailer who charges a transshipment price. If this request is rejected, the unsatisfied customer may go to another retailer with a customer overflow probability. Each retailer decides on the initial order quantity from a manufacturer and on the acceptance/rejection of each transshipment request. For two retailers, we show that retailers' optimal transshipment policies are dynamic and characterized by chronologically nonincreasing inventory holdback levels. We analytically study the sensitivity of holdback levels to explain interesting findings, such as smaller retailers and geographically distant retailers benefit more from transshipments. Numerical experiments show that retailers substantially benefit from using optimal transshipment policies compared to no sharing. The expected sales increase in all but a handful of over 3,000 problem instances. Building on the two-retailer optimal policies, we suggest an effective heuristic transshipment policy for a multiretailer system.

“In-Season Transshipments Among Competitive Retailers, *MSOM*, Nagihan Çömez, Kathryn E. Stecke, Metin Çakanyıldırım

5.2.4 Optimal Transshipments and Reassignments Under Periodic or Cyclic Holding Cost Accounting

Participants: K. Strecke, Nagihan Çömez, me, and Metin Çakanyıldırım

In a centrally-managed system, available inventory at a retailer can be transshipped to a stocked-out retailer to meet customer demand. On the other hand, since the inventory at the former retailer may be in demand for future customers of that retailer and transshipment time/cost is non-negligible, it can be more profitable to not transship. An optimal transshipment policy suggests transshipping in some situations, but not always. Unsatisfied customer demand can be backordered. As demand uncertainty resolves over time, the cost trade-off between backordering at the stocked-out retailer and holding inventory at the other retailer changes. Hence reassignment of inventory to a previously backordered demand can perhaps become profitable.

Despite this intuition, we prove that *no reassignments* are necessary for cost optimality under periodic holding cost accounting. On the contrary, reassignments are necessary for optimality when holding costs are accounted for only at the end of each cycle. However they save costs not significantly. These results facilitate efficient optimization of transshipments over time.

“Optimal Transshipments and Reassignments Under Periodic or Cyclic Holding Cost Accounting,” Nagihan Çömez, Kathryn E. Stecke and Metin Metin Çakanyildirim, *Journal of the Operational Research Society*, Vol 64, Issue 10, pp1517-1539 (October 2013)

5.2.5. Analysis of Product Rollover Strategies in the Presence of Strategic Customers

Participants: Metin Çakanyildirim, Suresh Sethi and Chao Liang

Frequent product introductions emphasize the importance of product rollover strategies. With single rollover, when a new product is introduced, the old product is phased out from the market. With dual rollover, the old product remains in the market along with the new product. Anticipating the introduction of the new product and the potential markdown of the old product, strategic customers may delay their purchases. We study the interaction between product rollover strategies and strategic customer purchasing behavior, and find that single rollover is more valuable when the new product's innovation is low and the number of strategic customers is high. Interestingly and counter to intuition, the firm may have to charge a lower price for the old product as well as receive a lower profit with a higher value disposal (outside) option for the old product under single rollover. Facing a market composed of both strategic and myopic customers, the firm does not necessarily reduce the stocking level as more myopic customers become strategic.

Çakanyildirim, M., Liang, C., and Sethi, S.P., “Analysis of Product Rollover Strategies in the Presence of Strategic Customers,” *Management Science*, 2014, 60(4), 1033-1056.

5.2.6. Impact of Strategic Customer Behavior and Rollover Strategies on Product Innovation

Participants: Metin Çakanyildirim, Suresh Sethi and Chao Liang

We study a monopolistic firm which introduces two product versions sequentially in two periods. We analyze and compare the firm's decisions of the innovation level of the new version, the production quantities and prices of both versions, and the associated profit in four settings: when the customers are myopic or strategic in period 1 and whether the leftover inventory of the old version is phased out from the market (single rollover strategy) or is sold in the market (dual rollover strategy). In period 2, newcomers who wish to buy the new version arrive in the market. We show that the firm can improve both its profit and its innovation level by adopting an appropriate rollover strategy when selling to strategic customers. This finding underscores

the importance of choosing a rollover strategy. Interestingly and differently from the existing literature, we see that strategic waiting behavior can accelerate innovation. These insights remain largely valid when some of the customers who cannot get the old version due to a stockout leave the market before the new version arrives, or when some of the newcomers are interested in the new version as well as the leftover old version.

Submitted:

Çakanyildirim, M., Liang, C., and Sethi, S.P., “Impact of Strategic Customer Behavior and Rollover Strategies on Product Innovation

5.2.7. A New Choice Model Based on Willingness to Pay: Empirical Validation & Pricing Applications

Participants: Metin Çakanyildirim, Varun Gupta

Customers’ Willingness To Pay (WTP) plays an anchoring role in determining prices. This paper proposes a new choice model based on WTP, incorporating a sequential process of making choices, where the products with positive utility of purchase are considered in the order of customer preference. We philosophically and analytically compare WTP-choice model with the commonly used (multi-choice) Logit model. We consider real-life data on sales of yogurt, ketchup, candy melt, and tuna, and simulated data, and check if a version of WTP-choice model (with uniform, triangle or shifted exponential WTP distribution) or Logit model fits better. These empirical tests establish that WTP-choice model compares well and should be considered as a legitimate alternative of Logit model. Using WTP-choice model in a duopoly, we obtain equilibrium prices in several contexts: without considering inventory, with lost sales, with backorders for “retailer favoring” customers or for “availability favoring” customers. One of the interesting results with WTP-choice model is the “loose coupling” of retailers; prices are not coupled but profits are. That is, each retailer should charge monopoly prices in the duopoly as these constitute the equilibrium but each retailer’s profit depends on both retailers’ prices. We also discuss three extensions of WTP-choice model that lead to coupling of the prices.

5.2.8 Two-Stage Pricing for Custom-Made Products

Participants: Ernan Haruvy, Tao Li, and Suresh P. Sethi

A commonly observed two-stage pricing strategy for a custom-made product involves a pre-purchase entry fee for a potential consumer and a purchase price if he decides to buy the product. We solve and compare two settings: In the first, the firm does not commit in advance to the second-stage price and in the second, the firm does. We show that without a commitment mechanism, the two price points are strategic complements, in that the higher pre-product fee implies a higher post-product price. With commitment, the two price points are strategic substitutes and the firm can improve profit over the no-commitment case by

offering a low purchase price in the second stage and extracting the surplus through an entry fee. When the production cost is sufficiently low, the commitment solution benefits both the firm and the consumer.

Haruvy, E., Li, T., and Sethi, S.P., “Two-Stage Pricing for Custom-Made Products,” *European Journal of Operational Research*, 2012, 219 (2) 405-414.

5.2.9. Inventory Commitment and Prioritized Backlogging Clearance with Alternative Delivery Lead Times

Participants: Haifeng Wang, Xiaoying Liang, Suresh P. Sethi, and Houmin Yan

We propose a model where customers are classified into two groups: short lead-time customers who require the product immediately and long lead-time customers to whom the supplier may deliver either immediately or in the next cycle. Unmet orders are backlogged with associated costs. Specifically, the supplier faces two problems: how the on-hand inventories should be allocated between the two classes of customers and how the backlogged orders should be cleared when replenishments arrive. We treat the former as an inventory commitment problem and handle the latter with priority rules. We characterize and compare the inventory commitment policies with three priority rules in clearing backlogs. We also explore the optimal inventory replenishment decision and evaluate the performance of each priority rule.

Wang, H., Liang, X., Sethi, S.P., and Yan, H., “Inventory Commitment and Prioritized Backlogging Clearance with Alternative Delivery Lead Times,” *Production and Operations Management*, 2014, 23(7), 1227-1242.

5.2.10. How Does Pricing Power Affect a Firm's Sourcing Decisions from Unreliable Suppliers?

Participants: Tao Li, Suresh P. Sethi, and Jun Zhang

We study sourcing decisions of price-setting and price-taking firms with two unreliable suppliers, where a price-setting firm sets the retail price after the supply uncertainty is resolved and a price-taking firm takes the retail price as given. We investigate the impacts of market conditions, suppliers' wholesale prices and their reliabilities on the optimal sourcing decisions of price-setting and price-taking firms, and examine how a firm's pricing power affects these impacts. We define a supplier's reliability in terms of the “size” or the “variability” of his random capacity using the concepts of stochastic dominance. We find that the supplier reliability affects the optimal sourcing decisions differently for price-setting and

price-taking firms. Specifically, with a price-setting firm, a supplier can win a larger order by increasing his reliability, it is not always so with a price-taking firm.

Li, T. Sethi, S.P. and Zhang, J., "How Does Pricing Power Affect a Firm's Sourcing Decisions from Unreliable Suppliers?" *International Journal of Production Research*, 51(23-24), 2013, 6990-7005.

