Course Guide

Moscow Summer Academy on Economic Growth and Governance of Natural Resources 2015 (MSA 2015)

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Scientific Coordinators

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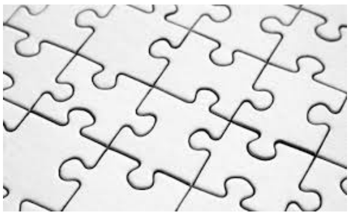

1 Course Concept

As the 21st century begins, humankind faces a challenge to find a wiser way to utilize Earth's resources to maintain economic growth, in developing countries as well as in the industrialized world, while avoiding overexploitation of ecosystem services and other natural resources. The global economy is still rooted in non-renewable resource exploitation. A transition to renewable energy and sustainable resource use will occur only in response to appropriate incentives and institutional changes facilitated by policy-makers. This is a daunting task for many reasons, including complex feedbacks between the institutional and economic system that may lead to path-dependencies that hinder or prevent such transitions.

Moreover, growing globalization and an accelerating level of industrial development are contributing to a shifting of the Earth systems from a quasi-equilibrium state that has traditionally supported human society. Environmental regime shifts may give rise to institutional tipping points, which may also trigger sudden transitions in socio-economic systems; these create a strong need for policy instruments that can take into account the feedbacks between elements of the whole. The need to maintain economic growth without unacceptable damage to Earth's capacity to support human society is embodied in the concepts of "sustainable development" and "green growth". This summer school is designed to examine and develop some of the analytical tools that can assist in decision support for policy makers trying to manoeuvre in this complex space.

The scientific community plays a key role in analyzing options for policies aimed at facilitating an efficient and fair use of natural resources, while ensuring that Earth systems retain their functionality. Recent developments in policy science reflect the understanding that research useful for decision support can no longer work with linearized approximations, ignoring nonlinearities, potential structural changes and regime shifts. A new generation of science supporting policy that responds to these complex global changes should address explicitly the issue of multiplicity of decision-makers and decision-making levels and their interactions. Moreover, the heterogeneity of agents involved in making and implementing decisions is playing an increasingly decisive role, highlighting the need to design fair and efficient institutions to support global policies on sustainable development.

MSA 2015 aims to attract a new generation of scientists from around the world to learn and discuss the challenges of natural resources management and economic growth, along with methodologies that are available to attack those challenges (e.g., optimal control theory, analysis of dynamic systems, and game theory with special focus on dynamic games and mechanism design).

The School will consider the Arctic as a special case, where the warming environment catalyzes changes in ecosystems and in opportunities for economic development, and where the small traditional population of the area will have to partner with national and international authorities to handle unprecedented challenges to traditional cultures, as well as opportunities for increased prosperity.

2 Prerequisites

The course will have a strong emphasis on theoretical modeling, so prior knowledge in mathematics, especially solid knowledge of mathematical analysis and differential equations, is assumed; basic knowledge of convex analysis, optimization theory, control theory and game theory is desired. Below is the list of the suggested reading for preparation.

Literature to be studied prior to the Summer School

To find out whether your prior knowledge is sufficient, it is recommended to read

- Hanley, N., Shogren J., and White, B. (1997): Environmental Economics in Theory and Practice, London: MacMillan Press [Chapter 9]

If you have difficulties understanding the text, we recommend consulting the following material:

- Weber, T. A. (2011): Optimal Control Theory with Applications in Economics, MIT Press, 2011
- Myerson, R. B. (2013): Game Theory, Harvard University Press (As an introduction to game theory)
- Fudenberg, D. and Tirole, J. (1991): Game Theory, MIT Press (As a more technical introduction on game theory)
- Perman, R. *et al.* (2011): Natural Resource and Environmental Economics, Pearson Education (Introduction on environmental natural resource economics)

Additional literature

For students who are not specialized in the field of theoretical modeling of resource economics and who have general interest to understand its methods and models, it may be enough to follow the MSA2015 lectures *in general* without necessarily digging into all technical details. If, however, you are interested to follow the lectures *in all details*, in addition to the list above, it is advised to be familiar with concepts and methods presented in the following materials.

