



Activity Report

November 19, 2013



Table of Contents

ICDRiA ACTIVITY REPORT	3
1. INTRODUCTION	3
2. CITY U HONG KONG- UTD AGREEMENT	3
3. FUNDING	3
4. EDUCATION PROGRAM	7
5. RESEARCH PROGRAM	8
5.1. <i>Risks and Uncertainties in Information Systems</i>	8
5.2. <i>Risks in Supply Chain Management</i>	9
5.3. <i>Risks in Financial and Economic Systems</i>	10
5.4. <i>Risks and Uncertainties in Alternative Energies</i>	12
5.5. <i>Risks on Technical Systems</i>	13
6. PRESENT ACTIVITIES.....	13
6.1. <i>Activities in the Security in Information Systems Domain</i>	13
6.2. <i>Activities in the Supply Chain Domain</i>	21
6.3. <i>Activities in Finance and Economics</i>	37
6.4. <i>Activities in Alternative Energies</i>	40
6.5. <i>Activities in Risks on Technical Systems</i>	40
7. PUBLICATIONS.....	44
8. RISK AND DECISION ANALYSIS JOURNAL.....	46
9. UTD News Article – NSF Grant Awarded.....	48
10. ICDRiA Board Members.....	50



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 2013

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 2013.

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 is much more that was envisaged in the preceding activity report, and is an excellent framework for many initiatives.

Concerning Korea, the funding from the government is stopped. The World Class University program to which we participated has come to an end. We are entering into a period of standby. However, we are very satisfied with the achievements and with the strong personal relations which have been established. This concerns primarily Korea, but also China. There is a possibility that an initiative similar to the WCU program takes place in China, with our involvement.

2. CityU Hong Kong-UTD Agreement



**MEMORANDUM OF UNDERSTANDING
 ON ACADEMIC EXCHANGE BETWEEN
 CITY UNIVERSITY OF HONG KONG,
 HKSAR, PEOPLE'S REPUBLIC OF CHINA
 AND**

**THE UNIVERSITY OF TEXAS AT DALLAS,
UNITED STATES OF AMERICA**

This Memorandum of Understanding (MOU) applies to City University of Hong Kong (“CityU”) of Tat Chee Avenue, Kowloon, HKSAR, People’s Republic of China and The University of Texas at Dallas (“UT Dallas”) of 800 West Campbell Road, Richardson, Texas, United States of America for the purpose of promoting academic exchange and further developing the cooperative relationship between the two institutions.

In consideration of mutual obligations below, the parties agree as follows:

1. Exchange of Academics, Research Personnel and Administrative Personnel

Both parties agree to dispatch academics, research personnel or administrative personnel to each other to participate in academic exchange activities and to explore possibilities of collaboration. The actual implementation of the academic exchange shall be negotiated separately between both parties.

2. Exchange of Students

Both parties agree to explore the possibility of student exchange. Any arrangement of student exchange shall be governed by a separate agreement on student exchange specifically signed for the purpose. The student exchange agreement may constitute a part of this MOU or may be signed independently.

3. Exploration of Teaching Collaboration

Both parties agree to explore the possibility of cooperation in offering degree programs and/or training courses. The actual implementation of collaborative projects shall be negotiated separately pursuant to the needs of both parties.

4. Scientific Research Collaboration

Both parties encourage scientific research collaboration in mutually interested research projects. The actual implementation of collaborative projects shall be negotiated separately pursuant to the needs of both parties.

5. Sharing of Joint Research Results

Results of any research achieved during the collaboration period (such as research papers, developed samples, physical products, etc.) and attributable profits shall be shared among the parties concerned according to their agreed extent of contribution on the basis of consultation.

Should any faculty collaboration result in any potential for intellectual property, the parties will immediately meet through designated representatives and seek an equitable and fair understanding as to ownership and other property interests that may arise. Any such discussions will at all times strive to preserve a harmonious and continuing relationship between the parties.

6. Exchange of Institutional Publications

Both parties will exchange institutional publications such as annual reports, research publications, etc.

7. Coordinators

Each institution shall designate a coordinator to oversee and facilitate the implementation of this MOU.

For UT Dallas: Rodolfo Hernandez Guerrero, Director, International Education, 800 W. Campbell Rd – GC52, Richardson, Texas, 75080, USA. Tel. (972) 883-6475, E-mail: rfo@utdallas.edu

For CityU: Ellsik Lee, External Liaison Officer, Mainland and External Affairs Office, Room 4105, Cheng Yick-chi Building, CityU, Tat Chee Avenue, Kowloon HKSAR. Tel. (852) 3442 7396, E-mail: ellsik.lee@cityu.edu.hk

8. General Intention

This MOU is not a contract. This MOU serves only as a statement of the general intention of the Parties and is not intended to be legally binding nor intended to be construed as an agreement on any matters mentioned. No oral agreement or conduct of the Parties (including partial performance) in respect of matters stated in this MOU shall be deemed to impose any obligation or liability on either Party.

This MOU is not intended to constitute, create, give effect to, or otherwise form a joint venture, or other business entity of any kind. Neither Party shall act as an agent for, or partner of, the other Party. There are neither any rights nor obligations of the Parties established under this MOU.

9. Rules and Regulations

The parties agree to comply with all applicable federal, state, and municipal laws; ordinances, rules, and regulations; all applicable requirements of any accreditation authority, and to certify such compliance upon request. In the case of UT Dallas, these are the rules and guidelines of the Texas Higher Education Coordinating Board and the Southern

Association of Colleges and Schools Commission on Colleges as well as the laws and regulations of the State of Texas and the United States of America. In the case of CityU, these are the laws, rules, and regulations of HKSAR.

10. Validity and Renewal

This MOU is made in a set of two. Each party will keep one copy. The MOU will take effect immediately once signed and is valid for five (5) years. Both parties reserve the right to terminate this MOU by giving an advance written notice of no less than six (6) months. Both parties shall discuss and decide on the continuation or revision of the MOU six (6) months prior to its expiration.