5.2.11. Inventory Sharing with Transshipment: Impacts of Demand Distribution Shapes and Setup Costs

Participants: Chao Liang, Suresh P. Sethi, Ruixia Shi, and Jun Zhang

We compare site-to-store and store-to-site strategies for dual-channel integration. The site-to-store (resp., store-to-site) strategy can fill unmet orders in the physical channel (resp., online channel) with the inventory in the online channel (resp., physical channel). With one (physical) retail store, when only one channel should have inventory, it is the channel with stochastically larger or less uncertain demand. Otherwise, with both channels carrying inventory, the optimal channel integration depends on product contribution margin and channel demand distribution shape. When there are multiple retail stores, the site-to-store (resp., store-to-site) strategy becomes more attractive for high-margin (resp., low-margin) products with larger number of retail stores. We propose a heuristic that only requires a comparison of online demand standard deviation and the sum of demand standard deviations of retail stores in identifying an effective integration strategy. Finally, we apply our results to a circular spatial model for dual-channel retailing systems and obtain insights on the impact of customer purchasing behavior on strategy selection.

Liang, C., Sethi, S.P., Shi, R., and Zhang, J., "Inventory Sharing with Transshipment: Impacts of Demand Distribution Shapes and Setup Costs," *Production and Operations Management*, 2013.

5.2.12. Managing with Incomplete Inventory Information (i3)

Participants: Suresh P. Sethi and Ruixia Shi

A critical assumption in the vast literature on inventory management has been that the current level of inventory is known to the decision maker. Some of the most celebrated results such as the optimality of base-stock policies have been obtained under this assumption. Yet it is often the case in practice that the decision makers have incomplete or partial information about their inventory levels. The reasons for this are many: Inventory records or cash register information differ from actual inventory because of a variety of factors including transaction errors, theft, spoilage, misplacement, unobserved lost demands, and information delays. As a result, what are usually observed are some events or surrogate measures, called signals, related to the

inventory level. These relationships can provide the distribution of current inventory levels. Therefore, the system state in the inventory control problems is not the current inventory level, but rather its distribution given the observed signals. Thus, the analysis for finding optimal production or ordering policies takes place generally in the space of probability distributions. The purpose of this paper is to review some recent developments in the analysis of inventory management problems with incomplete information.

Sethi, S.P. and Shi, R, “Managing with Incomplete Inventory Information (i3),” *Proceedings of the 7th IFAC Conference on Manufacturing, Modeling, Management and Control (MIM 2013)*, Saint Petersburg, Russia, June 19-21, 2013, 1-6.

5.2.13. Supply Diversification with Responsive Pricing

Participants: Tao Li, Suresh P. Sethi, and Jun Zhang

We study sourcing and pricing decisions of a firm with correlated suppliers and a price-dependent demand. With two suppliers, the insight—cost is the order qualifier while reliability is the order winner—derived in the literature for the case of exogenously determined price and independent suppliers, continues to hold when the suppliers’ capacities are correlated. Moreover, a firm orders only from one supplier if the effective purchase cost from him, which includes the imputed cost of his unreliability, is lower than the wholesale price charged by his rival. Otherwise, the firm orders from both. Furthermore, the firm’s diversification decision does not depend on the correlation between the two suppliers’ random capacities. However, its order quantities do depend on the capacity correlation, and, if the firm’s objective function is unimodal, the total order quantity decreases as the capacity correlation increases in the sense of the super modular order. With more than two suppliers, the insight no longer holds. That is, when ordering from two or more suppliers, one is the lowest-cost supplier and the others are not selected on the basis of their costs. We conclude the paper by developing a solution algorithm for the firm’s optimal diversification problem.

Li, T. Sethi, S.P. and Zhang, J., “Supply Diversification with Responsive Pricing,” *Production and Operations Management*, 22(2) 2013, 447-458

5.2.14. Evaluating Long-Term Service Performance under Short-Term Forecast Updates

Participants: Alain Bensoussan, Qi Feng, and Suresh P. Sethi

Managing customer satisfaction in a cost effective way has always been a major challenge faced by inventory managers. We study the problem of a newsvendor selling a perishable product with short-term demand patterns and a long-term service target. The newsvendor determines his long-term order at the first stage, and revises the order according to a short-

term forecast update at the second stage. He also evaluates a long-term service target for his overall performance across all possible forecast updates. We characterize his optimal inventory policy that minimizes the expected inventory cost such that the long-term service target is met. Both in-stock rate and fill rate targets are examined.

Bensoussan, A., Feng, Q., and Sethi, S.P., "Evaluating Long-Term Service Performance under Short-Term Forecast Updates," *Proceedings of the 14th IFAC Symposium on Information Control Problems in Manufacturing*, Bucharest, Romania, May 23-25, 2012, CD, paper #84.

5.2.15. Contracting and Coordination under Asymmetric Production Cost Information

Participants: Metin Cakanyildirim, Qi Feng, Xianghua Gan, and Suresh P. Sethi

We analyze a supply chain consisting of a supplier and a retailer. The supplier's unit production cost, which characterizes his type, is only privately known to him. When trading with the retailer, the supplier demands a reservation profit that depends on his unit production cost. We model this problem as a game of adverse selection. In this model, the retailer offers a menu of contracts, each of which consists of two parameters: the ordering quantity and the supplier's share of the channel profit. We show that the optimal contract depends critically on a surrogate measure—the ratio of the types' reservation profit differential to their production cost differential. An important implication from our analysis is that information asymmetry alone does not necessarily induce loss in channel efficiency. The optimal contract can coordinate the supply chain as long as the low-cost supplier's cost efficiency is neither much overvalued nor much undervalued in the outside market. We further discuss the retailer's preference of the supplier's type under different market conditions, as well as evaluate the effects of the supplier's reservation profit, the retail price, and the demand uncertainty on the optimal contract.

Cakanyildirim, M., Feng, Q., Gan, X., and Sethi, S.P., "Contracting and Coordination under Asymmetric Production Cost Information," *Production and Operations Management*, 21(2), 2012, 345–360.

5.2.16. Impulse Control with Random Reaction Periods: A Central Bank Intervention Problem

Participants: Alain Bensoussan, Hongwei Long, Sandun Perera, and Suresh P. Sethi

We model an impulse control problem when the controller's action affects the state as well as the dynamics of the state process for a random amount of time. We apply our model to solve a central bank intervention problem in the foreign exchange market when the market observes and reacts to the bank's interventions.

Bensoussan, A., Long, H., Perera, S., and Sethi, S.P., "Impulse Control with Random Reaction Periods: A Central Bank Intervention Problem," *Operations Research Letters*, 40, 2012, 425-

430; This paper under the title “Market-Reaction-Adjusted Optimal Central Bank Intervention Policy in a Foreign Exchange Market,” Second Place, INFORMS Financial Services Section Best Student Research Paper Award, 2012.

5.2.17. Feedback Stackelberg Solutions of Infinite-Horizon Stochastic Differential Games

Participants: Alain Bensoussan, Shaokuan Chen, and Suresh P. Sethi

We present a sufficient condition for a feedback Stackelberg equilibrium of a stochastic differential game on an infinite horizon. This condition gives rise to a system of elliptic partial differential equations involving a static Stackelberg game at the level of Hamiltonian. As an example, we consider a linear quadratic problem, obtain the corresponding algebraic Riccati equation, and provide its solution in the scalar case.

Bensoussan, A., Chen, S., and Sethi, S.P., “Feedback Stackelberg Solutions of Infinite-Horizon Stochastic Differential Games,” *Models and Methods in Economics and Management Sciences, Essays in Honor of Charles S. Tapiero*, Fouad El Ouardighi and Konstantin Kogan (Eds.), Series 6161, Vol. 198 Springer International Publishing Switzerland, 2014, 3-15..

5.2.18. New Results on the Newsvendor Model and the Multi-Period Inventory Model with Backordering

Participants: G. Janakiraman, S. Park, S. Seshadro and Q. Wu

We analyze the newsvendor model and the multi-period inventory model, and provide some new results. For the newsvendor model, the best case newsvendor cost over all demand distributions with a given demand mean and variance is zero. In addition, under symmetric demand distributions, the newsvendor’s costs remain the same when the holding and shortage costs are switched. For the multi-period inventory model with stochastic lead times, a dilation ordering of lead times implies an ordering of optimal costs.