- Aseev, S. M. (2009): Infinite-Horizon Optimal Control with Applications in Growth Theory, Moscow, MSU CMC Publ. Dep., MAKS Press
- Barrett, S. (2005): The Theory of International Environmental Agreements [Chapter 28], In: Göran Mäler, K. and Vincent, J. R. (Eds.), Handbook of Environmental Economics, Elsevier, Volume 3, pp. 1457-1516
- Dockner, E.J, Jørgensen, S., Van Long, N., and G. Sorger, G. (2000): Differential Games in Economics and Management Science, Cambridge, Cambridge University Press
- Hanley, N., Shogren, J., and White, B. (1997): Environmental Economics in Theory and Practice, London, MacMillan Press
- Lambertini, L. (2013), Oligopoly, the Environment and Natural Resources, London, Routledge
- Mas-Colell, A., Whinston, M., and Green, J. (1995): Microeconomic Theory, University Press, Oxford

3 Learning Outcomes

After successful completion of this course participants are expected to be able to

- Understand the theoretical foundations of dynamical systems theory, optimal control theory and game theory
- Apply the optimal control theory to model the issues related to the management of nonrenewable and renewable natural resources (such as fish, ecosystems), taking into account concerns of equity and sustainability
- Use game theory to formulate strategic interactions of resource users
- Compare contemporary models of economic growth and how they are account for environmental constraints
- Analyze how environmental policies affect natural resource use
- Formulate how emerging complexities in the human- earth system can be modelled as dynamical systems
- Describe how institutional dynamics and resource dynamics mutually influence each other in a social-ecological system
- Translate real-world problems into mathematical models

4 Lecturers

Sergey Aseev	Leading Research Scholar, Steklov Mathematical Institute of the Russian Academy of Sciences, Russia Research Scholar, International Institute for Applied Systems Analysis, Austria
Stefan Behringer	Member of the Chair for Managerial Economics, Universität Duisburg-Essen, Germany
Michael Ghil	Distinguished Research Professor of Atmospheric and Oceanic Sciences, University of California, Los Angeles (UCLA), USA Emeritus Professor of Geosciences, Ecole Normale Supérieure, France
Itziar Lazkano	Assistant Professor, University of Wisconsin–Milwaukee, USA
Andrea Mantovani	Associate Professor, Department of Economics, University of Bologna, Ital
Linda Nøstbakken	Associate Professor, Department of Economics, Norwegian School of Economics (NHH), Bergen, Norway
Alessandro Tavoni	Assistant Professorial Research Fellow, Grantham Institute on Climate Change and the Environment, London School of Economics, United Kingdom
Andries Richter	Assistant Professor, Wageningen University, the Netherlands Researcher, Centre for Ecological and Evolutionary Synthesis, University of Oslo, Norway
Thomas Weber	Associate Professor, École Polytechnique Fédérale de Lausanne, Switzerland
Anastasios Xepapadeas	Professor of Economic Theory and Policy, Athens University of Economics and Business, Greece

5 Themes

Particular themes on which the school will focus include:

a) Endogenous growth theory and new drivers of economic growth: moving towards inclusiveness and sustainability

b) Mutual feedbacks and different time scales of changes in institutional, economic, climatic, and ecological systems

c) Nonlinearities, structural changes, regime shifts and tipping points in human-earth systems' functioning: understanding, predicting and steering

d) Incentivizing sustainable behavior: institution design

e) Cooperation, fairness, and resource sharing

f) The Arctic as a focal case of a non-linear social-ecological system undergoing rapid change

Lecture set	**Lecturer**	**Methods used**	**Applications**	**Relevance to school's themes**
1	Aseev	Optimal control	Resource management, optimal growth models	a
2	Behringer	Game theory, Mechanism design	Public goods / Common pool resources	d,e,f
3	Ghil	Bifurcation theory, integrated models	Climate systems, coupled climate-economy models Endogenous business cycle, Arctic climate	c
4	Xepapadeas	Optimal control, game theory	Complex social-environmental systems	a,b,c,d,e
5	Lazkano	Neoclassical / endogenous growth models	Economic growth model with environmental and natural resources constraints	a
6	Nøstbakken	Optimal control	Petroleum Economics	a,e
7	Tavoni	Game theory, experimental economics	Social-ecological systems, public goods	d,e
8	Richter	General equilibrium models, Evolutionary game theory	Trade and in natural resource use, Evolution of institutions governing natural resources	b,c,e
9	Weber	Optimal control theory, stochastic programming	Information acquisition, fairness	a,e
10	Mantovani	Game theory, micro models	Environmental policy – international agreements, consumers, trade	a,d,e,f