Executed for and on behalf of
City University of Hong Kong

Executed for and on behalf of
The University of Texas at Dallas

Prof. Arthur Ellis
Provost

Prof. Hobson Wildenthal
Executive Vice President and Provost

Date:

Date:

We have been at the origin of this agreement, but our ambition was not to target the university level. This very positive evolution is quite encouraging and motivating. In particular, it will allow the Schools of Engineering to be involved.

Of course, not much has been finalized yet. The Dean of the Johnson School of Engineering and the Chairman of the Department of Systems Engineering at UTD will visit Hong Kong for initial contacts next June. There are already existing relations between the Jindal School of Management at UTD and the College of Business at CityU. The Dean at City U is a former professor at UTD and the Dean of the Jindal School of Management has been visiting Hong Kong regularly. Some common research will be mentioned below.

3. Funding

New funding obtained this year:

3.1 Mean Field Games, Mean Field Type Control and Extensions

National Science Foundation

Alain Bensoussan (PI)

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

3.2 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 contracts with EDF-EN and CEA will terminate at the end of this year. The perspectives for renewal are not favorable, due to the economic difficulties in France. We hope that it will be possible to continue with minimal support. Anyway, the results are highly received by the contractors and the outcome in terms of publications is quite favorable. The expertise which has been accumulated bodes well for further opportunities.

4. 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. It will be offered in alternation with the class “Risk and Decision Analysis”. 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.

5. 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.

axb046100 11/9/2013 4:20 PM

Deleted:

5.1. 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.

5.2. 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.

5.3. 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, in 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 got a strong boost this year, with the obtaining of an NSF grant and RGC-GRF grant. We will be able to fund PhD students and post-doc. We have already two PhD students, one in Dallas, one in Hong Kong and one post-doc who will come next year to Dallas.

5.4. Risks and Uncertainties in Alternative Energies

We are completing 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 have here to find the right partner and the funding agency.

5.5. 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. The best that we can hope for is a relatively symbolic support, to show that the contracts is not cut. We try to obtain other sources of funding, in particular from the cooperative research program between France and Hong Kong.

6. Present Activities

6.1. Activities in the Information Systems Domain

6.1.1. From Business Intelligence to Competitive Intelligence Inferring Competitive Measures Using Augmented Site-Centric Data.

Participants: Zheng, Z., Fader, P., Padmanabhan, B.

Managers routinely seek to understand firm performance relative to the competitors. Recently competitive intelligence (CI) has emerged as an important area within business intelligence (BI) where the emphasis is on understanding and measuring a firm's external competitive environment. A requirement of such systems is the availability of the rich data about a firm's competitors, which is typically hard to acquire. This paper proposes a method to incorporate competitive intelligence in BI systems by using less granular and aggregate data which is usually easier to acquire. We motivate, develop, and validate an approach to infer key competitive measures about customer activities without requiring detailed cross-firm data. Instead, our method derives these competitive measures for online firms from simple "site-centric" data that are commonly available, augmented with aggregate data summaries that may be obtained from syndicated data providers. Based on data provided by comScore Networks we show empirically that our method performs well in inferring several key diagnostic competitive measures – the *penetration*, *market share* and the *share of wallet* – for various online retailers.

Zheng, Z., Fader, P. Padmanabhan, B., "From Business Intelligence to Competitive Intelligence" Inferring Competitive Measures Using Augmented Site-Centric Data," *Information Systems Research*, " 2013, 23 (3), 698-720.

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

Participants: Jabar, W., Z. 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.

W., Z. Zheng. "Know Yourself and Know Your Enemy: An Analysis of Firm Recommendations and Consumer Reviews in a Competitive Environment" 2013. *Forthcoming at MISQ*.

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

Participants: Z.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.

6.1.4. 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.

6.1.5. No Free Lunch: Price Premium for Privacy Seal-Bearing Vendors

Participants: Bin Mai, Nirup M Menon, and Sumit Sarkar

Privacy is a significant concern of customers in the business-to-consumer online environment. Several technical, economic, and regulatory mechanisms have been proposed to address online privacy. A current market-based mechanism is the privacy seal, under which a third-party assures adherence by a vendor to its posted privacy policy. In this paper, we present empirical evidence of the impact of displaying a privacy seal on the product prices of online vendors of electronic books, downloadable audio books, and textbooks. Using data collected on these relatively homogeneous products sold by online vendors, we find, while controlling for vendor-specific characteristics, that vendors bearing privacy seals charge a premium for such products compared to vendors not bearing a seal. The paper provides empirical evidence of the economic value of privacy assurance from the customers' perspective as measured by the price premium charged for products. The research has implications for researchers and policy makers by providing evidence that privacy is another factor that creates friction in e-commerce, and that prices on the internet for homogeneous products need not converge.

Mai, Bin, N. Menon, and Sumit Sarkar. No Free Lunch: Price Premium for Privacy Seal-Bearing Vendors, *Journal of Management Information Systems*, 27(2) (2010) pp. 189 – 212.

6.1.6. 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 for Privacy-Preserving Data Sharing and Analysis*. ICIS 2010 Proceedings, Paper 58, (2010).

6.1.7. When Hackers Talk: Managing Information Security Under Variable Attack Rates and Information Dissemination

Participants: Vijay Mookerjee, Wei Yue, Radha Mookerjee, and Alain Bensoussan

This paper analyzes interactions between a firm that seeks to discriminate between normal users and hackers that try to penetrate and compromise the firm's information assets. We develop an analytical model in which a variety of factors are balanced to best manage the detection component within information security management. The approach not only considers conventional factors such as detection rate and false-positive rate, but also factors associated with hacker behavior that occur in response to improvements in the detection system made by the firm. Detection can be improved by increasing the system's discrimination ability (i.e., the ability to distinguish between attacks and normal usage) through the application of maintenance effort. The discrimination ability deteriorates over time due to changes in the environment. Also, there is the possibility of sudden shocks that can sharply degrade the discrimination ability. The firm's cost increases as hackers become more knowledgeable by disseminating security knowledge within the hacker population. The problem is solved to reveal the presence of a steady-state solution in which the level of system discrimination ability and maintenance effort are held constant. We find an interesting result where, under certain conditions, hackers do not benefit from disseminating security knowledge among one another. In other situations, we find that hackers benefit because the firm must lower its detection rate in the presence of knowledge dissemination. Other insights into managing detection systems are provided. For example, the presence of security shocks can increase or decrease the optimal discrimination level as compared to the optimal level without shocks.

Bensoussan, A., R. Mookerjee, V. Mookerjee and W.T. Yue. When Hackers Talk: Managing Information Security under Variable Attack Rates and Information Dissemination, *Information Systems Research*, (online 2010), 22(3) pp. 606. doi: 10.1287/isre.1100.0341
<http://isr.journal.informs.org/content/early/2011/04/08/isre.1100.0341.full.pdf+html>

6.1.8. Managing Information Security Under Continuous Drift and Sudden Shocks

Participants: Vijay Mookerjee, Wei Yue, Radha Mookerjee, and Alain Bensoussan

This paper analyzes the optimal amount of effort that should be exerted to best maintain a detection component within information security management. We consider a problem over an infinite horizon in which detection system suffers continuous and sudden deterioration of performance quality. The firm exerts maintenance effort to counter the drop in performance quality. We develop an analytical model in which the performance quality of the detection system can be improved (i.e., the ability to distinguish between attacks and normal usage) through the application of maintenance effort. The discrimination ability deteriorates over time due to changes in the environment (e.g. hacker behavior). Also, there is the possibility of sudden shocks that can sharply degrade the discrimination ability. We find the presence of shocks will result in the system maintained at a lower discrimination ability level. When shocks can be eliminated if the discrimination ability of the system is to be maintained at a certain threshold level, surprisingly, the optimal decision may not be to maintain the system at this threshold level.

Bensoussan, A., R. Mookerjee, V. Mookerjee and W.T. Yue. Managing Information Security Under Continuous Drift and Sudden Shocks, *Conference on Information Technologies and Systems (CIST)* Charlotte, N.C., November, 2011. Forthcoming.

6.1.9. 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*.

6.1.10. 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 disincentivizes 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)*.

6.1.11. 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.

6.1.12. Investment in Privacy-Preserving Technologies under Uncertainty

Participants: Alain Bensoussan, Celine Hoe, Murat Kantarcioglu

Entrepreneurs face investment decisions on privacy-preserving technology (PPT) adoption as privacy-concerned consumers may decide whether to use firms' services based on the extent of privacy that firms are able to provide. Kantarcioglu et.al. (2010)[9] contributes to guide-lines for entrepreneurs' adoption decisions through a novel framework, which combines copula functions and a Stackelberg leader-follower game with consumers taking the role of the follower (referred as static-copula- game model hereafter). The valuation requires a clearly defined bivariate distribution function of two random variables, the consumer's valuation of private information and the consumer's profitability to a firm. Copula functions are used to construct the bivariate distribution function from arbitrarily univariate marginals with various dependence structures fitting into different market/industry segments. This study extends the static-copula-game model to include project value uncertainty, simultaneously considering different market competition structures and the regulatory promise of random arrival of government mandatory adoption. The project value from the static-copula-game model is used as an estimate of the initial (current) project value for the stochastic evolution. By doing so, we retain the advantages of applying copulas and preserve the established valuation property exclusively applicable to the valuation of

PPT adoption. The extension model makes several improvements including: (1) Reduce concerns about myopic PPT adoption decisions that may result when static valuation is employed. (2) Overcome the potential biased PPT adoption decision that may arise due to negligence of market competition impact. (3) Understand the regulatory influence of government mandatory adoption with uncertainty. We find that: (1) if one can link univariate marginals and dependence structures to industry groups, one can determine for which industries project value uncertainty has no impact on the entrepreneur's immediate PPT adoption decision. For these industries, there is no need for government intervention/regulation to accelerate/induce PPT adoption even though the project value is uncertain. (2) Under project value uncertainty, competition may suggest either a later or an earlier PPT adoption compared with the monopoly case. (3) The promise of government mandatory adoption has the potential to accelerate PPT adoption. The PPT adoption guidelines considering competition and regulatory promises of government mandatory adoption when the project value is uncertain bring useful recommendations to both entrepreneurs and policymakers.

Bensoussan, A., S. Hoe and M. Kantarcioglu Investment in Privacy-Preserving Technologies under Uncertainty, *GamSec 2011, LNCS Vol 7037*.

6.2. Activities in the Supply Chain Domain

6.2.1. Partially Observed Inventory Systems

Participants: Alain Bensoussan, Metin Çakanyildirim and Suresh Sethi

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.

Bensoussan, A., M. Çakanyildirim, J.A. Minjarez-Sosa, S.P. Sethi, and R. Shi. An Incomplete Information Inventory Model with Presence of Inventories or Backorders as Only Observations, *Journal of Optimization Theory and Applications*, 146(3), (September 2010) pp. 544-580.

Bensoussan, A., Q. Feng, and S.P. Sethi. Achieving a Long-Term Service Target with Periodic Signals: A Newsvendor Framework, *Manufacturing & Service Operations Management (MSOM)* (May 2010).

Bensoussan, A., M. Çakanyildirim, and S.P. Sethi. Filtering for Discrete-Time Markov Processes and Applications to Inventory Control with Incomplete Information, *Handbook on Nonlinear Filtering*, D. Crisan and B. Rozovsky (Eds.), Oxford University Press (April 2011) pp. 500-525.

Bensoussan, A., M. Çakanyildirim, J.A. Minjarez-Sosa, S.P. Sethi, and R. Shi. Computation of Approximate Optimal Policies in Partially Observed Inventory Model with Rain Checks, *Automatica*, 47(8), (27 July 2011 online), pp. 1589-1604.

6.2.2. 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*, World Scientific. Forthcoming.

6.2.3. Optimal Policy and Value of Information in an Inventory Model with Lost Sales and Demand Updates

Participants: Alain Bensoussan, Metin Çakanyildirim, Qi Feng, Suresh Sethi

Under many circumstances, demand observations are often censored due to the lack of tracking lost sales caused by stock outs. To understand the impact of the lost sales information on the ordering decisions, a periodic-review inventory model is formulated in which only the sales information is obtained immediately upon the realization of the demand. Subsequently, the lost sales information is obtained after a delay. In the resulting model, an optimal policy, if exists, reveals a very complex structure. By decomposing the derivative of the value function, we demonstrate two different roles of inventory in our model: satisfying the demand and deducing the demand information. We show that the optimal inventory levels under the delayed observation of the lost sales are always higher than those for which the demands are fully observed. Moreover, as illustrated in numerical examples, the optimal policy possesses a counterintuitive behavior with respect to the problem parameters. To understand the key drivers of the optimal decisions, we further compare the costs under different demand observations. Two important observations are made. First, a lower cost is obtained when the realized demand is observed than when the demand is only observed to be higher than that level, and, furthermore, the cost difference represents the value of demand information. Second, if the demand observation is censored, improved demand information may not always be desirable as it may actually lead to an increased expect cost.

6.2.4. Transshipment Price Negotiation and Coordination of Two Independent Retailers

Participants: M. Çakanyildirim, K. Stecke and N. Çömez

Transshipments among two retailers ordering from a manufacturer at the beginning of a season are studied. Retailers consider sending transshipments one-by-one in each period during the season. They also compete for demand as an unsatisfied customer at a retailer may visit another retailer. We prove that retailers can maximize their profits without making any transshipment before a stock out. For each period and inventory levels, we construct a transshipment price interval, all of whose members coordinate transshipment decisions. We map this price characterization to a threshold- based transshipment policy for ease of implementation. We also illustrate a negotiation mechanism that leads to a unique price in the interval. Resulting transshipment prices can be static or dynamic depending on retailer powers, although the interval is always dynamic. Next, we provide a simple and transparent purchase cost sharing mechanism to coordinate orders for the case of static and coordinating transshipment price. This mechanism eliminates independent retailers' incentives to order too much by appropriately increasing the unit purchase cost. We show how this mechanism can be made Pareto-improving for retailers and illustrate profit improvements obtained by coordinating the orders in addition to transshipments. The transshipment prices, policies, and orders described above completely determine retailer actions. To our knowledge, this paper is the first to dynamically study independent retailers' transshipment price negotiations or to hierarchically address the coordination of transshipments and orders.

Some recently published papers on Transshipments:

Çömez, N., M. Çakanyildirim and K. Stecke. Optimal Transshipments and Reassignments under Periodic or Cyclic Holding Cost Accounting. *Journal of the Operational Research Society* Vol.64, 2013: 1517–1539

Çömez, N., K. Stecke, and M. Çakanyildirim. Multiple In-Cycle Transshipments with Positive Delivery Times. *Production and Operations Management*. Vol.21, No2, 2012: 378-395.

Çömez, N., K. Stecke, and M. Çakanyildirim. In-Season Transshipments among Competitive Retailers. *Manufacturing and Service Operations Management*. Vol.14, No.2, 2012: 290-300.

6.2.5. 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 together with the new product. We

study the interaction between product rollover strategies and strategic customers' purchase behavior. We find that single rollover is more valuable when the innovation of the new product is low and the number of strategic customers is high. Interestingly and counter to intuition, the firm may suffer from a high value disposal option for the old product.

C. Liang, M. Çakanyildirim and S. Sethi. Analysis of Product Rollover Strategies in the Presence of Strategic Customers. Forthcoming in *Management Science*.

6.2.6. 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.

6.2.7. 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.

6.2.8. 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 together with the new product. We study the interaction between product rollover strategies and strategic customers' purchase behavior. We find that single rollover is more valuable when the innovation of the new product is low and the number of strategic customers is high. Interestingly and counter to intuition, the firm may suffer from a high value disposal option for the old product.

6.2.9. 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, forthcoming.

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

Participants: Metin Cakanyildirim, Chao Liang, and Suresh P. Sethi

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.

Cakanyildirim, M., Liang, C., and Sethi, S.P., "Analysis of Product Rollover Strategies in the Presence of Strategic Customers," *Management Science*, 2013, forthcoming.

6.2.11. 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*, 2013, forthcoming.

6.2.12. 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*, 2013, forthcoming.
Procurement Flexibility under Price Uncertainty

6.2.13. 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, forthcoming.

6.2.14. 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.

6.2.15. 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

6.2.16. 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.

6.2.17. 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.

6.2.18. 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.

6.2.19. 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, Dedicated to Professor Charles Tapiero*, Fouad El Ouardighi and Konstantin Kogan (Eds.), Series 6161, Springer International Publishing Switzerland, 2013.

6.2.20. 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*. 41: 4: 373-376

6.2.21. 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 (Forthcoming in POMS)

6.2.22. 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. (Submitted to Management Science after a Minor Revision decision)

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

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

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**, Robustness of Order-up-to Policies in Lost-Sales Inventory Systems (Being revised for resubmission to *Operations Research* (Technical Note). Third round decision: Minor Revision [received in Fall 2013]).

6.2.24. 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^{\sharp} -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^{\sharp} -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 (Being revised for resubmission to *Operations Research*. Third round decision: Minor Revision [received in Summer 2013]).

6.2.25. 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 policies 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 2013.)

6.2.26. 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 (Submitted to *Management Science* in Summer 2013)

6.2.27. Understanding the Operational Impact of Minimum Support Prices in Agriculture

Participants: T. Rajapakshe, **M. Dawande and G. Janakiraman**

A minimum support price (MSP) for a crop is a guaranteed per-unit price, announced before the growing season, at which a governmental entity promises to procure the crop from farmers. An MSP for a crop is essentially a lever to enhance the input effort by the farming community in producing the crop and, thereby, its consumption by the population. MSPs for a wide variety of crops are currently in existence in many developing countries. The government's decision to offer an MSP (and its value) influences the input effort of the farmers (and, consequently, production) and the quantities they choose to sell to the government and in the open market. In turn, the government's MSP decision takes into consideration this reaction of the farmers. We consider a sequential game between a homogenous farming community (that is engaged in a

Cournot game) and a social planner. The social planner decides the MSP for a crop, after which each farmer decides the input effort in the presence of yield uncertainty (i.e., the ratio of crop output to input effort). Then, the yield uncertainty is realized and the farmers simultaneously decide how much to sell in the market and how much to sell to the government. The social planner distributes the quantity procured under the MSP, either for free or at a subsidized price, to a homogenous population. Under this setting, we investigate the following main questions with the help of both analytical results and numerical computations: (i) When should the social planner offer an MSP? (ii) How do the production cost and the magnitude of yield uncertainty affect the farmers' production and selling decisions under an MSP? (iii) What is the impact of an MSP on the total consumption by the population? and (iv) What is the impact of an MSP on the social utility?

An MSP for a crop is a governmental intervention that affects the farming community as well as the consuming population. As such, in reality, the decisions about whether or not to offer an MSP and its value are susceptible to non-quantifiable forces, such as demographic pressures and political compulsions. Therefore, our aim in this paper is not necessarily to explain practice, but to take the first steps in deriving analytically-supported insights about MSP programs.

T. Rajapakshe, **M. Dawande** and **G. Janakiraman**, Understanding the Operational Impact of Minimum Support Prices in Agriculture (Submitted to *POMS* in October 2013)

6.2.28. Overbooking Limits for a Two-Dimensional Cargo Problem

Participants: L. Moussawi, and M. Çakanyildirim.

This article considers a two-dimensional cargo overbooking problem, with the objective of finding the optimal weight and volume overbooking limits that maximize the profit from shipping cargos on a particular flight. The pricing structure is nonlinear because it uses the chargeable weight of the showing up cargo, as implemented in practice, as opposed to the approximate additive structure considered in the literature. An aggregate formulation that does not require much data is provided and solved under infinite and finite booking requests. The optimal overbooking curve is shown to be a 'box', defined by only two threshold numbers, one for volume and one for weight. Furthermore, the aggregate formulation can be solved efficiently and its simple 'box' solution can be implemented with ease by air cargo practitioners. The aggregate formulation is then compared to the detailed or actual overbooking formulation, in which the revenues are computed individually cargo by cargo. Using real-life data, we show that our model approximates well the actual cargo problem, when the density of the cargo shipped is not highly variable, more specifically, when it ranges between 6.2 and 16.2 lb/ft³, which is the case for high-technology, low density products such as computers and consumer electronics. We find that this applies to 60 per cent of the flights. Also, we compare our model to the additive one, and numerically prove that savings up to 13.8 per cent can be achieved when implementing the aggregate model as opposed to the existing additive model.

Moussawi, L. and M. Çakanyildirim. Optimal Overbooking Limits for a Two-Dimensional Cargo Problem. *Journal of Revenue and Pricing Management*. Forthcoming.

6.2.29. 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.

6.2.30. 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.

6.2.31. 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.

6.3. Activities in Finance and Economics

6.3.1. Real Options and Game Models

Participants: Alain Bensoussan, David Diltz and 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

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. *Incremental Investment and Singular Control*, IOS Press, 2012

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

Participants: Alain Bensoussan, Hongwei Long, Sandun Perera, Suresh 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., H. Long, S. Perera and S. Sethi, 2012 Impulse Control with Random Reaction Periods: A Central Bank Intervention Problem*. *Operations Research Letters* 40(6) 425-430.

*This article under the title "Market-Reaction-Adjusted Optimal Central Bank Intervention Policy in a Foreign Exchange Market," was awarded the second place in INFORMS FSS Best Student Research Paper Competition 2012.

6.3.4. Credit Risk with Selection of Effort and Volatility

Participants: A. Bensoussan, A. Cadenillas, H.K. Koo and J. Sung

One considers a bank which lends money to an investor. The investor selects effort and projects. One computes the choice of decisions. In addition, one wants to compute the fair amount of money that the bank should charge the investor for lending him/her money. We also consider ambiguity in the parameters and look for robust solutions. We solve this problem with a new approach to Dynamic Programming. We do not try to solve it directly, but indirectly via the martingale method.

Bensoussan, A., A. Cadenillas, H-K Koo *Entrepreneurial Decisions on Effort and Project Risk with a non concave objective function*

6.3.5. 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.

6.4. Activities in Alternative Energies

6.4.1. 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.

A first paper has been published, concerning the model without seasonality. A second one covering seasonality is submitted to SERRA.

Bensoussan A., Bertrand P.R. and Brouste Alexandre "*Forecasting the Energy produced by a Windmill on a Yearly Basis*", SERRA, 2012

Bensoussan A., Bertrand P.R., Brouste Alexandre and Haouas Nabiha
Impact of Seasonality on Forecasting the Energy produced by a Windmill

6.5. Activities in Risks on Technical Systems

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

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

6.5.2. 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, 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

2012

- Forecasting the Energy Produced by a Windmill on a Yearly Basis, *Stochastic Environmental Research and Risk Assessment (SERRA)*, vol 26, Issue 8, pp1109-1122, Springer-Verlag with P. BERTRAND and A. BROUSTE. ISSN: 1436-3240
- Existence and Compactness for Weak Solutions to Bellman Systems with Critical Growth, *AIMS Journals (DCDS-B)*, vol. 17, no. 6, (September 2012, online May 2012) with M. BULÍČEK and J. FREHSE. ISSN: 1729-1750
- Nash and Stackelberg Differential Games, *Chinese Annals of Mathematics, Series B.*, vol. 17 no. 6 (May 29, 2012), 317-332, Springer-Verlag, with J. FREHSE and J. VOGELGESANG
- Obtaining the Critical Excitation for Elasto-Plastic Oscillators by Solving an Optimal Control Problem (In Memoriam of Drumi Bainov), *Communications in Applied Analysis*, V. 16 no. 4, (October, 2012) 589-608 with K. CHANDRASEKHARAN, J. TURI 1083-2564
- Discrete-Time Inventory Problems with lead-Time and Order Time Constraint, *Optimization, Control and Applications of Stochastic Systems - In Honor of Onésimo Hernández-Lerma*, D. Hernández-Hernández, J. Adolfo Minjárez-Sousa (EDS) (August 14, 2012) pp 13-29, with L. BENKHEROUF. [Book Chapter](#)
- Long Cycle Behavior of the Plastic Deformation of an Elasto-Perfectly-Plastic Oscillator with Noise, *Comptes Rendus de l'Académie Des Sciences Mathématique*, Vol 350 (2012) 853-859 with L.MERTZ and S.C.P. YAM.
- Asymptotic Analysis of Stochastic Variational Inequalities Modeling an Elastic-Plastic Problem with Vanishing Jumps, *Asymptotic Analysis* 80 (2012) 171-187 with H. JASSO-FUENTES, S. MENOZZI, L. MERTZ
- Existence and Uniqueness of Solutions for a Partially Observed Stochastic Control Problem, *Stochastic Process, Finance and Control, A Festschrift in Honor of Robert J. Elliot, S. Cohen, D. Madan, T. Siu, H. Yang (Eds.)* World Scientific Publishing Co. (Sept, 28, 2012) 393-414 with . M. ÇAKANYLDIRIM, M. LI, S. P. Sethi [Book Chapter](#)
- Threshold-Type Policies for Real Options Using Regime-Switching Models, *SIAM Financial Math* Vol 3, Issue 1, (Oct 18, 2012) 667-689, with Z. YAN, G. YIN.
- Impulse Control with Random Reaction Periods: A Central Bank Intervention Problem, *Operations Research Letters* (Nov. 2012) Vol. 40, Issue 6, pp 425-430. Elsevier Publisher, with H. LONG, S. PERERA, S.P. SETHI ISSN: 0167-6377
- Control Inventories with Markov Demand, *Springer Proceedings in Mathematics & Statistics: Stochastic Analysis and Related Topics-In Honor of Ali Süleyman Üstünel*, L. Decreusefond, J. Najim (EDS) Heidelberg: Springer with (August 4, 2012) 29-55. ISBN: 3642299814 [Book Chapter](#)
- 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.
- A Game Theoretical Analysis of Lemonizing Cybercriminal Black Markets, *Proceedings of GameSec-Decision and Game Theory for Security*, Budapest, Hungary (Nov 2012), pp 66-67 with C. HOE, M. KANTARCIOGLU.
- Studying Dynamic Equilibrium of Cloud Computing Adoption with Application of Mean Field Game, *Allerton Conference on Communication, Control and Computing.*, Monticello, IL (Oct 2012) with S. HOE, M. KANTARCIOGLU.

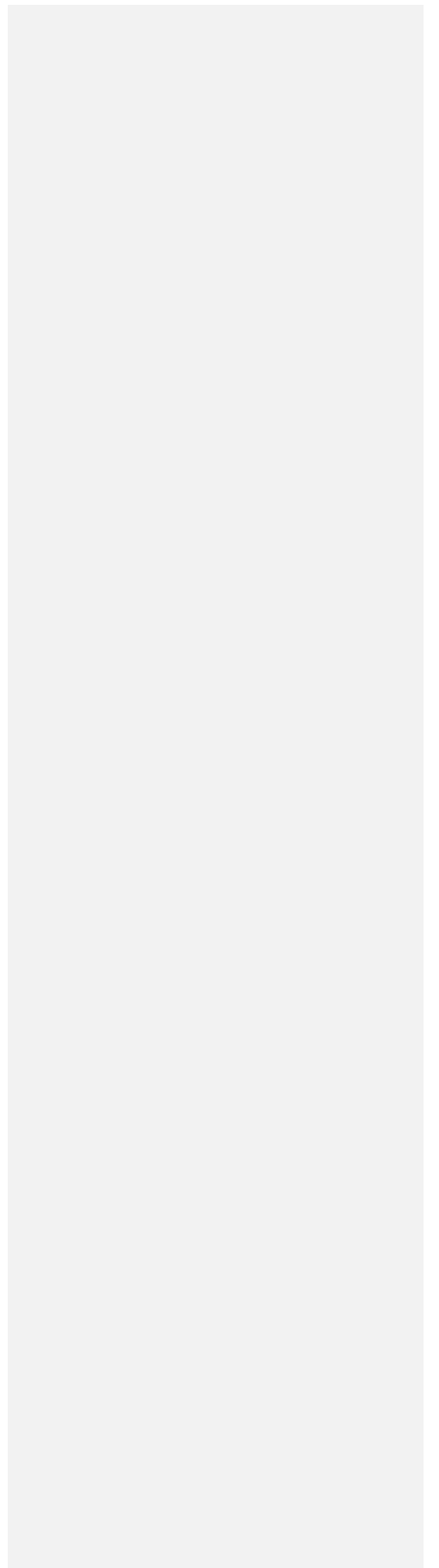
2013

- Forecasting Renewable Energy with Intermittency, with P. BERTRAND, A. BROUSTE, N. HAOUAS, M. FHIMA, D. KOULIBALY, *ESAIM P & S (European Series in Applied & Industrial Mathematics – Probability & Statistics)*, 2013
- Optimal Inventory Control with Shrinkage and Observed Sales - In Memory of Michael Taksar, with M. ÇAKANYLDIRIM, M. LI, S. P. Sethi, *Stochastics: An International Journal of Probability and Stochastic Processes*, 2013
- Linear Quadratic Differential Games with Mixed Leadership: The Open-Loop Solution, “*Numerical Algebra Control and Optimization (NACO) Special Issue for Professor George Leitmann,*” AIMS, March 2013, V. 3, Issue 1, pp 95-108 ISBN: 2155-3289, with S. CHEN, S.P. SETHI
- Control and Nash Games with Mean Field Effect, *Chinese Annals of Mathematics*, (Dedicated to J.L. Lions), Series B, April 28, 2013, V. 34B (1/2), pp 161 -192, with J. FREHSE Springer-Verlag ISSN: 0252-9599
- Feedback Stackelberg Solutions of Infinite-Horizon Stochastic Differential Games, “*Models and Methods in Economics and Management Sciences,*” (Dedicated to Professor Charles Tapiero, Fouad El Ouardighi and Konstantin Kogan (EDS), with S. CHEN and S.P. SETHI, 2013, Series 6161, Springer International Publishing, Switzerland
- Unemployment Risks and Optimal Retirement in an Incomplete Market, *Chinese International Conference in Finance*, July 10-13, 2013, Shanghai, China with B.-G. JANG, S. PARK
- Feedback Stackelberg Solutions of Infinite-Horizon Stochastic Differential Games, “*9th International Society of Dynamic Games (ISDG) Workshop,*” Barcelona, Spain (July 5-6, 2013) with S. CHEN, S. P.SETHI
- Feedback Stackelberg Solutions of Infinite-Horizon Stochastic Differential Games, “*INFORMS, Applied Probability Society Conference,*” San Jose, Costa Rica, July 15-17, 2013 with S. CHEN, S. SETHI
- Linear-Quadratic Time-Inconsistent Mean Field Games, “*Dynamic Games and Applications*” Vol 2, Issue 2, Springer, Birkhäuser, (July 16, 2013) with K.C. J. SUNG and P. YAM. ISSN: 2153-0785
- Optimizing Production and Inventory Decisions in a Supply Chain with Lot Size, Production Rate and Lead Time Interactions, *Applied Mathematics and Computation*, 224, Elsevier (2013) pp 150-165 with HUA-MING SONG and HUI YAN
- The Maximum Principle for Global Solutions of Stochastic Stackelberg Differential Games, *INFORMS*, Minneapolis, Minnesota, October 6-9, 2013, [Presentation](#): SHAOKUAN CHEN

Loooooooooooo

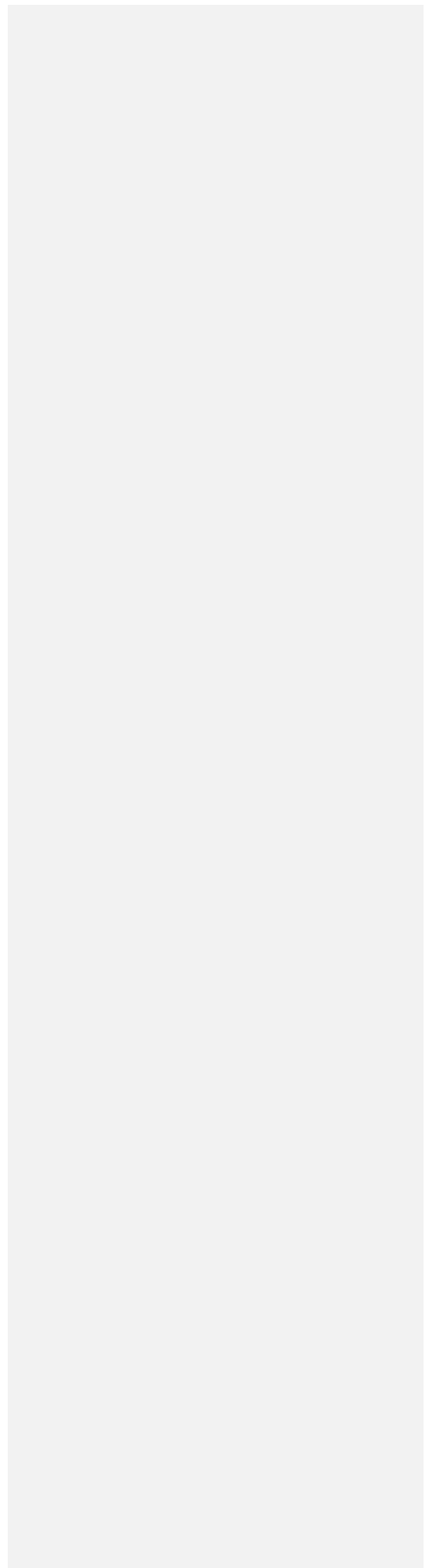
Looooo

Loooooooooooo

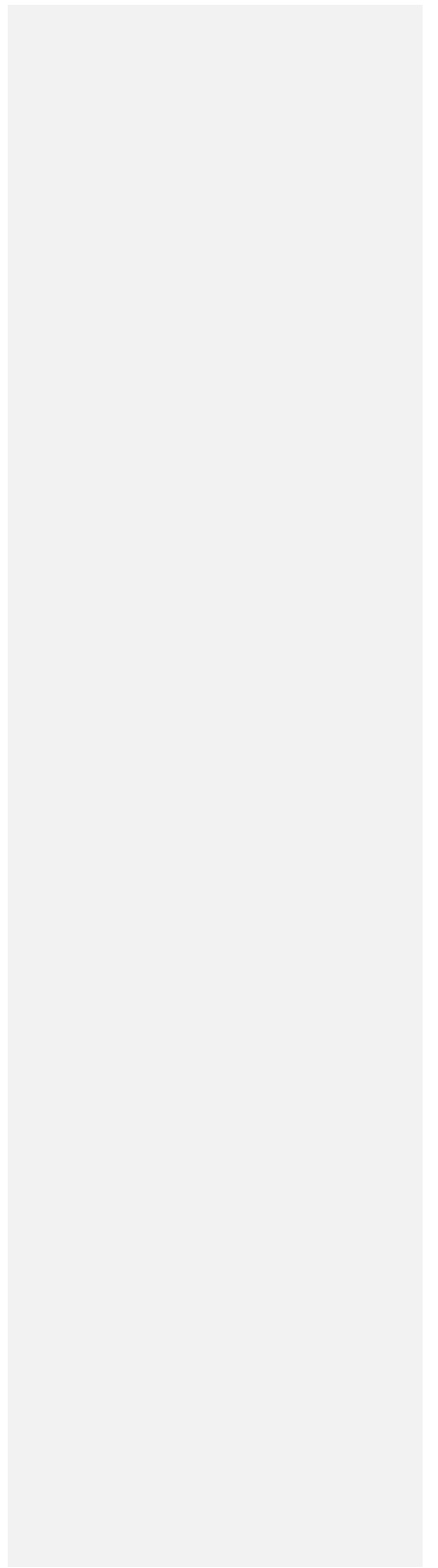


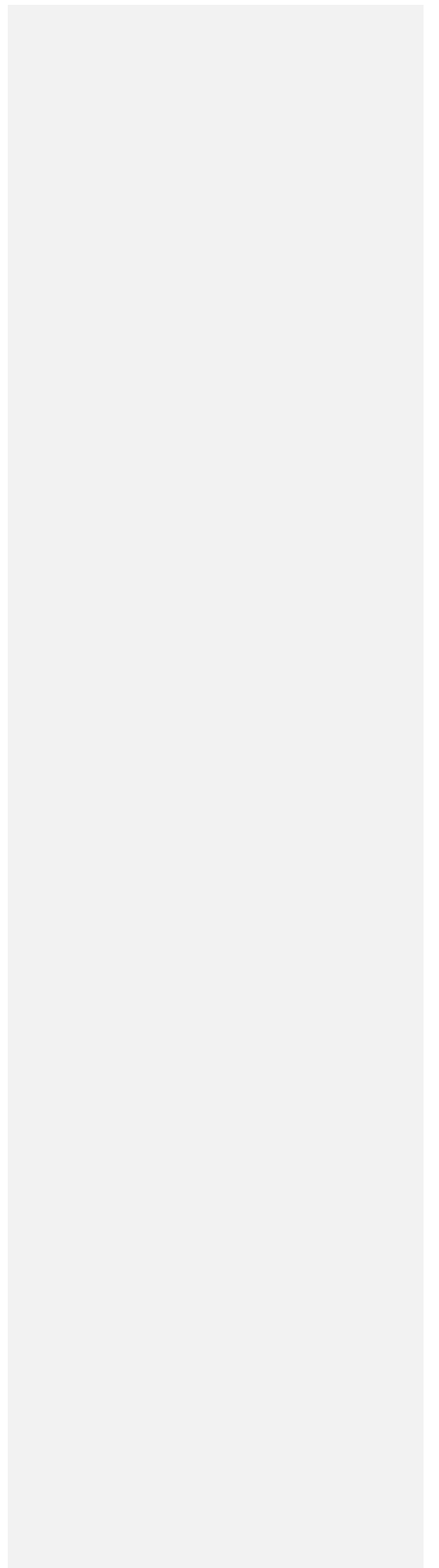
Loooooooo

Loooooooooooo



9. UT News Announcement of NSF Grant





10. ICDRiA ADVISORY BOARD

FACULTY		TITLE
Bensoussan	Alain	Distinguished Professor / Dir. of ICDRiA
Cakanyildirim	Metin	Professor - Management
Cavusoglu	Huseyin	Associate Professor - Management
Flannery	Carole	Sr. Lecturer Management
Gnade	Bruce	VP for Research
Janakiraman	Ganesh	Professor - Management
Kantarcioglu	Murat	Assistant Professor - Computer Science
Katok	Elena	Ashbel Smith Professor - JSOM
Kieschnick	Robert	Assistant Professor - Management
Mookerjee	Radha	Clinical Professor - Management
Mookerjee	Vijay	Endowed Professor - Management
Muharremoglu	Alp	Associate Professor - Management
Nadin	Mihai	Ashbel Smith Professor - Arts & Humanities
Ozer	Ozalp	Professor - Management
Pirkul	Hasan	Dean - School of Management
Primbs	James	Associate Professor - Systems Engineering
Radhakrishnan	Suresh	Professor - Management
Raghunathan	Srinivasan	Professor - Management
Rajamani	Divakar	Clinical Professor
Rotea	Mario	Professor - Mechanical Engineering
Sarkar	Sumit	Ashbel Smith Professor - Academic Dir ICDRiA
Sethi	Suresh	Distinguished Professor - JSOM
Shah	Rajiv	Endowed Clinical Chair
Shapiro	Jonathan	Director - Research
Stecke	Kathryn	Ashbel Smith Professor - Operations
Thuraisingham	Bhavani M.	Professor - Computer Sciences
Turi	Janos	Professor - Mathematical Sciences
Vidyasagar	Sagar (Mathukumalli)	Professor - Systems Engineering
Wildenthal	Hobson	Executive VP & Provost
Zheng	Eric	Associate Professor - Management
INDUSTRY		
Barnett	Robert	
Bergeron	Rob	TRWD/DWU Integrated Pipeline Project
Carrier	John	President
Chemla	Jean-Marc	Ameriprise Financial Services, CRPC®, APMA

Guragai	Bishoram	Controller, DesigneRx Pharmaceuticals Inc.
Ho	Celine	
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
Mjjgal	Tahar	International Capital Managemetn Corp. (ICMC) Dir of Risk management and Technical Analyst
Olah	Laslo	President/CEO
Parry	Daniel	Chief Credit Officer
Ratnam	Arun	
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
Turi	Greg	Valspar, Demand Planner
Vignal	Jean Paul	Partner
White	Chris	Director of Development/ViaSim Solutions
INVITEES		
Dearing	Ron	Clinical Professor - Math
Mukherjee	Ashok	Director - Modira, Inc.
Starks	Laura	President, Starks Energy
ICDRiA	STUDENTS	
Chen	Shaokuan	PhD Student & TA
Kadiyala	Bharadway	PhD Candidate in Mgmt Sciences
Meng	Li	PhD
Sandun	Perera	PhD Candidate in Mgmt Sciences
Skaaning	Sonny	PhD Student in Mathematics
Zhou	Ming	Visiting Professor