G. Janakiraman, S. Park, S. Seshadro and Q. Wu, New Results on the Newsvendor Model and the Multi-Period Inventory Model with Backordering, *Operations Research Letters*. 2013 41: 4: 373-376

5.2.19. Integrality in Stochastic Inventory Models

Participants: W.Chen, M. Dawande and G. Janakiraman

We study several dynamic, stochastic inventory control models with integer demands: the newsvendor model, its multi-period extension and a single-product, multi-echelon assembly model. Equivalent linear programs are formulated for the corresponding stochastic dynamic programs, and integrality results are derived based on the total unimodularity of the constraint matrices. Specifically, for all these models, starting with integer inventory levels, we show that there exist optimal policies that are integral. For the most general single product, multi-echelon assembly system model, integrality results are also derived for a practical alternative to stochastic dynamic programming, namely rolling-horizon optimization by a similar argument. We also present a different approach to prove integrality results for stochastic inventory models. This new approach is based on a generalization we propose for the one dimensional notion of piecewise linearity with integer breakpoints to higher dimensions. The usefulness of this new approach is illustrated by establishing the integrality of both the dynamic programming and rolling-horizon optimization models of a two-product capacitated stochastic inventory control system.

W. Chen, M. Dawande and G. Janakiraman 2014 Integrality in Stochastic inventory Models. (Forthcoming in POMS)

5.2.20. Analysis of Tailored Base-Surge Policies in Dual Sourcing Inventory Systems

Participants: G. Janakiraman, S. Seshadri and A. Sheopuri

We study a model of a firm managing its inventory of a single product by sourcing supplies from two supply sources, a regular supplier who offers a lower unit cost and a longer lead time than a second, emergency, supplier. A practically implementable policy for such a firm is a Tailored Base-Surge (TBS) Policy (Allon and van Mieghem, 2010) to manage its inventory: Under this policy, the firm procures a constant quantity from the regular supplier in every period and dynamically makes procurement decisions for the emergency supplier. Allon and Van Mieghem describe this practice as using the regular supplier to meet a base level of demand and the emergency supplier to manage demand surges, and they conjecture that this practice is most effective when the lead time difference between the two suppliers is large. We confirm these statements in two ways. First, we show the following analytical result: When demand is composed of a base demand random component plus a surge demand random component, which occurs with a certain small probability, the best TBS Policy is close to optimal (over all policies) in a well-defined sense. Second, we also numerically investigate the cost-effectiveness of the best TBS policy on a test bed of problem instances. The emphasis of this investigation is the study of the effect of the lead time difference between the two suppliers. Our study reveals that the cost difference between the best TBS policy and the optimal policy decreases dramatically as the lead time of the regular supplier increases. On our test bed, this cost difference decreases from an average (over the test bed) of 21 % when the lead time from the regular supplier is two

periods (the emergency supplier offers instant delivery) to 3.5 % when that lead time is seven periods.

G. Janakiraman, S. Seshadri and A. Sheopuri, Analysis of Tailored Base-Surge Policies in Dual Sourcing Inventory Systems. (Forthcoming in Management Science)

5.2.21. Robustness of Order-up-to Policies in Lost-Sales Inventory Systems

Participants: M. Bijvank, W.T. Huh, G. Janakiraman and W. Kang

We study an inventory system under periodic review when excess demand is lost. It is known [Huh et al., 2009] that the best base-stock policy is asymptotically optimal as the lost-sales penalty cost parameter grows. We now show that this result is robust in the following sense: Consider the base-stock level which is optimal in a backordering system (with a per-unit-per-period backordering cost) in which the backorder cost parameter is a function of the lost-sales parameter in the original system. Then, there is a large family of functions (mapping the lost-sales cost parameter to the backorder cost parameter) such that the resulting base-stock policy is asymptotically optimal. We also demonstrate the robustness phenomenon through a second result. We consider the base-stock level which is optimal in a backordering system in which a unit of backorder is charged a penalty cost only once (such a system has been studied by Rosling [2002]). More specifically, Archibald [1981] proposes to subtract the expected number of backorders from the best base-stock level when this per-unit backorder cost equals the lost-sales penalty cost as a heuristic to set the base-stock level in a lost-sales inventory system. This approach has not been studied in the literature. We prove that the asymptotic optimality result is also preserved for this base-stock policy. In particular, we numerically test the performance of this heuristic policy for a wide spectrum of values for the lost-sales penalty cost parameter and illustrate its superior performance.

M. Bijvank, W.T. Huh and G. Janakiraman and W. Kang, Robustness of Order-up-to Policies in Lost-Sales Inventory Systems (Forthcoming in *Operations Research*)

5.2.22. Fixed-Dimensional Stochastic Dynamic Programs:

Participants: W. Chen, M. Dawande and G. Janakiraman

We study fixed-dimensional stochastic dynamic programs in a discrete setting over a finite horizon. Under the primary assumption that the cost-to-go functions are discrete L -convex, we propose a pseudo-polynomial time approximation scheme that solves this problem to within an arbitrary pre-specified additive error of $\varepsilon > 0$. The proposed approximation algorithm is a generalization of the explicit-enumeration algorithm and offers us full control in the tradeoff between accuracy and running time. The main technique we develop for obtaining our scheme is

approximation of a fixed-dimensional L -natural-convex function on a bounded rectangular set, using only a selected number of points in its domain. Furthermore, we prove that the approximation function preserves L^q -convexity. Finally, to apply the approximate functions in a dynamic program, we bound the error propagation of the approximation. Our approximation scheme is illustrated on a well-known problem in inventory theory, namely the single-product problem with lost sales and lead times (Morton 1969, Zipkin 2008b). We demonstrate the practical value of our scheme by implementing our approximation scheme and the explicit-enumeration algorithm on instances of this inventory problem.

W. Chen, M. Dawande and G. Janakiraman, Fixed-Dimensional Stochastic Dynamic Programs: An Approximation Scheme and Inventory Applications, *Operations Research*, 2014, **62**, (I), 81-103.

5.2.23. Capacitated Serial Inventory Systems: Bounds for Simple Policies

Participants: W. T. Huh, G. Janakiraman, M. Nagarajan

We study the following prototypical model of a large scale supply chain: A periodically reviewed multi-echelon serial inventory system with a capacity constraint on the order quantity at every stage. Our goal is to find policies that minimize the sum of the expected long run average holding and shortage costs for this system. It is well known that for this problem, characterizing the structure of the optimal policy and computing it are very difficult. This problem is a generalization of two well-understood and fundamental building blocks in inventory theory, namely the one of managing uncapacitated multi-echelon serial systems and that of managing capacitated single location inventory systems. We consider the use of echelon basestock policies for our system (even though they are known to be sub-optimal) and propose algorithms for finding base-stock levels. Our algorithms are based on integrating existing optimal or near-optimal algorithms for the two building blocks and therefore easy to understand and implement (in fact, two of our three algorithms only involve newsvendor computations). We derive bounds on the ratios between the costs achieved by our algorithms and the optimal costs (over all policies). Our algorithms are shown to be asymptotically optimal in the sense that our bounds are close to one in high service-level environments. Next, we perform a computational investigation of the performance of our algorithms on a sample bed of problem instances in which the service levels range from modestly high (67%) to very high (99%). On each problem instance, we evaluate the costs of our algorithms and compare them with the cost of the best base-stock policy and with a lower bound on the optimal cost. The best of our algorithms achieves a cost which is only 1.7% more, on an average, than the cost of the best base-stock policy. Further, our computational investigation reveals that the cost of the best base-stock policy is, on an average, no more than 0.6% higher than a lower bound on the optimal cost. This seems to confirm that base-stock policies are effective (even though sub-optimal, in general) for managing capacitated serial inventory systems. Finally, the development of our algorithms is robust in that they can immediately exploit advances made by researchers in the computations of polices for the two building blocks to provide heuristics for serial capacitated inventory systems.

W.T. Huh, G. Janakiraman and M. Nagarajan, Capacitated Serial Inventory Systems: Bounds for Simple Policies (Under revision for resubmission to *MSOM* by Fall 2014.)

5.2.24. Generalized Reverse-Japanese Auctions: Simple and Optimal Mechanisms for Procurement under Operational Constraints

Participants: W. Chen, M. Dawande, S. Gupta and G. Janakiraman,

In this paper, we examine a class of auction mechanisms – Generalized Reverse Japanese (GRJ) auctions – for e-Procurement. GRJ auctions are endowed with the attractive property of simplicity from the viewpoint of suppliers: They find the rules of the auction easy to understand and are also able to trivially identify their bidding strategies. We are interested in the following question: For which procurement problems that incorporate commonly-occurring operational constraints is a suitably-defined GRJ auction an optimal mechanism (i.e., minimizes the buyer’s expected cost)? We answer this question in the affirmative for three problems.