6 Selected talks on bringing models to life - Inspiration, impact, and real-world applications

- **Advice to young scientists** (Nils Chr. Stenseth, Research Professor and Chair of the Centre for Ecological and Evolutionary Synthesis (CEES), University of Oslo, Norway)

- **The Science - Policy Divide: Policy Relevant Science doesn't always mean Policy Impact** (Margaret Goud Collins, Program Director, Capacity Building and Academic Training, International Institute for Applied Systems Analysis (IIASA), Austria)

- **Arctic Research of the Institute of Geography: history, directions and methodologies** (Andrey Medvedev, Institute of Geography, Russian Academy of Science)

- **Multiple global, regional and local drivers affect natural resource production in marine systems** (Susa Niiranen, GreenMar scholar at the Stockholm Resilience Centre, Sweden)

- **Modelling ecological regime shifts and economic implications in the Nordic Seas** (Marcos Llopes, GreenMar scholar at the Centre for Ecological and Evolutionary Synthesis, CEES, University of Oslo, Norway and researcher at the Instituto Español de Oceanografia, Spain.

7 Content of Lectures

Block I: Contemporary Theory and Methodologies Used to Study Economic Growth and Governance of Natural Resources

Sergey Aseev: Infinite-horizon Optimal Control with Applications in Growth Theory

(2 lecture blocks of 90 minutes + 2 tutorials of 90 minutes)

Lectures:
The lectures provide an introduction to optimal control theory, which is a main tool in analysis of various models of dynamic allocation of resources in economics. The main attention is paid to a recently developed "complete" version of the Pontryagin maximum principle for infinite-horizon problems and its applications to optimal growth models including models with natural resources.

Lectures will cover the following topics:

1. Optimal control problems with finite and infinite time horizons. Examples of optimal control problems in economics.
2. The Pontryagin maximum principle as a general necessary condition of optimality. Economic sense of the maximum principle.
3. "Complete" version of the maximum principle with an explicitly specified adjoint variable.
4. Models of optimal economic growth with renewable and nonrenewable resources.

Tutorials:

Tutorials will be focused on questions (which could appear after the lectures) and particular model examples of infinite-horizon optimal control problems.

Literature:

- Aseev, S.M., Besov, K.O, and Kryazhimskii A.V. (2012): Infinite-horizon Optimal Control Problems in Economics, Russ. Math. Surv., Volume 67, Issue 2, pp. 195–253
- Aseev, S.M. and Kryazhimskiy, A.V. (2004): The Pontryagin Maximum Principle and Transversality Conditions for a Class of Optimal Control Problems with Infinite Time Horizons, SIAM J. Control Optim., Volume 43, pp. 1094–1119
- Aseev, S.M. and Kryazhimskii, A.V. (2007): The Pontryagin Maximum Principle and Optimal Economic Growth Problems, Proc. Steklov Math. Inst., Volume 257, pp. 1–255
- Aseev, S.M. and Veliov, V.M. (2014): Maximum Principle for Infinite-horizon Optimal Control Problems under Weak Regularity Assumptions, Tr. IMM UrO RAN, Volume 20(3), pp. 41-57
- Carlson, D.A., Haurie, A.B. and Leizarowitz A. (1991): Infinite Horizon Optimal Control. Deterministic and Stochastic systems, Springer, Berlin
- Pontrjagin, L.S., Boltyanskii, V.G., Gamkrelidze, R.V., and Mishchenko, E.F. (1964): The Mathematical Theory of Optimal Processes, Oxford, Pergamon
- Ramsey, F.P. (1928): A Mathematical Theory of Saving, Economic Journal, Volume 38, pp. 543–559
- Seierstad, A. and Sydsæter, K. (1987): Optimal Control Theory with Economic Applications, Amsterdam, North-Holland
- Weitzman, M.L. (2003): Income, Wealth, and the Maximum Principle, Cambridge, Harvard University Press

Stefan Behringer: Governance of public goods: Game-theoretic approaches

(2 lecture blocks of 90 minutes + 2 tutorials of 90 minutes)

Lectures:

Lectures start with a refresher of game-theoretic concepts and then focuses on public goods and mechanism design to overcome market failures. Lectures will cover the following topics:

- Game theory introduction/refresher: Static games, Nash equilibrium, Nash theorem, dynamic games, subgame perfection.
- Game theory continued: repeated games and Folk theorems, public good provision under full information.
- Public good provision under incomplete information, Bayesian Nash equilibrium, mechanism design and some limit results.
- Public goods and common pool resources, e.g. fisheries. Differential games and Markov Equilibria.

Tutorials:

- Exercises refreshing game theory and some applications.
- Further exercises and applications of repeated games.
- Specific mechanisms for public good provision, e.g. in an environmental context.
- Problems of fishing and common goods. Optimal harvesting of renewable resources.

In the last tutorial we will discuss optimal dynamic management of fish stocks with an emphasis on sustainability. Climate change causes sub-arctic fish stocks to extend into Arctic areas leading to increased fishing activity there.

Literature:

- Börgers, T. (2015): An Introduction to the Theory of Mechanism Design, University Press, Oxford
  Baliga, S. and Maskin, E. (2003): Mechanism Design for the Environment in: Mäler, K. G. and Vincent J. R. (Eds.), Handbook of Environmental Economics, Elsevier,Edition 1, Volume 1, Chapter 7, pp. 305-324
- Behringer, S. and Upmann, T. (2014): Optimal Harvesting of a Spatial Renewable Resource, Journal of Economic Dynamics and Control, Volume 42, pp.105-120
- Behringer, S. and Koriyama, Y. (2015): Public Good Provision with Many Agents: The k-success Technology", (Working paper)

Michael Ghil: Bifurcations and Tipping Points: From Climate to Coupled Climate-Economy Systems

(2 lecture blocks of 90 minutes + 2 computer practicums of 90 minutes)

Lectures:

The lectures will provide an introduction to dynamical systems theory and its applications to the analysis and interpretation of climate and economic data, as well as to the modeling and qualitative understanding of the climate and economic systems. They will start by asking what dynamical systems are and why we need the concepts and tools of their theory in such highly interdisciplinary fields as coupled climate-economic modeling. The theoretical material will include fixed points, limit cycles and more complicated attractors of differentiable dynamical systems (DDS); it will be closely linked with simple examples from the climate sciences and macroeconomics. The examples will include energy balance models (EBMs) in discussing multiple equilibria and saddle-node bifurcations, and endogenous business cycles (EnBCs) in covering limit cycles, Hopf bifurcations, and deterministically chaotic solutions.

Singular-spectrum analysis (SSA) and the SSA-MTM Toolkit will be presented as suitable tools for identifying trends, oscillatory modes and noise in irregular time series; the connection with nonlinear dynamics will be made and statistical tests for the robustness of results will be introduced. The applications will include the longest instrumental record in climate and hydrology, namely the Nile River floods (622–1922 AD), and the longest annual macroeconomic record, namely the multivariate indicator of the U.S. economy (1954–present). In the context of the latter example, we will also consider the impact of natural disasters on a dynamic economy with EnBCs.

Computer practicums:

The practicums will provide the students with hands-on experience in applying the theoretical concepts and tools discussed in the lectures to climate and economic examples of interest. The tutorials will deal with applying existing software for continuation methods and bifurcations to simple systems of ordinary differential equations (ODEs) — such as the Van der Pol oscillator and the Lorenz three-ODE model for Rayleigh-Bénard convection — and then to examples of direct interest to the participants. Furthermore, the practicums will cover first applications of SSA and multi-channel SSA (M-SSA) to a well-behaved time series, the Southern Oscillation Index (SOI), for which the separation of the oscillatory modes from the noise is relatively easy. This property of the data set also accounts for the relative ease of predicting the SOI for 6–12 months in advance, in real time. Next, SSA, M-SSA and other methods in the SSA-MTM Toolkit will be applied to more difficult data sets proposed by the participants.

1. Application of bifurcation software to simple ODE systems
    a. the Van der Pol oscillator
    b. the Lorenz (1963) convection model
2. Application to bring-your-own-system
3. Applications of the SSA-MTM Toolkit to a "nice" data set
    a. the Southern Oscillation Index
4. Application to BYO data set

Literature:

- Ghil, M. (1994): Cryothermodynamics: The chaotic dynamics of paleoclimate, Physica D, Volume 77, pp. 130–159
- Ghil, M. (2001)**:** Hilbert problems for the geosciences in the 21st century, Nonlin. Processes Geophys., Volume 8, 211–222
- Ghil, M., Allen, M.R., Dettinger, M.D., Ide, K., Kondrashov, D., Mann, M.E., Robertson, A.W., Saunders, A., Tian, Y., Varadi, F. and Yiou, P. (2002): Advanced spectral methods for climatic time series, Rev. Geophys., Volume 40(1), pp. 3.1–3.41, doi: 10.1029/2000RG000092.
- Groth, A., Dumas, P., Ghil M., and Hallegatte S. (2015): Impacts of natural disasters on a dynamic economy, AGU Monograph on Observations, Modeling and Economics of Extreme Events, M. Chavez et al. (Eds.) [In press]
- Jordan, D. and Smith P. (1987): Nonlinear Ordinary Differential Equations, 2nd ed., Oxford Univ. Press [Especially the last two chapters]

Block II: Prominent Examples of Policy-relevant Studies in the Field of Economic Growth and Governance of Natural Resources

Anastasios Xepapadeas: Models of Environmental and Resource Management

(One Skype lecture of 60 minutes)

Lectures:

The lecture present approaches to model environmental and resource management, in particular, differential games with nonlinear feedback strategies. In particular, we look at i) Cooperative solutions, ii) Open Loop Nash equilibrium, iii) Feedback Nash equilibrium, iv) Using the Hamilton Jacobi Bellman equation to derive feedback strategies, v) Regulation.

Literature:

- Kossioris, G., Plexoysakis, M., Xepapadeas, A., de Zeeuw, A. and Mäler K.-G. (2008): Feedback Nash Equilibria for Non-Linear Differential Games in Pollution Control, Journal of Economic Dynamics and Control, Volume 32, pp. 1312–1331

- Kossioris, G., Plexoysakis, M., Xepapadeas, A., and de Zeeuw A. (2011): On the Optimal Taxation of Common-Pool Resources, Journal of Economic Dynamics and Control, Volume 35, pp. 1868-1879
- Mäler, K-G., Xepapadeas A., and de Zeeuw A. (2003): The Economics of Shallow Lakes, Environmental and Resource Economics, Volume 26, Issue 4, pp. 603–624
- Jorgensen, S., Martin-Herran, G., and Zaccour G. (2010): Dynamic Games in the Economics and Management of Pollution. Environmental Modeling and Assessment, Volume 15, Issue 6, pp. 433-467

Itziar Lazkano: Modern Economic Growth and the Environment

(2 lecture blocks of 90 minutes + 1 modeling workshop of 90 minutes)

Lectures:

The lectures introduce modern growth theories and their applications as they relate to environmental problems. These theories attempt to address questions such as: Are there limits to growth? Can we maintain economic growth without sacrificing the environment? Can we delay the cleaning of the environment? Should developing nations like China, India or Brazil postpone cleaning up the environment until they become richer?

To answer these questions, several distinct models/applications are presented. Starting with the Solow growth model and the neoclassical growth model, the drivers of long-run growth are analyzed. Next, environmental and resource constraints are introduced into endogenous growth models. Third, a directed technological change model is presented to study how to direct innovation towards greener technologies. Finally, a case study shows the importance of electricity storage to ensure a transition towards greener technologies.

Literature:

- Acemoglu, D. (2008): Introduction to Modern Economic Growth, