## Course developed Spring/Summer 1999

## Updated Sep 2000; Dec 2000; Feb 10, 2007; Dec 21, 2018; Jan 26, 2019; Mar 11, 2020; Nov 11, 2021; Dec 20, 2021

**Game Theory and Risk Analysis**

University of Stavanger

Faculty of Science and TechnologyUniversity of Stavanger4036 Stavanger, Norway

kjell.hausken@uis.no

https://www.uis.no/article.php?articleID=73839&categoryID=11198

**Instructor:** Kjell Hausken

**Room** To be announced

**Time** Tuesday and Thursday 12:15-14:00

**Credit points:** 10

**Students** For PhD/MSc students

**Admission:** Mzz in mathematics, Mzz in calculus and linear algebra, Mzz in probability theory, Mzz in stochastic theory, Mzz in economics

# Course description

When people and businesses pursue their interests in competition or collaboration with others, they play a game. In a game, the players have to think through how their own choices affect the choices of others. This gives rise to strategic behavior. Game theory is the economists' theory of strategic behavior. By using game theory one can reach a deeper understanding of economic interaction. In any situation where people act strategically to achieve their goals, game theory can help us both to predict behavior, and to understand the types of outcomes that are stable, what we call equilibrium. Game theory is one of the most important analytical tools for economists today. Game theory requires at least two players, that at least one player has a strategy set (a range of strategies) consisting of at least two strategies, and that each player's payoff (utility, reward) depends on the strategies chosen by all players. Most real-world decisions involve interaction with others. This course exposes us to competitive and cooperative behavior when several players (individuals, groups, firms, countries, etc.) with conflicting, mixed, or overlapping interests must interact.

The course focuses on risk analysis by illustrating situations faced by strategically interacting players involved in accidents, catastrophes, crises, disasters, emergencies, hazards, terrorism, where phenomena related to reliability, risk, safety, security, uncertainty, vulnerability are involved. At the individual level actors’ attitude towards risk is described, and what kind of interaction can take place between individuals or groups of individuals who one-sidedly choose non-compatible strategies under uncertainty and incomplete information about surrounding parameters, utility (payoffs), and preferences. The collective implications of individual strategies are described, and what strategies can be chosen to trigger or dampen crises and conflicts. At the collective or societal level is described how premises or pre-conditions can be laid to create incentives for individuals to behave compatibly with individual and societal safety.

### **Learning outcome**

Knowledge:
Students will become able to explain and understand key game theoretical and risk analysis concepts and models, and apply these to real world situations at the individual, group, and societal levels.

Skills:
Students will acquire abilities to apply game theory and risk analysis to analyze phenomena involving competition, coordination, collaboration, cooperation, conflict, mixed motives, deception, attack, and protection.

General competence:

Game theory is used to understand situations where people and/or firms act strategically to achieve their well-defined goals. After completing the course, students will have a deeper understanding of strategic behavior, equilibrium, and risk.

### **Contents**

The first part of the course discusses game theoretical assumptions about human behavior, and what it takes to call a situation a game. Students are then introduced to the Nash equilibrium, mixed strategies, extensive games, and repeated games. Game theory is thereafter combined with probabilistic risk analysis, and applied to the precautionary principle, interdependent systems, information security, infrastructures, multi-state systems, individual components and overarching structures, special versus general protection and attack, terrorism, natural disasters, other hazards, protection of infrastructures through time, protection towards strategic threats in repeated games, and stockpiling.

### **Prerequisites**

Mzz in mathematics, Mzz in calculus and linear algebra, Mzz in probability theory, Mzz in stochastic theory, Mzz in economics

### Recommended previous knowledge

MØA120 Microeconomic Analysis

### **Exam**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Weight** | **Duration** | **Marks** | **Aid** |
| Written exam | 1/1 | 4 hours | A - F | Valid calculator |

**Coursework requirements**

Weekly assignments

Information about the coursework requirement will be published on Canvas.

### **Subject teacher(s)**

**Course teacher**

Kjell Hausken

**Course coordinator**

Kjell Hausken

### **Method of work**

Teaching will take the form of lectures.

Expected workload: 250-300 hours.

### **Open to**

UiS – PhD program

UiS International program

Business Administration - Master of Science

### **Course assessment**

Student evaluation will be carried out in accordance with the UiS evaluation system.

### **Literature**

The textbook for the course is the following book designed for the graduate level. The book presents the main topics of game theory at a level suitable for our purposes and emphasizes the theory’s foundations as well as recent topics in game-theoretic research. It provides precise definitions and full proofs of a broad range of results. The notation and mathematical definition in the book are standard:

Osborne, M.J. and Rubinstein, A. (1994), A Course in Game Theory, MIT Press, Cambridge, https://arielrubinstein.tau.ac.il/books/GT.pdf.

Two optional books for the course are Osborne (2003) designed for the undergraduate level and Watson (2013) designed for advanced undergraduates:

Osborne, M.J. (2003), Introduction to Game Theory, Oxford University Press, Oxford, http://pioneer.netserv.chula.ac.th/~ptanapo1/gamebook.pdf.

Watson, J. (2013), Strategy, an Introduction to Game Theory. Third Edition, W. W. Norton & Company, New York, NY.

The literature for risk analysis is listed below.

This listed study program for 2020/2021 is subject to change.

### FACTS

**Course code:** PhDzzz, MSczzz

**Credits (ECTS):** 10

**Semester tuition start:** Autumn

**Number of semesters:** 1

**Exam semester:** Autumn

**Language of instruction:** English

**Offered by:** UiS

# Course Schedule

**Week 1: Introduction and Nash Equilibrium**

Required reading

Introduction: Chapter 1 in Osborne and Rubinstein (1994:1-8).