W. Chen, M. Dawande, S. Gupta and G. Janakiraman, Generalized Reverse-Japanese Auctions: Simple and Optimal Mechanisms for Procurement under Operational Constraints (Under revision for resubmission to *POMS* in Fall 2014)

5.2.25 Optimal Procurement Auction under Multi-Stage Supplier Qualification

Participants: W. Chen, M. Dawande, and G. Janakiraman,

A firm is soliciting bids from a fixed-size pool of yet-to-be-qualified suppliers for an indivisible sourcing contract. The contract can only be awarded to a supplier who passes a multi-stage qualification process. For each stage of qualification, the buyer selects a subset of those suppliers who have passed all previous stages and tests them simultaneously. In each stage, the buyer incurs a fixed testing cost for each supplier she chooses to test in that stage; these fixed costs differ across stages. The buyer seeks an optimal mechanism, i.e., one that minimizes her total expected procurement cost, which consists of the qualification cost and the procurement cost. Our main results are optimal mechanisms (auctions) for (i) a symmetric setting, where the suppliers’

private costs are realized from the same distribution and the passing probability in a stage is the same for the suppliers admitted to that stage, and (ii) an asymmetric setting, where there are two different pools of suppliers – new and mature – that differ both in their costs and passing probabilities. In particular, we show that the optimal admission policy for supplier selection in each stage is based on non-uniform reserve prices. We also present supplier-friendly descending implementations of our optimal auctions. Technically, the novelty of our approach for deriving the optimal mechanisms lies in three steps: (i) reduction of the mechanism design problems to equivalent stochastic DPs that capture the dynamic supplier-qualification process and involve

set-based decisions, (ii) conversion of set-based decisions into cardinality-based decisions to reduce the feasible action space, and (iii) exploitation of special structural properties of these DPs; e.g., convexity of the cost-to-go functions, and monotonicity and special relationships in other associated functions, and establishing their preservation through the DP recursion.

W. Chen, M. Dawande, and G. Janakiraman, Optimal Procurement Auction under Multi-Stage Supplier Qualification (under review in Operations Research)

5.2.26 A Note on Integrality in Deterministic and Stochastic Inventory Models

Participants: Y. Bo, M. Dawande, G. Janakiraman and T. McCormick

The integrality question for dynamic optimization models of inventory control asks if there exists an integral optimal policy, given integral initial inventory levels, capacities and demand realizations. One practical implication of this question lies in whether or not full-truckload shipping is optimal if customer demand is in integral number of truckloads. For single-product, deterministic- and stochastic-demand problems in multi-echelon assembly systems, the answer to the integrality question is yes (Chen et al. 2013), thus implying the optimality of Full-Truckload shipping. In this note, we show the following for single-product, multi-echelon distribution systems: Integrality holds under deterministic demands, but fails to hold under stochastic demands. In distribution systems with stochastic demands, Less-Than-Truckload shipping can be significantly cheaper than the cost of the optimal Full-Truckload shipping solution, even in the presence of economies of scale. This statement continues to hold even if we impose the additional restriction that the shipments from the retail locations to the customers be in full truckloads. The same result holds for assembly- distribution networks, in which assembly is followed by distribution. For distribution-assembly networks, in which distribution is followed by assembly, integrality can fail even with deterministic demands.

Y. Bo, M. Dawande, G. Janakiraman and T. McCormick, A Note on Integrality in Deterministic and Stochastic Inventory Models (under review in Operations Research)

5.2.27 Managing Nonperishable Inventories with Learning on Stock-out Times

Participants: A. Bensoussan and Pengfei Guo

We consider the dynamic inventory management of nonperishable products with a Poisson demand process and learning on the demand rate through past sales. We consider three information scenarios on past sales: no, partial and full. The no- and full-information scenarios represent, respectively, unobservable and observable lost sales cases. The partial information represents the case where lost sales are unobservable whereas the stock-out times are observable. We show that system performance is always improved with more information and the optimal

decision under partial information is larger than the one under full information. Our results generalize the past literature on Bayesian inventory management into richer information scenarios and provide a parsimonious information updating device for solving other Bayesian inventory management problems.

Technical Note: Managing Nonperishable Inventories with Learning about Demand Arrival Rate through Stock-Out Times, A. Bensoussan, Pengfei Guo *Submitted to Operations Research*

5.2.28. Competing on Time: An Integrated Framework to Optimize Dynamic Time-to-Market and Production Decisions.

Participants: Özer, Ö and O. Uncu

This study develops a comprehensive framework to optimize new product introduction timing and subsequent production decisions faced by a component supplier. Prior to market entry, the supplier performs process design activities, which improve manufacturing yield and the chances of getting qualified for the customer's product. However, a long delay in market entry allows competitors to enter the market and pass the customer's qualification process before the supplier, reducing the supplier's share of the customer's business. After entering the market and if qualified, the supplier also needs to decide how much to produce for a finite planning horizon by considering several factors such as manufacturing yield and stochastic demand, both of which depend on the earlier time-to-market decision. To capture this dependency, we develop a sequential, nested, two-stage decision framework to optimize the time-to-market and production decisions in relation to each other. We show that the supplier's optimal market entry and qualification timing decision need to be revised in real time based on the number of qualified competitors at the time of market-entry decision. We establish the optimality of a threshold policy. Following this policy, at the beginning of each decision epoch, the supplier should optimally stop preparing for qualification and decide whether to enter the market if her order among qualified competitors exceeds a predetermined threshold. We also prove that the supplier's optimal production policy is a state-dependent, base-stock policy, which depends on the time-to-market and qualification decisions. The proposed framework also enables a firm to quantify how market conditions (such as price and competitor entry behavior) and operating conditions (such as the rate of learning and inventory/production-related costs) affect time-to-market strategy and post-entry production decisions

Özer, Ö and O. Uncu. Competing on Time: An Integrated Framework to Optimize Dynamic Time-to-Market and Production Decisions. *Production and Operations Management* 22(3) pp. 473-488, 2013.

5.2.29. Mechanism Design for Capacity Planning under Dynamic Evolutions of Asymmetric Demand Forecasts

Participants: OH, S. and Ö. Özer.

This paper investigates the role of time in forecast information sharing and decision making under uncertainty. To do so, we provide a general framework to model the evolutions of forecasts generated by multiple decision makers who forecast demand for the same product. We also model the evolutions of forecasts when decision makers have asymmetric demand information and refer to it as the Martingale Model of Asymmetric Forecast Evolutions. This model helps us study mechanism design problems in a dynamic environment. In particular, we consider a supplier's (principal's) problem of eliciting credible forecast information from a manufacturer (agent) when both firms obtain a symmetric demand information for the end product over multiple periods.

The supplier uses demand information to better plan for a capacity investment decision. When the supplier postpones building capacity and screening the manufacturer's private information, the supplier and the manufacturer can obtain more information and update their forecasts. This delay, however, may increase (respectively, decrease) the degree of information asymmetry between the two firms, resulting in a higher (respectively, lower) cost of screening. The capacity building cost may also increase because of a tighter deadline for building capacity. Considering all such trade-offs, the supplier has to determine (i) when to stop obtaining new demand information and build capacity, (ii) whether to offer a screening contract to credibly elicit private forecast information or to determine the capacity level without information sharing, (iii) how much capacity to build, and (iv) how to design the overall mechanism so that both firms benefit from this mechanism. This paper provides an answer to these questions. In doing so, we develop a new solution approach for a class of dynamic mechanism design problems. In addition, this paper provides a framework to quantify the option value of time for a strategic investment decision under the dynamic evolutions of asymmetric forecasts.

Oh, S. and Ö. Özer. *Mechanism Design for Capacity Planning under Dynamic Evolutions of Asymmetric Demand Forecasts.*, Management Science, **59(4)** pp. 987-1007, 2013.

5.2.30 All You Need is Trust? An Examination of Interorganizational Supply Chain Projects

Participants: Brinkhoff, A., Ö. Özer., Sargut G.

This study examines the antecedents of supply chain project success. We first propose and test a model that describes the roles relationship-level factors (trust and asymmetric dependence) and project-level factors (between-firm communication and within-firm commitment) in determining supply chain project success. We find that project-level factors completely mediate the effect of trust on project success. We conclude that trust, despite being a stronger predictor compared to asymmetric dependence, is necessary but not sufficient for supply chain project success. We

then proceed to further explore the role of these factors by introducing a categorical scheme that differentiates supply chain projects based on the decision rights configuration of each project. This categorization enables us to explore how relationship-level and project-level factors can have different impact on performance based on the characteristics of a supply chain project. The findings offer insights into how to effectively manage supply chain projects and inter-firm alliances.

Brinkhoff, A., Ö. Özer., Sargut, G. “*All You Need is Trust? An Examination of Interorganizational Supply Chain Projects,*” POMS May 8, 2014 forthcoming.

5.2.31 Trust, Trustworthiness and Information Sharing in Supply Chains Bridging China and the U.S.

Participants: Ö. Özer., Zheng, Y., Ren, Y.