Nash Equilibrium: Chapter 2 in Osborne and Rubinstein (1994:9-30).

Optional reading

Nash Equilibrium: Theory, Chapter 2 in Osborne (2003:11-52).

Nash Equilibrium: Illustrations, Chapter 3 in Osborne (2003:53-96).

**Week 2: Mixed Strategy Equilibrium**

Required reading

Mixed, Correlated, and Evolutionary Equilibrium: Chapter 3 in Osborne and Rubinstein (1994:31-52).

Rationalizability and Iterated Elimination of Dominated Actions: Chapter 4 in Osborne and Rubinstein (1994:53-66).

Knowledge and Equilibrium: Chapter 5 in Osborne and Rubinstein (1994:67-86).

Optional reading

Mixed Strategy Equilibrium, Chapter 4 in Osborne (2003:97-150)

**Week 3: Extensive Games with Perfect Information**

Required reading

Extensive Games with Perfect Information: Chapter 6 in Osborne and Rubinstein (1994:87-116).

Bargaining Games: Chapter 7 in Osborne and Rubinstein (1994:117-132).

Optional reading

Extensive Games with Perfect Information: Theory, Chapter 5 in Osborne (2003:151-178)

Extensive Games with Perfect Information: Illustrations, Chapter 6 in Osborne (2003:179-200).

Extensive Games with Perfect Information: Extensions and Discussion, Chapter 7 in Osborne (2003:201-234).

**Week 4: Repeated Games**

Required reading

Repeated Games: Chapter 8 in Osborne and Rubinstein (1994:133-162).

Complexity Considerations in Repeated Games: Chapter 9 in Osborne and Rubinstein (1994:163-176).

Implementation Theory: Chapter 10 in Osborne and Rubinstein (1994:177-196).

Optional reading

Repeated games: The Prisoner’s Dilemma, Chapter 14 in Osborne (2003:389-410)

Repeated games: General Results, Chapter 15 in Osborne (2003:411-420)

Hausken, K. (2005), “The Battle of the Sexes when the Future is Important,” Economics Letters 87, 1, 89-93.

**Week 5: Extensive Games with Imperfect Information**

Required reading

Extensive Games with Imperfect Information: Chapter 11 in Osborne and Rubinstein (1994:197-218).

Sequential Equilibrium: Chapter 12 in Osborne and Rubinstein (1994:219-254).

**Week 6: Game Theory and Digital Currencies**

Wang, G. and Hausken, K. (2021), “Governmental Taxation of Households Choosing Between a National Currency and a Cryptocurrency,” Games 12, 2, 1-26, Article 34; <https://doi.org/10.3390/g12020034>.

Wang, G. and Hausken, K. (2021), “Conventionalists, Pioneers and Criminals Choosing Between a National Currency and a Global Currency,” Manuscript, University of Stavanger.

Wang, G. and Hausken, K. (2021), “A Game Between Central Banks and Households Involving Central Bank Digital Currencies, Other Digital Currencies and Negative Interest Rates,” Manuscript, University of Stavanger.

Wang, G. and Hausken, K. (2021), “Central Bank Digital Currencies, Other Digital Currencies and Negative Interest Rates, University of Stavanger.

**Week 7: Game Theory and Probabilistic Risk Analysis**

Hausken, K. (2002), “Probabilistic Risk Analysis and Game Theory,” Risk Analysis 22, 1, 17-27.

**Week 8: The Precautionary Principle, Game Theory and Principal Agent Theory**

Hausken, K. (2018), “Formalizing the Precautionary Principle Accounting for Strategic Interaction, Natural Factors, and Technological Factors,” Risk Analysis 38, 10, 2055-2072.

Hausken, K. (2019), “Principal Agent Theory, Game Theory and the Precautionary Principle,” Decision Analysis 16, 2, 105–127.

Hausken, K. (2020), “The Precautionary Principle and Game Theory,” in Engemann, K.J. and Abrahamsen, E.B. (eds.), Safety Risk Management: Integrating Economic and Safety Perspectives, Walter de Gruyter, Berlin/Boston, pages 55-74.

Hausken, K. (2021), “The Precautionary Principle as Multi-Period Games Where Players Have Different Thresholds for Acceptable Uncertainty,” Reliability Engineering & System Safety, 206, Article 107224, 10 pages, <https://doi.org/10.1016/j.ress.2020.107224>.

**Week 9: Game Theory and Information Security**

Required reading

Hausken, K. (2007), “Information Sharing among Firms and Cyber Attacks,” Journal of Accounting and Public Policy 26, 6, 639-688.

Hausken, K. (2017), “Security Investment, Hacking, and Information Sharing Between Firms and Between Hackers,” Games 8, 2, 23 pages, doi: 10.3390/g8020023.

Hausken, K. (2020), “Cyber Resilience in Firms, Organizations and Societies,” Internet of Things 11, Article 100204, 9 pages, <https://doi.org/10welburn.1016/j.iot.2020.100204>.

Pala, A. and Zhuang, J. (2019), “Information Sharing in Cybersecurity: A Review,” Decision Analysis 16, 3, 157-237.

Optional reading

Hausken, K. (2009), “Security Investment and Information Sharing for Defenders and Attackers of Information Assets and Networks,” in Rao, H.R. and Upadhyaya, S.J. (eds.), Information Assurance, Security and Privacy Services, Handbooks in Information Systems, Volume 4, ISBN 978-1-84855-194-7, ISSN 1574-0145, Emerald Group Pub Ltd, United Kingdom, 503-534.

Hausken, K. (2014), “Returns to Information Security Investment: Endogenizing the Expected Loss,” Information Systems Frontiers 16, 2, 329-336.

Hausken, K. (2015), “A Strategic Analysis of Information Sharing Among Cyber Attackers,” Journal of Information Systems and Technology Management 12, 2, 245-270.

Hausken, K. (2017), “Information Sharing Among Cyber Hackers in Successive Attacks,” International Game Theory Review 19, 2, 1750010, 33 pages, doi: 10.1142/S0219198917500104.

Hausken, K. (2018), “Proactivity and Retroactivity of Firms and Information Sharing of Hackers,” International Game Theory Review 20, 1, 1750027, 30 pages, doi: 10.1142/S021919891750027X.

Hausken, K. and Welburn, J.W. (2020), “Attack and Defense Strategies in Cyber War Involving Production and Stockpiling of Zero-Day Cyber Exploits,” Information Systems Frontiers 23, 6, 1609-1620.

Levitin, G., Hausken, K., Taboada, H.A., and Coit, D.A. (2012), “Data Survivability vs. Security in Information Systems,” Reliability Engineering & System Safety 100, 19-27.

Wang, G., Welburn, J.W. and Hausken, K. (2020), “A Two-Period Game Theoretic Model of Zero-Day Attacks with Stockpiling,” Games 11, 4, 1-26, Article 64, <https://doi.org/10.3390/g11040064>.

**Week 10: Game Theory and Risk in Interdependent Systems and Substitution Effects**

Required reading

Hausken, K., 2006. Income, Interdependence, and Substitution Effects Affecting Incentives for Security Investment. Journal of Accounting and Public Policy 25, 6, 629-665.

Hausken, K. (2019), “Defense and Attack of Complex Interdependent Systems,” Journal of the Operational Research Society 70, 3, 364–376.

Kunreuther, H., Heal, G., 2003. Interdependent Security. The Journal of Risk and Uncertainty 26, 2/3, 231-249.

Optional reading

Enders, W., Sandler, T., 2003. What do we know about the substitution effect in transnational terrorism? in A. Silke and G. Ilardi (eds) Researching Terrorism: Trends, Achievements, Failures (Frank Cass, Ilfords, UK), <http://www-rcf.usc.edu/~tsandler/substitution2ms.pdf>

Hausken, K. (2017), “Defense and Attack for Interdependent Systems,” European Journal of Operational Research 256, 2, 582-591, doi: 10.1016/j.ejor.2016.06.033.

Lakdawalla, D., Zanjani, G., 2002. Insurance, Self-Protection, and the Economics of Terrorism. Ms., RAND and NBER Working Paper No. W9215, Federal Reserve Bank of New York.

Zhuang, J., Bier, V.M., Gupta, A. 2007. Subsidies in Interdependent Security With Heterogeneous Discount Rates, Engineering Economist, 52, 1, 1-19.

**Week 11: Game Theory, Economic and Financial Risk, and Financial Crises**

Hausken, K. and Pluemper, T. (2002), “Containing Contagious Financial Crises: The Political Economy of Joint Intervention into the Asian Crisis,” Public Choice 111, 3-4, 209-236.

Welburn, J.W. and Hausken, K. (2015), “A Game Theoretic Model of Economic Crises,” Applied Mathematics and Computation 266, 738-762.

Welburn, J.W. and Hausken, K. (2017), “Game Theoretic Modeling of Economic Systems and the European Debt Crisis,” Computational Economics 49, 2, 177-226, [https://rdcu.be/6gs9](http://em.rdcu.be/wf/click?upn=lMZy1lernSJ7apc5DgYM8cqYRF-2Bf8S4TgqGUMF9MsDo-3D_-2BN3wsIsqK-2B7Axsx6NPP9pvEfzF-2BXRI-2BaPlrqZY2p5Wqu3c0GzFgS7LjuQAE9zJdFvYXZW6R7EOjuGGGPDQEVbAc-2BILcM1q0tG5Zol63o1j3kXKG9AgIQSb2NWwZjqhXCeZ0PeW3vGojkTOj0-2F1snvXaXpxs-2BuYGqlr4IhVfkM9MzXMGAwmQ7Oiv24WAbg3fWSSWqKs1HGUKdEEZc5Rz47liIq8JA7Ax-2FpMW01kbAkACgekZH9hBMrueIh6acpBH4O8mKblzuvwQGqgoJwN7UzQ-3D-3D).

Hausken, K. and Welburn, J.W. (2020), “Assessing the 2010-2018 Financial Crisis in Greece, Portugal, Ireland, Spain, and Cyprus,” Journal of Economic Studies, Vol. ahead-of-print No. ahead-of-print. <https://doi.org/10.1108/JES-08-2020-0406>.

**Week 12: Game Theory, Companies, Governments, Risk Analysis**

Hausken, K. and Zhuang, J. (2016), “How Companies and Governments React to Disasters,” Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability 230, 4, 417-426.

Hausken, K. and Zhuang, J. (2013), “The Impact of Disaster on the Interaction Between Company and Government,” European Journal of Operational Research 225, 2, 363–376.

Hausken, K. and Zhuang, J. (2016), “The Strategic Interaction Between a Company and the Government Surrounding Disasters,” Annals of Operations Research 237, 1, 27-40.

Willigers, B.J.A., Bratvold, R.B. and Hausken, K. (2009), “A Game Theoretic Approach to Conflicting and Evolving Stakeholder Preferences in the E&P Industry,” SPE Economics & Management 1, 1, 19-26.

Willigers, B.J.A., Hausken, K., and Bratvold, R.B. (2010), “Uncertainty and Preferences in a Joint E&P Development Program Analyzed in a Game Theoretic Framework,” Journal of Petroleum Science and Engineering 74, 1-2, 88-98.

Willigers, B.J.A. and Hausken, K. (2013), “The Strategic Interaction Between the Government and International Oil Companies in The UK: An Example of a Country With Dwindling Hydrocarbon Reserves,” Energy Policy 57, 276-286.

**Week 13: Game Theory and the Protection of Infrastructures**

Required reading

Hausken, K. (2008), “Strategic Defense and Attack for Reliability Systems,” Reliability Engineering & System Safety 93, 11, 1740-1750.

Hausken, K. and He, F. (2016), “On the Effectiveness of Security Countermeasures for Critical Infrastructures,” Risk Analysis 36, 4, 711-726.

Hausken, K. and Levitin, G. (2012), “Review of Systems Defense and Attack Models,” International Journal of Performability Engineering 8, 4, 355-366.

Optional reading

Brown, G., Carlyle, M., Salmer´on, J. and Wood, K., 2006, Defending Critical Infrastructure, Interfaces 36, 530-544.

Hausken, K. and Bier, V. (2011), “Defending Against Multiple Different Attackers,” European Journal of Operational Research 211, 2, 370-384.

Hausken, K. (2008), “Strategic Defense and Attack for Series and Parallel Reliability Systems,” European Journal of Operational Research 186, 2, 856-881.

Hausken, K. (2008), “Whether to Attack a Terrorist’s Resource Stock Today or Tomorrow,” Games and Economic Behavior 64, 2, 548–564.

Hausken, K. (2010), “Whether to Attack Growing Assets and Enterprises Today or Tomorrow,” International Journal of Business Continuity and Risk Management 1, 4, 339-362.Hausken, K. (2010), “Tactical Identification of Wide Intruders,” Military Operations Research 15, 2, 51-60.

Patterson, S., Apostolakis, G., 2007. Identification of Critical Locations Across Multiple Infrastructures for Terrorist Actions. Reliability Engineering & System Safety 92, 9, 1183-1203.

**Week 14: Game Theory and Risk in Complex Multi-State Systems**

Required reading

Hausken, K. (2011), “Protecting Complex Infrastructures Against Multiple Strategic Attackers,” International Journal of Systems Science 42, 1, 11-29.

Hausken, K. and Levitin, G. (2009), “Minmax Defense Strategy for Complex Multi-State Systems,” Reliability Engineering & System Safety 94, 2, 577-587.

Optional reading

Hausken, K. (2010), “Defense and Attack of Complex and Dependent Systems,” Reliability Engineering & System Safety 95, 1, 29-42.

Levitin, G. and Hausken, K. (2008), “Protection vs. Redundancy in Homogeneous Parallel Systems,” Reliability Engineering & System Safety 93, 10, 1444-1451.

**Week 15: Game Theory and Risk for Individual Components and Overarching Structures, and Special versus General Protection and Attack**

Required reading

Hausken, K. (2014), “Individual vs Overarching Protection and Attack of Assets,” Central European Journal of Operations Research 22, 1, 89–112.

Hausken, K. (2017), “Special versus General Protection and Attack of Parallel and Series Components,” Reliability Engineering & System Safety 165, 239-256.

Levitin, G., Hausken, K., and Dai, Y. (2013), “Individual vs. Overarching Protection for Minimizing the Expected Damage Caused by an Attack,” Reliability Engineering & System Safety 119, 117-125.

Optional reading

Hausken, K. (2013), “Combined Series and Parallel Systems Subject to Individual versus Overarching Defense and Attack,” Asia-Pacific Journal of Operational Research 30, 2, 1250056 (33 pages).

Hausken, K. (2019), “Special Versus General Protection and Attack of Two Assets,” Operations Research and Decisions 29, 4, 53-93, DOI: 10.5277/ord190404.

Levitin, G. and Hausken, K. (2012), “Individual vs. Overarching Protection Against Strategic Attacks,” Journal of the Operational Research Society 63, 7, 969-981.

Levitin, G., Hausken, K., and Dai, Y. (2014), “Optimal Defense with Variable Number of Overarching and Individual Protections,” Reliability Engineering & System Safety 123, 81–90.

**Week 16: Balancing defense against terrorism, natural disaster, and other hazards**

Required reading

Bier, V. and Hausken, K. (2011), “Endogenizing the Sticks and Carrots: Modeling Possible Perverse Effects of Counterterrorism Measures,” Annals of Operations Research 186, 1, 39-59.

Hausken, K., Bier, V. and Zhuang, J. (2009), “Defending Against Terrorism, Natural Disaster, and All Hazards,” in Bier, V.M. and Azaiez, M.N. (eds.), Game Theoretic Risk Analysis of Security Threats, Springer, New York, 65-97.

Keohane, N., Zeckhauser, R.J., 2003. The Ecology of Terror Defense. The Journal of Risk and Uncertainty 26, 2/3, 201-229.

Optional reading

Glaeser, E.L., 2005. “The Political Economy of Hatred,” The Quarterly Journal of Economics, MIT Press, vol. 120(1), pages 45-86, January.

Lakdawalla, D. and Zanjani, G., 2002. Insurance, self-protection, and the economics of terrorism. Ms., RAND and NBER, Federal Reserve Bank of New York.

Zhuang, J., Bier, V., 2007, Balancing Terrorism and Natural Disasters - Defensive Strategy with Endogenous Attacker Effort, Operations Research 55, 5, 976-991.

**Week 17: Game Theory and the Protection of Infrastructures Through Time**

Required reading

Hausken, K. (2008), “Whether to Attack a Terrorist’s Resource Stock Today or Tomorrow,” Games and Economic Behavior 64, 2, 548–564.

Hausken, K. (2011), “Strategic Defense and Attack of Series Systems when Agents Move Sequentially,” IIE Transactions 43, 7, 483-504.

Optional reading

Hausken, K. (2011), “Game Theoretic Analysis of Two Period Dependent Degraded Multistate Reliability Systems,” International Game Theory Review 13, 3, 247-267.

Hausken, K. and Zhuang, J. (2011), “Governments’ and Terrorists’ Defense and Attack in a T-period Game,” Decision Analysis 8, 1, 46-70.

Hausken, K. and Zhuang, J. (2012), “The Timing and Deterrence of Terrorist Attacks due to Exogenous Dynamics,” Journal of the Operational Research Society 63, 6, 726-735.

**Week 18: Game Theory and Protection in Repeated Games**

Required reading

Hausken, K. and Levitin, G. (2010), “Defence of Homogeneous Parallel Multi-State Systems Subject to Two Sequential Attacks,” Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability 224, 3, 171-183.

Hausken, K. and Levitin, G. (2010), “Two Sequential Attacks of a Parallel System when Defense and Attack Resources are Expendable,” International Journal of Performability Engineering 6, 4, 343-354.

Optional reading

Levitin, G., Hausken, K., and Ben Haim, H. (2014), “False Targets in Defending Systems Against Two Sequential Attacks,” Military Operations Research 19, 1, 19-35.

Levitin, G. and Hausken, K. (2009), “Parallel Systems under Two Sequential Attacks,” Reliability Engineering & System Safety 94, 3, 763-772.

Levitin, G. and Hausken, K. (2012), “Parallel Systems under Two Sequential Attacks with Imperfect Detection of the First Attack Outcome,” Journal of the Operational Research Society 63, 11, 1545-1555.

**Week 19: Game Theory, Risk and Stockpiling**

Required reading

Hausken, K. and Zhuang, J. (2011), “Defending Against a Terrorist Who Accumulates Resources,” Military Operations Research 16, 1, 21-39.

Levitin, G. and Hausken, K. (2011), “Defense Resource Distribution Between Protection and Redundancy for Constant Resource Stockpiling Pace,” Risk Analysis 31, 10, 1632-1645.

Optional reading

Hausken, K. and Zhuang, J. (2011), “Defending Against a Stockpiling Terrorist,” The Engineering Economist 56, 4, 321-353.

Levitin, G. and Hausken, K. (2013), “Defence Resource Distribution Between Protection and Decoys for Constant Resource Stockpiling Pace,” Journal of the Operational Research Society 64, 9, 1409-1417.

**Week 20: Game Theory, Risk, and the Defense and Attack of Systems**

Required reading

Azaiez, N., Bier, V.M., 2007. Optimal Resource Allocation for Security in Reliability Systems. European Journal of Operational Research 181, 2, 773-786.

Bier, V.M., Nagaraj, A., Abhichandani, V., 2005. Protection of Simple Series and Parallel Systems with Components of Different Values. Reliability Engineering and System Safety 87, 315-323.

Bier, V.M., Oliveros, S., Samuelson, L., 2007. Choosing What to Protect: Strategic Defense Allocation Against an Unknown Attacker. Journal of Public Economic Theory 9, 4, 563-587.

Hausken, K. (2014), “Choosing What to Protect when Attacker Resources and Asset Valuations are Uncertain,” Operations Research and Decisions 24, 3, 23-44.

Hausken, K. and Levitin, G. (2008), “Efficiency of Even Separation of Parallel Elements with Variable Contest Intensity,” Risk Analysis 28, 5, 1477-1486.

Optional reading

Bier, V.M., 2004. Should the model for security be game theory rather than reliability theory. In Mathematical and Statistical Methods in Reliability (Wilson et al., editors), Series on Quality, Reliability and Engineering Statistics, World Scientific, Singapore, 2005, pages 17-28.

Levitin, G., 2003. Optimal allocation of multi-state elements in linear consecutively connected systems with vulnerable nodes, European Journal of Operational Research 150, 406-419.

Levitin, G., Dai, Y., Xie, M., Poh, K.L., 2003. Optimizing survivability of multi-state systems with multi-level protection by multi-processor genetic algorithm, Reliability Engineering and System Safety 82, 93-104.

**Week 21: Prospect theory**

Kahneman, D. and Tversky, A. (1979), “Prospect Theory: An Analysis of Decision Under Risk,” Econometrica 47,263-291.

Tversky, A. and Kahneman, D. (1979), “The Framing of Decisions and the Psychology of Choice,” Science 211, 453-458.

Tversky, A. and Kahneman, D. (1979), “Judgment under Uncertainty: Heuristics and Biases,” Science 185, 1124-1131.

Viscusi, W.K. and Chesson, H. (1999), “Hopes and Fears: The Conflicting Effects of Risk Ambiguity,” Theory and Decision 47, 153-178.

**Week 22: Bounded rationality**

Padgett, J.F. (1980), “Bounded Rationality in Budgetary Research,” American Political Science Review 74, 354-372.

Lindblom, C.E. (1959), “The Science of ‘Muddling Through’,” Public Administration Quarterly 19, 79-88.

Simon, H.A. (1955), “A Behavioral Model of Rational Choice,” Quarterly Journal of Economics 69, 99-118.

**Week 23: Game Theory, Rent Seeking and Additive Efforts**

Hausken, K. (2020), “Additive Multi-Effort Contests,” Theory and Decision 89, 2, 203-248.

Hausken, K. (2020), “Additive Multi-Effort Contests with Multiple Investment Opportunities,” Applied Economics Letters 27, 1, 67-71.

Hausken, K. (2021), “Axiomatizing Additive Multi-Effort Contests,” SN Business & Economics 1, 11, Article 159.

Hausken, K. (2021), “A Review of Axioms for Group Contest Success Functions,” Manuscript, University of Stavanger.

**Week 24: Game Theory and Media**

Hausken, K. (2019), “A Game Theoretic Model of Adversaries and Media Manipulation,” Games 10, 4, 1-15, Article 48, <https://doi.org/10.3390/g10040048>.

Hausken, K. (2020), “Game Theoretic Analysis of Ideologically Biased Clickbait or Fake News and Real News,” Operations Research and Decisions 30, 2, 39-57.

Hausken, K. (2021), “Theoretic Model of Adversaries and Media Manipulation: A Two-Period Extension,” International Game Theory Review Forthcoming.

**Week 25: Game Theory and Medical Decision Making**

Hausken, K. and Ncube, M. (2020), “Game Theoretic Analysis of Persons, the Pharmaceutical Industry, and Donors in Disease Contraction and Recovery,” Humanities & Social Sciences Communications 7, Article 150, 17 pages, <https://doi.org/10.1057/s41599-020-00626-4>.

Hausken, K. and Ncube, M. (2021), “Decisions of Persons, the Pharmaceutical Industry, and Donors in Disease Contraction and Recovery Assuming Virus Mutation,” Health Economics Review 11:26, 1-14, https://rdcu.be/cpN6W.

Hausken, K. and Ncube, M. (2021), “A Game Theoretic Analysis of Competition Between Vaccine and Drug Developers During Disease Contraction and Recovery,” Medical Decision Making Forthcoming.

**Week 26: Game Theory and the Dynamics of Terror Organizations**

Hausken, K. (2019), “The Dynamics of Terrorist Organizations,” Operations Research Perspectives, Volume 6, Article 100120, 14 pages, <https://doi.org/10.1016/j.orp.2019.100120>.

Hausken, K. (2019), “Governmental Combat of the Dynamics of Multiple Competing Terrorist Organizations,” Mathematics and Computers in Simulation 166, 33-55.

Hausken, K. (2020), “Governmental Combat of Migration Between Competing Terrorist Organizations,” Operations Research and Decisions 30, 3, 21-46.

Hausken, K. (2021), “Government Intervention to Combat the Dynamics of Terrorist Organizations,” Journal of the Operational Research Society 72, 1, 217-226.

Hausken, K. (2021), “Governments Playing Games and Combating the Dynamics of a Terrorist Organization,” International Game Theory Review 23, 2, 2050013, <https://doi.org/10.1142/S0219198920500139>.

**Week 27: Game Theory and the Value of a Player in n-Person Games**

Hausken, K. and Mohr, M. (2001), “The Value of a Player in n-Person Games,” Social Choice and Welfare 18, 3, 465-483.

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**Week 28: Tradeoffs between behavioral and economic views, self-interest, altruism, ideology**

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Epstein, R.A. (1996), “Catastrophic Responses to Catastrophic Risks,” Journal of Risk and Uncertainty 12, 287-308.

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**Week 30: Game Theory and Risk**

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**Week zzz: Game Theory, Civil War, Insurgent Attacks, and Government Protection**

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**Week zzz: Utilities and a decision oriented approach to risk analysis**

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*Possible topics for PhD project within risk analysis and game theory*

1. *Several players with different attitudes towards risk interact with each other in static and dynamic (over time) situations. These can be theoretically analyzed with prescriptive and descriptive analysis tools and investigated empirically. Just like mathematics, probability theory, and operational analysis are the most natural analysis tools in the engineering disciplines, game theory is a natural analysis tool when the behavioral dimension is involved. Game theory gained an important Nobel prize in economics in 1994, represents today the main core of microeconomics, and has found its place within most disciplines where the behavioral dimension is involved, for example biology, economics, evolutionary theory, finance, international relations, law, mathematical sociology, political science. The following 18 game theorists have received the Nobel Prize: Samuelson 1970, Arrow 1972, Harsanyi 1994, Nash 1994, Selten 1994, Lucas 1995, Vickrey 1996, Aumann 2005, Schelling 2005, Hurwicz 2007, Machine 2007, Myerson 2007, Roth 2012, Shapley 2012, Tirole 2014, Hart 2016, Holmstrom 2016, Thaler 2017. Game theory requires at least two players, that at least one player can choose at least two strategies, and that each player receives a payoff given the combinations of strategies chosen by all players. Operational analysis can be characterized as a game by an actor against "dead nature." The four most common games are the prisoner's dilemma, chicken, battle of the sexes, and insurance games. The payoff or utility function is assumed to be arbitrarily general e.g. regarding subjectivity and specified attitude towards risk.*
2. *Quantitative analysis tools within economics, political science, and mathematical sociology can be used for analyzing the behavioral dimension in risk, safety, security, and resilience research. These tools can be used to analyze and find empirical support for stakeholder attitudes towards risk, the types of interaction that occur and may occur between individuals or groups of individuals who unilaterally choose incompatible strategies under uncertainty and incomplete information about environmental parameters, payoffs, beliefs, and preferences. The collective consequences of individual strategies can be explored. It is possible to analyze which strategies are optimal for triggering or curbing crises and conflicts. At the collective or societal level, it is possible to analyze, prescriptively and descriptively, how principles or guidelines can be designed to create incentives for profit-seeking and/or safety-seeking and/or security-seeking individuals to act in harmony with self-interest, collective interests, and/or societal safety and security.*
3. *Players’ attitudes towards risk: Strategically interacting actors at different levels, e.g. at the individual, group, organizational and societal levels, are involved in accidents, disasters, crises, emergencies, accidents, hazards, and devastations, where phenomena related to reliability, risk, safety, security, uncertainty, and vulnerability are relevant. An actor can be stereotypically characterized as risk-seeking, risk-neutral, risk-averse. Theoretical and empirical work by e.g. Kahneman and Tversky (1979) show e.g. that an actor instead of following classical probability theory operates with a value function which is concave for gains, convex for losses, and typically steeper for losses than for gains. Theories of this kind, as well as the assessment of empirical support, emerges and evolves frequently in today's international research literature. It is important that Norway gains insight and contributes to the development of this literature.*
4. *Complex systems contain both the technical and human dimension. The engineering disciplines have a long tradition of developing understanding of the technical dimension, such as reliability analysis, probabilistic risk analysis, etc. In addition, the essential behavioral dimension should be incorporated. A model can be developed where the technical system is influenced by decisions and actions, which in turn are influenced by management and organizational factors, where Bayesian probability theory is used in the analysis. A principal-agent model can be developed where each component of a system is an agent-machine system. The principal maximizes system reliability given three conditions that impose constraints and incur costs. 1. Divergent views/requirements from different stakeholders (interest groups, bodies with decision-making authority, etc.). 2. Incentive systems for agents maximizing utility. 3. Expenditure on the operation and maintenance of technical components. These models can be further developed, empirical support can be given, and alternative models can be developed. The key is to achieve explanatory power according to conventional scientific criteria.*
5. *Financial risk: Financial crises reveal the necessity of analyzing the strategic interaction between various players such as countries, central banks, banks, firms, households, and financial inter-governmental organizations, supplementing the abundance of econometric analysis and time series analysis within finance. Each player has a strategy set, with strategies such as setting interest rates, lending, borrowing, producing, consuming, investing, importing, exporting, defaulting, and penalizing default. Markets for goods, debt, and capital are subject to shocks and contagion through time, caused by and impacting players.*
6. *Information security: The information revolution has introduced new technologies, and changed the way firms, organizations and individuals in the private and public domain interact and conduct business. Cyber security has moved to center stage. Exchange of information and economic transactions increasingly take place via digital electronic activities focused primarily on the interconnectivity obtained via the Internet. One critical part of this interconnectivity is the way organizations integrate their accounting and financial management systems with Internet based applications. Another part is how firms store and transfer information they seek to keep confidential. Organizations on the one hand seek efficient transfer of information, data, and transactions, but on the other hand seek to do this in a secure manner. Gains can be made by intruders breaking through safeguards, violating confidentiality, and unlawfully appropriating information, data, and assets. The field of information security develops at an amazing speed. The mechanisms need to be understood. Firms compete with each other and with external intruders such as hackers over their assets. In this new environment each firm needs to determine the optimal investment in security technology, and the optimal amount of information about security breaches and other events to share with other firms, and public and private information agencies of various kinds. Similarly, the objectives of the intruders need to be understood. Examples of objectives are financial gain, political gain, leisure activities, a desire for challenges, and a desire for causing destruction. Intruders can be profiled psychologically. There are income effects for intruders, and interdependence and substitution effects between firms. These phenomena can be studied from economic, political, psychological, sociological, and technological viewpoints. There is a need for theoretical development, combined with generation and application of empirics. Examples of key words are Technology, Infrastructure, Vulnerabilities, Threats, Risks, Accidental, Incidental, Computer Attack, Cyber Incident, Network Vulnerabilities, Technical Solutions, Forensics, Incident Analysis, Intelligence Analysis, Criminological Approaches, Tracing and Tracking Methodologies, Behavioral Research, Psychology Profiling, Resilience Management, Procedures, Policies, Organizational Management, Cooperation, Global Phenomenon. Examples of agencies which in recent years have improved their collection and to some extent systematic categorization of empirics, e.g. related to cyber incidents, are various statistics bureaus, CERT, CERIAS, the Centre for Information Security, the Norwegian National Authority for the Investigation and Prosecution of Economic and Environmental Crime, the Financial Supervisory Authority of Norway, the UK National Hi-Tech Crime Unit, the UK Home Office, the UK Asset Recovery Agency, the UK Serious Organised Crime Agency, the Securities and Exchange Commission, the FBI, Interpol/Europol, Symantec, various organizations (Statoil, Shell, SR-Bank, Ibas, etc.), Honeynet, and empirics can be compiled by questionnaires, interviews, and other research methods.*
7. *Strategic interaction and societal safety: Strategically interacting agents are involved in accidents, catastrophes, crises, disasters, emergencies, hazards, where phenomena related to reliability, risk, safety, security, uncertainty, vulnerability are involved. At the individual level actors’ attitude towards risk needs to be understood, and what kind of interaction occurs between individuals or groups of individuals who choose strategies under uncertainty and incomplete information about surroundings, utilities, beliefs, and preferences. The collective implications of individual strategies also need to be understood, and what strategies can be chosen to trigger or dampen crises and conflicts. At the collective or societal level premises or pre-conditions can be laid to create incentives for individuals to behave compatibly with individual and societal safety.*
8. *Terrorism: Terrorism is a typical phenomenon involving at least two players, one seeking to create or produce terror, and one seeking to prevent terror. The probability of a terrorism event, and the consequences if it occurs, depend on a plethora of factors such as the preferences and beliefs of the players, their competence, available resources, and resource allocation. For example, resource allocation for the defender has to be made between potential targets and across time, between prevention, addressing the terrorism event if it unfolds, and remedying the consequences; and between terrorism and non-terrorism. Resource allocation for the attacker may consist of determining where, when, how, and how fiercely to attack. Multiple players usually face a collective action challenge regarding who shall incur the costs of combating and producing terrorism.*
9. *Power, conflict, and risk: Power and conflict are pervasive in all interaction and are usually analyzed as political and economic phenomena. The relationships of power and conflict to reliability, risk, safety, security, uncertainty, and vulnerability need to be understood. Power, conflict, and risk play a role at all levels of organization for strategically interacting agents involved in accidents, catastrophes, crises, disasters, emergencies, hazards.*
10. *Probabilistic Risk Analysis and Game Theory: The behavioral dimension matters in Probabilistic Risk Analysis since players throughout a system incur costs to increase system reliability interpreted as a public good. Individual strategies at the subsystem level generally conflict with collective desires at the system level. Game theory, the natural tool to analyze individual-collective conflicts that affect risk, has been integrated into Probabilistic Risk Analysis by Hausken (2002). Conflicts arise in series, parallel, and summation systems over which player(s) prefer(s) to incur the cost of risk reduction. Frequently, the series, parallel, and summation systems correspond to the four most common games in game theory, i.e., the coordination game, the battle of the sexes and the chicken game, and prisoner's dilemma, respectively. The following three further developments to the merger of Probabilistic Risk Analysis and basic game theory can be made.*
	1. *One-shot play can be substituted with repeated play. Common equilibrium concepts are sequential equilibrium and trembling-hand perfect equilibrium, with subsequent equilibrium refinements. Repeating a game finitely many times gives the same one-shot solution in every round, due to the argument of backward recursion. For infinitely repeated games, the Folk Theorem is especially famous. It states that "any individually rational payoff [i.e., utility] vector of a one-shot game of complete information can arise in a perfect equilibrium of the infinitely repeated game if players are sufficiently patient." Applied to the prisoner's dilemma, mutual cooperation can be sustained as an equilibrium in the infinitely repeated game if the discount factor is sufficiently close to one. An alternative is Axelrod's (2006) tit-for-tat strategy, which may also sustain cooperation through time.*
	2. *Complete information can be substituted with incomplete information, successfully formalized in the Harsanyi doctrine (Harsanyi, 1967), which lets each player form a subjective probability distribution over the alternative possibilities, or types, of incomplete information for the other players (This superseded earlier infinite recursions of the kind "If I think that you think that I think ...."). A player's type is thus his characteristics of psychological, physical, or other nature. Examples of types are a player's ability to work (which may be high or low), his competence, his ability to handle risk diligently, his discounting of the future, his threshold level for fatigue, and his reservation price (when buying or selling an asset). Incomplete information can be symmetric or asymmetric across players, e.g., one-sided, two-sided, or n-sided.*
	3. *The utility to each player can in accordance with principal-agent theory be supplemented with a utility to a manager (principal) which allocates compensation to each player (agent) which incurs maintenance or capital costs for each unit. The principal's strategy set is the range of possibilities for paying the agents and incurring unit costs. The principal maximizes his utility under the constraint that each agent that works for him is maximizing at the same time. Informational issues usually play a role, a typical example being that agents are fully informed and the principal incompletely informed. Hausken (1996, pp. 21-29) considers a simple principal-agent problem with adverse selection, where a risk-neutral, incompletely informed principal assigns probabilities to two possible types (high versus low cost of production) for a risk-averse agent which is fully informed. The principal maximizes utility and obtains a second-best solution while the high-cost agent type is held down to his individual rationality constraint (participation constraint), where the incentive compatibility constraint of the low-cost agent type is binding.) The conventional economic theory of the firm, ignoring technical characteristics, defines property rights and designs incentive systems to address types of misbehavior such as free-riding, moral hazard, and adverse selection. The further potential is to develop a theory of the firm comprising a system with multiple units equipped with both behavioral and technical characteristics, in addition to one or several principals. Clever principals are aware of internal conflicts and address the public good incentive question by structuring utilities such that agents have a reason to cooperate across tasks. The principal can be conceived as a (detached) decision maker maximizing according to multiple attributes as specified by the preferences of multiple stakeholders.*

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# *Possible alternative course description*

*The course reveals a broad range of issues relevant for understanding and appraising game theory and risk analysis. Starting with a grounding at the individual level, the course gradually moves to consider the most influential fields and directions involving game theory and risk analysis at the organizational and societal levels. Each introduced topic is presented from two or several different and often diametrically opposite viewpoints prevalent in contemporary research. The course trains you to make consciously intelligent and scientifically justifiable stands within each sub-field, and contributes to your ability to organize these stands into a coherent whole.*

# *Possible alternative course requirements*

*Each student will write a 3 pages double-spaced (say 600 words) essay due in class every week, starting the second week. Write concisely. I do not want to read a superfluity of sesquipedalian obfuscatory prolixity. You can take stands on the issues, but you need to justify them. You will be evaluated on your command of the material, and on the comprehension you reveal of the major factors relevant for each week's topic. Every week 2-4 of you will present your essays in class. Assignments will be arranged on the first week of class ensuring that the major viewpoints of each topic get presented. These essays to be presented are to be provided at www.zzz.no at 11:00 the day before every class. With less than 15 students, the course will be run as an informal lecture/discussion course. With more than 20 students, a larger auditorium will be assigned, and the course will be held in a more formal lecturing tone. Each student will write a final paper, due Thursday of exam week at 16:00 at www.zzz.no. The paper should be 12-15 pages single spaced with font size 12 Times New Roman, 25-30K, and on a topic relevant for the course. Please come and see me if you want to discuss your topic, or if you want me to suggest possible topics for you. You will be evaluated 50% on your essays, 30% on your final paper, and 20% on your oral presentation including how well you withstand critique from the other students and myself. Office hours are Monday and Thursday 12.30-15.30 in room zzz.*