Whether and how trust and trustworthiness differ between a collectivist society, e.g., China, and an individualistic one, e.g., the U.S., generate much ongoing scientific debate and bear significant practical values for managing cross-country transactions. We experimentally investigate how supply chain members' countries of origin -- China versus the U.S. -- affect trust, trustworthiness, and strategic information sharing behavior in a cross-country supply chain. We consider a two-tier supply chain in which the upstream supplier solicits demand forecast information from the retailer to plan production; but the retailer has an incentive to manipulate her forecast to ensure abundant supply. The levels of trust and trustworthiness in the supply chain and supplier's capability to determine the optimal production quantity affect the efficacy of forecast sharing and the resulting profits. We develop an experimental design to disentangle these three aspects and to allow for real-time interactions between geographically distant and culturally heterogeneous participants. We observe that, when there is no prospect for long-term interactions, our Chinese participants consistently exhibit lower spontaneous trust and trustworthiness than their U.S. counterparts do. We quantify the differences in trust and trustworthiness between the two countries, and the resulting impact on supply chain efficiency. We also show that Chinese individuals exhibit higher spontaneous trust towards U.S. partners than Chinese ones, primarily because they perceive that individuals from the U.S. are more trusting and trustworthy in general. This positive perception towards U.S. people is indeed consistent with the U.S. participants' behavior in forecast sharing. In addition, we quantify that a Chinese supply chain enjoys a larger efficiency gain from repeated interactions than a U.S. one does, as the prospect of building a long-term relationship successfully sustains trust and trustworthiness by Chinese partners. We advocate that companies can reinforce the positive perception of Westerners held by the Chinese population and commit to long-term relationships to encourage trust by Chinese partners. Finally, we also demonstrate that both populations exhibit similar pull-to-center bias when solving a decision problem under uncertainty (i.e., the newsvendor problem).

Ö. Özer, Zheng, Yanchong and Ren, Yufei, “Trust, Trustworthiness and Information Sharing in Supply Chains Briding China and the U.S. Management Science, January 1, 2014 Forthcoming

5.3. Activities in Finance and Economics

5.3.1. Real Options and Game Models

Participants: Alain Bensoussan, Celine Hoe

We consider optimal investment strategies for projects under uncertainty, when there is competition. We study the situation of complete and incomplete markets. Both a Leader-Follower Stackelberg game and a Nash Equilibrium game are considered. The approach of real options bears similarity with that of American options in financial engineering. A major component of the decision is when to invest (or to enter into the market). It is a random time. Each of the players has to decide when to enter. However, in the Stackelberg game the follower cannot enter before the leader whereas in the Nash game both players face the preemption risk when making investment decisions. There is in addition a regulation which clarifies how they share the market, if they decide both to compete. A regime-switching model is also introduced to catch cash flow variations caused by switching among different market modes. The assumption of complete or incomplete markets plays a fundamental role in defining the objective functions of both players. As it is customary for optimal stopping time problems, Dynamic Programming leads to Variational Inequalities. However, new structures arise with interesting mathematical questions. In most cases, we are able to solve completely the problems and to obtain optimal stopping strategies. But the results are not intuitive.

Bensoussan, A., S. Hoe and H-K Koo. *Real Options and Variational Inequalities*, Hyeng Kuen Koo and Jaeyoung Sung (Eds.), IOS Press. 2012

Bensoussan, A., S. Hoe. Real Options with Competition and Incomplete Markets, in *Inspired by Finance: The Musiela Festschrift. Yuri Kabanov, Marek Rutkowski, and Thaleia Zariphopoulou, eds.,Springer (2013)*.

Bensoussan, A., S. Hoe. Real Options Games - Stackelberg Competition vs. Pre-emption in Complete and Incomplete Markets"

Bensoussan, A., S. Hoe, Z. Yang, and G. Yin. Real Options with Competition and Regime Switching Mathematical Finance, Forthcoming

6.3.2. Real Options with Time and Scale Flexibility

Participants : A. Bensoussan and B. Chevalier-Roignant

The modeling of investment problems as being analogous to the exercise of perpetual American call options has become commonplace in economics and finance. By exploiting the analogy with traded options, most real options models ignore management's flexibility to decide on scale at the time of investment, an assumption at odds with business practice. In this paper, we study a situation in which an incumbent firm has leeway in choosing when and by how much to raise capital. We consider a general setting and prove the uniqueness and optimality of a threshold policy under certain conditions. The literature on real options analysis typically considers the timing of lump-sum investments wherein the change in scale is known beforehand. In another stream of the economic literature, stochastic models of capital accumulation deal with situations where, at each instant, the firm decides on its optimal level of capital goods with the aim to maximize its expected discounted revenues netted of capital expenditures; fixed adjustment costs are ignored in this perspective. We consider fixed and variable adjustment costs and allow for the optimal time of investment and choice of scale. We thus reconcile these two distinct approaches in a unified theory of investment under uncertainty with time and scale flexibility.

Bensoussan A., Chevalier-Roignant B. Real Options with Time and Scale Flexibility, in *Real Options, Ambiguity, Risk and Insurance*, A. Bensoussan, S.Peng,J. Song editors, IOS Press, 2012

5.3.3 Entrepreneurial Decisions on Effort and Project with a Non-Concave Objective Function

Participants: A. Bensoussan, A. Cadenillas, H.K. Koo

We propose and solve a general entrepreneurial/managerial decision making problem. Instead of employing concave objective functions, we use a broad class of non-concave objective functions. We approach the problem by a martingale method. We show that the optimization problem with a non-concave objective function has the same solution as the optimization problem when the objective function is replaced by its concave hull, and thus the problems are equivalent to each other. The value function is shown to be strictly concave and to satisfy the Hamilton-Jacobi-Bellman equation of dynamic programming. We also show that the final wealth cannot take values in the region where the objective function is not concave; the entrepreneur would like to avoid her/his wealth ending up in the non-concave region. Because of this, her/his risk taking explodes as time nears maturity if her/his wealth is equal to the right end point of the non-concave region.

Bensoussan, A., Cadenilla, A., H-K Koo, “*Entrepreneurial Decisions on Effort and Project with a Non-Concave Objective Function*”, Mathematics of Operations Research, October, 2014 forthcoming.

5.3.4. Optimal Retirement with Unemployment Risks in an Incomplete Market

Participants: A. Bensoussan, Bong-Gyu Jang and Seyoung Park

In this work, one investigates the optimal retirement of an individual in the presence of involuntary unemployment risks and borrowing constraints in an incomplete market. We provide a solution when the degree of incompleteness is small. Our numerical calculations show some robustness of our solution. We plan to submit a paper in the near future.

5.4. Activities in Alternative Energies

5.4.1. Participants: Alain Bensoussan, P. Bertrand and A. Brouste

This research is supported by EDF. We have developed a new approach concerning the forecast of annual production of wind energy by a windmill. This is important at the investment level, since it is essential to obtain an accurate estimate of the potential energy to assess the profitability. As a matter of fact, we have shown that a substantial amount of uncertainty is overlooked by the current approaches, both in the literature and in the practitioners' techniques. This uncertainty is structural; it is not linked to the estimation errors. It is linked to the randomness of wind. In fact, we noticed that the correlation between successive periods is at the origin of most of the volatility. At the beginning, we have neglected seasonality. We then developed a more accurate model of seasonality, with two sources of periodicity, day and night, and winter, autumn, spring, summer. We get more complex forecasting formulas, but thanks to them, we can lower the estimate of the structural volatility.

Bensoussan A., Bertrand P.R. and Brouste A. “*Forecasting the Energy Produced by a Windmill on a Yearly Basis*”, *Stochastic Environmental Research and Risk Assessment*, **26 (8)**, 1109-1122 (2012)

A. Bensoussan, Pierre Raphaël Bertrand, Alexandre Brouste, Nabiha Haouas, “*Impact of Seasonality on Interquartile Range for Annual Wind Power Production.*” *Journal of Applied Statistics*, 2013

5.4.2 Wind Speed Modeling for Short-Term Forecasting

Wind model for short-term forecasting is a key element in the operational management of a wind farm. The type of problem to be faced by the provider is to guarantee a given amount of energy, for a given duration, at a given price. One of the major difficulties is that the capacity of

production comes from wind turbines and solar plants. Therefore, this capacity is highly dependent on the wind speed and direction, or sun availability. We already proposed calibration methods for static models with seasonal parameters; this method used Generalized Linear Models theory.

Bensoussan, A., Bertrand, P.R. and Brouste A. “ *A GLM Approach to Seasonal Aspects of Wind Speed Modeling*, ” Journal of Applied Statistics **42 (8)**, (January, 2014) 1694-1707

Bensoussan, A., Bertrand P.R. and Brouste A., “*Estimation Theory for GLM in future Perspectives*” in Risk Models and Finance edited by A. Bensoussan, D. Guegan and C. Tapiero, Springer-Verlag 2014

Alain Bensoussan, Pierre Raphaël Bertrand, Alexandre Brouste, Nabiha Haouas, Medhi Fhima, Daouda Koulibaly. “*Confidence Intervals for Annual Wind Power Production*, ” *ESAIM Proceedings*, **44**, (January, 2014) 150-158

5.5. Activities in Risks on Technical Systems

5.5.1. Elastic-Plastic Systems Excited by Non-White Noise

Participants: Alain Bensoussan, Laurent Mertz

A stochastic variational inequality is proposed to model an elasto-plastic oscillator excited by a filtered white noise. We prove the Ergodic property of the process and characterize the corresponding invariant measure. This extends Bensoussan-Turi’s method (Degenerate Dirichlet Problems Related to the Invariant Measure of Elasto-Plastic Oscillators, AMO, 2008) with a significant additional difficulty of increasing the dimensions. Two points boundary value problem in dimension 1 is replaced by elliptic equations in dimension 2. In the present context, Khasminskii’s method (Stochastic Stability of Differential Equations, Sijthoff and Noordhof, 1980) leads to the study of degenerate Dirichlet problems with partial differential equations and nonlocal boundary conditions.

Bensoussan A., Mertz L., Degenerate Dirichlet Problems Related To the Ergodic Property of an Elasto-Plastic Oscillator Excited By A Filtered White Noise (*accepted with minor revisions for IMA Journal of Applied Mathematics.*)

Participants: Alain Bensoussan, Laurent Mertz and Sheung Chi Phillip Yam

In the literature, before our present work, failure risk analysis on most elasto-perfectly-plastic (EPP) oscillators is essentially focused on those excited by a white noise, which is rather restrictive from the modeling perspective. Our present article aims to generalize the models so as to provide a comprehensive study of the stochastic variational inequality (SVI) for elasto-plastic oscillators excited by a filtered noise. We characterize the solutions of the SVI by introducing a class of partial differential equations (PDEs) with nonlocal Dirichlet conditions. We establish the unique existence of solutions of these PDEs by extending the method developed in an earlier work by the first author and Janos Turi; a major

mathematical challenge here is to carry out the analysis of boundary value problems for elliptic equations in dimension 2 rather than that in dimension 1. Finally, a probabilistic interpretation of these solutions is provided.

Bensoussan A., Mertz L., Yam P., Stochastic variational inequality for an elasto-plastic oscillator excited by a filtered noise, preprint

5.5.2. New Results on the long time behavior of Elastic-Plastic Systems

Several works related to this domain are collected here:

Participants: Laurent Mertz and Cyril Feau

Statistical properties of the plastic deformation related to an elastic perfectly plastic oscillator under standard white noise excitation are studied in this paper. Our approach relies on a stochastic variational inequality governing the evolution between the velocity and the non-linear restoring force. Bensoussan and Turi have shown that the solution is an ergodic Markov process. First, we exhibit, by means of probabilistic simulations, the phenomenon of micro-elastic phases which are small as well as numerous. The main difficulty related to this phenomenon is that the transitions between elastic and plastic phases are not well defined and quantities of interest such as frequency of plastic deformations cannot be characterized. Therefore, we investigate elastic phasing by means of the invariant probability measure of the problem. We present approximations of the probability density function of the elastic component and a similar expression to the Rice formula related to frequency of threshold crossings. These quantities are solutions of partial differential equations. Numerical experiments on these equations show that the non-linear restoring force tends to be highly distributed in the neighborhood of plastic thresholds. Finally, an interesting criterion is provided to discard micro-elastic phases and to evaluate statistics of plastic deformations which make sense for engineering purposes.

Mertz L., Feau C., An empirical study on plastic deformations of an elasto-plastic problem with noise, Probabilistic Engineering Mechanics 30 (2012) 60–69

Participants: Alain Bensoussan and Laurent Mertz

In an earlier work made by the first author with J. Turi (Degenerate Dirichlet Problems Related to the Invariant Measure of Elasto-Plastic Oscillators, AMO, 2008), the solution of a stochastic variational inequality modeling an elasto-perfectly-plastic oscillator has been studied. The existence and uniqueness of an invariant measure have been proven. Nonlocal problems have been introduced in this context. In this work, we present a new characterization of the invariant measure. The key finding is the connection between nonlocal PDEs and local PDEs which can be interpreted with short cycles of the Markov process solution of the stochastic variational inequality.

Bensoussan A., Mertz L., An analytic approach to the ergodic theory of a stochastic variational inequality, C. R. Acad. Sci. Paris, Ser. I 350 (2012) 365–370

Participants: Alain Bensoussan, Laurent Mertz and Sheung Chi Phillip Yam

We have obtained new approaches for proving ergodicity of Elastic-Plastic Oscillators. They are purely analytic and are related to the solution of non-local P.D.E. We have also rigorously proved a well-known result identified empirically by engineers using simulation. This concerns the variance of displacement during a period of time, which grows linearly with the length of the period. This has enhanced the credibility of our mathematical methods with respect to practitioners.

Bensoussan A., Mertz L., Yam P., Long cycle behavior of the plastic deformation of an elasto-perfectly-plastic oscillator with noise, C. R. Acad. Sci. Paris, Ser. I 350 (2012) 853–859.

Participants: Alain Bensoussan, Cyril Feau, Laurent Mertz and Sheung Chi Phillip Yam

Since a few decades ago, there has been a huge amount of studies of plastic deformation of elasto-plastic oscillators in the engineering literature. In one of our recent works/cite {BenMerYam}, we introduced a novel notion of long cycle behavior of the Markovian solution of the corresponding stochastic variational inequality of an elasto-perfectly-plastic oscillator, which can characterize in a probabilistic framework the variance of the plastic deformation. In this paper, we provide an analytical formula for the characteristic function of the probability distribution of the plastic deformation on long cycles; from our result we also derive a deterministic representation of the variance of the plastic deformation on long cycles.

Bensoussan A., Mertz L., Yam P., An analytical approach for the growth rate of the variance of the deformation related to an elasto-plastic oscillator excited by a white noise, preprint

Participants: Alain Bensoussan, Héctor Jasso-Fuentes H., Stéphane Menozzi and Laurent Mertz

In a previous work by the first author with J. Turi - [Appl. Math. Optim. **58(1)** (2008), 1–27], a stochastic variational inequality has been introduced to model an elasto-plastic oscillator with noise. A major advantage of the stochastic variational inequality is to overcome the need to describe the trajectory by phases (elastic or plastic). This is useful, since the sequence of phases cannot be characterized easily. In particular, when a change of regime occurs, there are numerous small elastic phases which may appear as an artifact of the Wiener process. However, it remains important to have information on both the elastic and plastic phases.

In order to reconcile these contradictory issues, we introduce an approximation of stochastic variational inequalities by imposing artificial small jumps between phases allowing a clear separation of the elastic and plastic regimes. In this work, we prove that the approximate solution converges on any finite time interval, when the size of jumps tends to 0.

Bensoussan A., Jasso-Fuentes H., Menozzi S., Mertz L., Asymptotic analysis of stochastic variational inequalities modeling an elasto-plastic problem with vanishing jumps, Asymptotic Analysis **80** (2012) 171–187

Participants: Héctor Jasso-Fuentes H., Laurent Mertz and Sheung Chi Phillip Yam

An important issue in failure analysis of some mechanical structures under seismic forcing is to estimate statistics of the response of an elasto-perfectly-plastic oscillator with noise. In a previous work, we noticed that due to the noise numerous and negligible plastic phases occur in the response on small time intervals at the instants of phase transition, therefore we gave an empirical criterion based on mathematical tools related to a stochastic variational inequality (SVI) to remove this phenomenon from relevant statistics. Recently, we proposed a SVI with jumps to separate clearly the phases. We showed that the approximate solution converges, as the size of jumps goes to 0. The present work is in the straightforward line of these two studies. Here, an asymptotic study of ergodic measures of approximate solutions of the SVI is investigated by a combination of a theoretical and an empirical analysis. First, we show that these measures converge as ϵ goes to 0. Then, numerical experiments on the convergence reveal, on the one hand, that the rate of convergence behaves as $A \exp(-B/\epsilon)$ where A and B are positive numbers and, from the other hand, there exists an empirical small number for which the measures have numerically converged. In terms of engineering interests, we provide an interesting criterion using to calibrate the model with jumps discarding the negligible plastic phases and to estimate statistics of plastic deformations.

Jasso-Fuentes H., Mertz L. and Yam P. Approximate solutions of a stochastic variational inequality modeling an elasto-plastic problem with noise, Applied Mathematics Research Express, first published online March 28, 2013

Participants: Laurent Mertz and Mathieu Laurière

In a recent work of A. Bensoussan and J. Turi Degenerate Dirichlet Problems Related to the Invariant Measure of Elasto-Plastic Oscillators, AMO, 2008, it has been shown that the solution of a stochastic variational inequality modeling an elasto-plastic oscillator excited by a white noise has a unique invariant probability measure. The latter is useful for engineering in order to evaluate statistics of plastic deformations for large times of a certain type of mechanical structure. However, in terms of mathematics, not much is known about its regularity properties. From then on, an interesting mathematical question is to determine them. Therefore, in order to investigate this question, we introduce in this paper approximate solutions of the stochastic variational inequality by a penalization method. The idea is simple: the inequality is replaced by an equation with a nonlinear additional term depending on a parameter n penalizing the solution whenever it goes beyond a prespecified area. In this context, the dynamics is smoother. In a first part, we show that the penalized process converges towards the original solution of the aforementioned inequality on any finite time interval as n goes to ∞ . Then, in a second part, we justify that for each n it has at least one invariant probability measure. We conjecture that it is unique, but unfortunately we are not (yet) able to prove it. Finally, we provide numerical experiments in support of our conjecture. Moreover, we give an empirical convergence rate of the sequence of measures related to the penalized process.

Laurière M., Mertz L., Penalization of a stochastic variational inequality modeling an elasto-plastic problem with noise, to appear in ESAIM: PROCEEDINGS, 2014.

7. Publications

2013

EDITED BOOK

Real Options, Ambiguity, Risk and Insurance

A. Bensoussan, Shige Peng, Jaeyoung Sung
Netherlands, IOS Press, (May 31, 2013)

BOOK

Mean Field Games and Mean Field Type Control Theory

Alain Bensoussan, Jens Frehse, Phillip Yam
New York Heidelberg Dordrecht London, Springer Brief (Oct 31, 2013)

PAPERS

Linear Quadratic Differential Games with Mixed Leadership: The Open-Loop Solution,

A. Bensoussan, Shaokuan Chen, Suresh P. Sethi
Numerical Algebra Control and Optimization **3** (1) (March 2013) 95-108

Optimal Inventory Control with Shrinkage and Observed Sales - In Memory of Michael Taksar

A. Bensoussan, M. Çakanyldirim, M. Li, S.P. Sethi
Stochastics: An International Journal of Probability and Stochastic Processes **85** (July 2013) 589-603

Control and Nash Games with Mean Field Effect

A. Bensoussan, Jens Frehse
Chinese Annals of Mathematics **34** (2) (April 2013) 161 -192

Unemployment Risks and Optimal Retirement in an Incomplete Market,

A. Bensoussan, Bong-Gyu Jang, Seyoung Park
Chinese International Conference in Finance, (July 10-13, 2013), Shanghai, China

Optimizing Production and Inventory Decisions in a Supply Chain with Lot Size, Production Rate and Lead Time Interactions

Hua-Ming Song, Hui Yang, A. Bensoussan
Applied Mathematics and Computation **224** (November 2013) 150-165

Time-Consistent Portfolio Selection under Short-Selling Prohibition: From Discrete to Continuous Setting,

A. Bensoussan, K.C. Wong, S.C.P. Yam, S.P. Yung
SIAM J. Finance Math **5** (1) (November 2013) 153-190

Linear-Quadratic Time-Inconsistent Mean Field Games

A. Bensoussan, K.C.J. Sung, S.C.P. Yam
Dynamic Games and Applications **3** Issue **4**, (December 2013) 537-552

PRESENTATIONS AT CONFERENCES

The Maximum Principle for Global Solutions of Stochastic Stackelberg Differential Games

A. Bensoussan, Shaokuan Chen, S.P. Sethi **Presenter:** Shoakuan Chen
INFORMS, Minneapolis, Minnesota (October 6 – 9, 2013)

Feedback Stackelberg Solutions Of Infinite-Horizon Stochastic Differential Games

A. Bensoussan, Shoakuan Chen, S.P. Sethi **Presenter:** S.P. Sethi
9th International Society of Dynamic Games, Barcelona, Spain (July 5-6, 2013)

Feedback Stackelberg Solutions of Infinite-Horizon Stochastic Differential Games

A. Bensoussan, Shaokuan Chen, S.P. Sethi **Presenter:** S.P. Sethi
INFORMS, Applied Probability Society Conference, San Jose, Costa Rica, (July 15-17, 2013)

SPEAKER INVITATIONS:

Mean Field Games and Related Topics

Control & Game Theory Colloquium
Warwick University, UK (May 7-10, 2013)

Mean Field Games and Related Topics

Departimento di Matematica,
Padua University, Padua, Italy (September 4-6, 2013)

Mean Field Games

Magno Coloquio de Doctorantes en Economía de la República Mexican,
Mexico City, Mexico, (November 14, 2013)

Control Theory, What Changes in 50 Years

INRIA, #30th Anniversary Colloquium
Sophia Antipolis, France (November 28, 2013)

Mean Field Type Control

ECM 2013 – Computational & Mathematical Finance
Hong Kong Polytechnic University, Hong Kong, PRC (December 2013)
2014

BOOK CHAPTER(S)

Feedback Stackelberg Solutions of Infinite-Horizon Stochastic Differential Games

A. Bensoussan, Shaokuan Chen, Suresh P. Sethi

Models and Methods in Economics and Management Sciences ed by Fouad El Ouardighi, Konstantin Kogan

Switzerland: Springer International Publishing (January 2014) 3-15

Real Options with Competition and Incomplete Markets

A. Bensoussan, Sing Ru (Celine) Ho

Inspired by Finance, ed. by Yuri Kabanov, Marek Rutkowski, Thaleia Zariphopoulou

Switzerland, Springer (2014) 29-45

PAPERS

Optimal Control of Hidden Markov Models w/ Binary Observations

A. Bensoussan, Arash Komaee

IEEE Transactions on Automatic Control V **59**, **1** (January 2014) 64-77

A GLM Approach to Seasonal Aspects of Wind Speed Modeling

Alain Bensoussan, Pierre Bertrand, Alexandre Brouste

Journal of Applied Statistics **41** Issue **8** (January 2014) 1694-1707

Optimal Decision Making in Multi-Product Dual Sourcing Procurement w/ Demand Forecast Updating,

Alain Bensoussan, Hua-Ming Song, Hui Yang, Ding Zhang

Computers & Operations Research, **41** (January, 2014) 200-308

Confidence Intervals for Annual Wind Power Production

Alain Bensoussan, Pierre Raphaël Bertrand, Alexandre Brouste, Nabiha Haouas, Medhi Fhima, Daouda Koulibaly

ESAIM Proceedings, **44**, (January, 2014) 150-158

Mean-Variance Pre-Commitment Policies revised via a Mean-Field Technique

A. Bensoussan, K.C. Wong, S.C.P. Yam

2012 Recent Advances in Financial Engineering ed. by Akhiko Takahashi, Yukio Muromachi, Takashi Shibata

World Scientific Publisher (April 2014), 177-198

A Class of Nonzero-Sum Stochastic Differential Investment and Reinsurance Games

A. Bensoussan, Chi Chung Siu, Sheung Chi Phillip Yam, Hailiang Yang

Automatica (April 2014)

Stochastic Differential Games with a Varying Number of Players

A. Bensoussan, Jens Frehse, Christine Grün

Communications on Pure & Applied Analysis, **13**, Number **5**, (September 2014)

Real Options with Competition and Regime Switching

A. Bensoussan, SingRu Hoe, ZhongFeng Yan, G. Yin

Mathematical Finance, (announced 2014)

PRESENTATIONS AT CONFERENCE(S)

Feedback Stackelberg Equilibrium in Mixed Leadership Games with an Application to Cooperative Advertising

A. Bensoussan, Shaokuan Chen, Anshuman Chutani, Suresh P. Sethi **Presenter:** S.P. Sethi

“16th International Symposium on Dynamic Games and Applications,” Amsterdam, Netherlands, July 9-12, 2014.

Uncertainties and Competition – Challenges for Real Life, Opportunities for Research

A. Bensoussan

“Korean Association of Financial Engineering” 2014 Annual Meeting,” Busan, South Korea, August 22-23, 2014

SPEAKER INVITATIONS

The Master Equation in Mean Field Theory

Sino-French Conference on Computational & Applied Mathematics
Fujian, China (June 2, 2014)

W.T. and Idalia Reid SIAM AWARD Lecture

SIAM Annual Conference

Chicago, Illinois (July 7-11, 2014)

University of Illinois - College of Business

Control of Partially Observable Inventory Systems
Urbana-Champaign, Illinois (September 8, 2014)

The Chinese University of Hong Kong

Dynamic Programming in Mathematical Finance
Hong Kong, China (December 22-23, 2014)

7. Risk and Decision Analysis Journal



New Co-Editor-in-Chief Risk and Decision Analysis

Professor Nassim Nicholas Taleb has recently been announced as new Co-Editor-in-Chief of [Risk and Decision Analysis](#), a journal about risk mathematics, risk modeling and management, published by [IOS Press](#).

"I am extremely proud to partake in this journal, which aims to inject real-world rigor into risk theories, and help develop an atmosphere of substance in risk management. Risk is the most important topic there is - everything depends on it - and we need to help authors who focus on rigorous relevance to find a publishing venue.", says the newly appointed Co-Editor-in-Chief.

Professors Alain Bensoussan and Charles Tapiero welcome Professor Taleb to their editorial team: "Professor Taleb is one of the most prolific researchers in Extreme Risks and their many manifestations. We're very glad that the author of *Black Swan* and *Anti-Fragility* is joining us in our efforts."

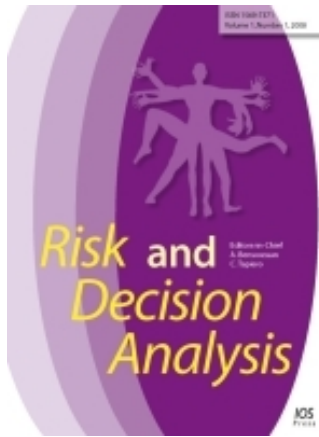


Nassim Nicholas Taleb

About Prof. Nassim Nicholas Taleb

Professor Taleb has a background in complex derivatives and risk management of nonlinear payoffs. He was a trader for 21 years before becoming a full-time researcher. Currently, Professor Taleb holds a position as Distinguished Professor of Risk Engineering at New York University's School of Engineering. For more information, see www.fooledbyrandomness.com.

About the journal



The journal **Risk and Decision Analysis** (RDA) emphasizes a theoretical and practical interdisciplinary vision of risk and its manifestations. RDA considers for publication research paper papers that contribute to a greater appreciation of risk mathematics, risk modeling and management and their broad application to general engineering, economic and financial systems, operational systems in industry and in the services, regulatory and control systems, eco-risks and urban systems, insurance, energy, safety and security, healthcare, environment, and related areas.

RDA's focus is on mathematical and systematic approaches to risk (statistics, probability theory), Bayesian statistics and learning, stochastic modeling, stochastic and optimal control in addition to quantitative approaches to extreme risks and their management.

[For the most recent contents, please click here.](#)

Editorial Board

Edward Altman, USA, John Baillieul, USA, Metin Çakanyildirim, USA, Rama Cont, USA, Robert Cooper, USA, Michel Crouhy, France, Raphael Douady, France, Tyrone Duncan, USA, Dan Galai, Israel, Helyette Geman, United Kingdom, Dominique Guegan, France, Yacov Y. Haimmes, USA, Jean-Michel Lasry, France, John J. Liu, China, Jean-Hervé Lorenzi, France, Ely Merzbach, Israel, Bertrand Munier, France, Mihai Nadin, USA, Shmuel S. Oren, USA, George Papanicolaou, USA, Bozenna Pasik-Duncan, USA, Elisabeth Pate-Cornell, USA, Stylianos Perrakis, Canada, Olivier P. Pironneau, France, Sumit Sarkar, USA, Suresh P. Sethi, USA, Ronnie Sircar, USA, Katepalli Raju Sreenivasan, USA, Meir Statman, USA, Lorne Switzer, Canada, Pierre Vallois, France, Paul Zipkin, USA

Submission of Papers

Please consult our website, www.iospress.nl/journal/risk-and-decision-analysis/#submission-of-manuscripts, for detailed information to authors.

Subscription Information

Risk and Decision Analysis (ISSN 1569-7371) will be published in 1 volume of 4 issues in 2015 (Volume 6). For current pricing, please click [here](#).

Abstracted / Indexed in

Google Scholar, Scopus, Ulrich's Periodicals, Zentralblatt MATH

ISSN 1569-7371
Volume 5, Number 1, 2014



Risk and Decision Analysis

Editors-in-Chief
A. Bensoussan
C. Tapiero

Risk and Decision Analysis

Volume 5, Number 1, 2014

CONTENTS

<i>S. Bianchi and A. Pianese</i> Multifractional processes in finance	1
<i>A. Melnikov and S. Tong</i> Valuation of finance/insurance contracts: Efficient hedging and stochastic interest rates modeling	23
<i>M. Parsa and T. Mallikarjunappa</i> Futures trading and commodity spot market volatility: Empirical evidence on selected commodities in Indian market	43
<i>S. Seshadri and Q. Wu</i> Production and inventory planning under decreasing absolute risk aversion: A unified approach for sensitivity analysis	63
<i>S. Stojanovic and A. Göncü</i> Pricing portfolios of contracts on cumulative temperature with risk premium determination	75

Abstracted / Indexed in: Scopus, Ulrich's Periodicals, Zentralblatt MATH

visit our website on www.iospress.nl

8. ICDRiA ADVISORY BOARD

Klenik, Bill CHAIRMAN of ICDRiA ADVISORY BOARD

Bensoussan, Alain Director of ICDRiA Advisory Board

FACULTY		TITLE
Cakanyildirim	Metin	Professor - Management
Cavusoglu	Huseyin	Associate Professor - Management
Dearing	Ron	Clinical Professor – Math Sciences
Flannery	Carole	Sr. Lecturer Management
Gnade	Bruce	VP for Research
Hoe	Celine	Assistant Professor, Texas A&M
Janakiraman	Ganesh	Professor - Management
Kantarcioglu	Murat	Associate Professor - Computer Science
Katok	Elena	Ashbel Smith Professor - JSOM
Kieschnick	Robert	Associate Professor - Management
Mookerjee	Radha	Clinical Professor - Management
Mookerjee	Vijay	Endowed Professor - Management
Muharremoglu	Alp	Associate Professor - Management
Nadin	Mihai	Professor - Arts & Humanities
Ozer	Ozalp	Professor - Management
Pirkul	Hasan	Dean - School of Management
Radhakrishnan	Suresh	Professor - Management
Raghunathan	Srinivasan	Professor - Management
Rajamani	Divakar	Clinical Professor - Management
Rotea	Mario	Professor - Mechanical Engineering
Sarkar	Sumit	Ashbel Smith Professor - Management
Sethi	Suresh	Endowed Professor - JSOM
Shah	Rajiv	Clinical Professor - Management
Shapiro	Jonathan	Director - Research
Stecke	Kathryn	Ashbel Smith Professor - Management
Thuraisingham	Bhavani M.	Professor - Computer Sciences
Turi	Janos	Professor - Mathematical Sciences
Vidyasagar	Sagar (Mathukumalli)	Professor - Systems Engineering
Zheng	Eric	Associate Professor - Management
INDUSTRY		
Bergeron	Rob	TRWD/DWU Integrated Pipeline Project
Black	Dennis	Comerica - Vice-President, Model Development Mgr
Carrier	John	VP Research and Development, ESSILOR
Chemla	Jean-Marc	Ameriprise Financial Services, CRPC®, APMA
Guragai	Bishoram	Controller, DesigneRx Pharmaceuticals Inc.

Humble	Monty	President, CCO - Brightman Energy LLC
Jain	Sudhanshu	Sr. Associate, PricewaterhouseCoopers, LLP /Transaction Services & Global Association of Risk Professionals - Dallas Chapter
Kohl	David	CPCU
Krenik	Bill	CTO - High Volume Linear Products at Texas Instruments, Chairman of the Advisory Board
Mjigal	Tahar	International Capital Management Corp. (ICMC) Dir of Risk management and Technical Analyst
Mukherjee	Ashok	Modria Inc. Director
Olah	Laslo	President/CEO
Parry	Daniel	Chief Credit Officer
Ratnam	Arun	GARP, Dallas Chapter Committee Member
Reid	Peter	Privacy Officer, HP Enterprise Business
Russo	Ray	Civil Works Integration Division
Shaw	David	Sr. Vice President, Astrapi Corp.
Solomon	Yoram	Vice President, Corporate Strategy & Business Development
Starks	Laura	Starks Energy Economics, President
Sutaria	Vinod	Comerica, Vice President, Operational Risk Mgr
Turi	Greg	Valspar, Demand Planner
Vignal	Jean Paul	Partner
White	Chris	Director of Development/ViaSim Solutions
ICDRiA	STUDENTS & SCHOLARS	
Chen	Shaokuan	PhD Student & TA
Cheng	Dayou	Visiting Scholar
Graber	P. Jameson	NSF, PHD
Kadiyala	Bharadwaj	PhD Candidate in Mgmt Sciences
Koo	Jun Lim	Visiting Scholar
Skaaning	Sonny	PhD Student in Mathematics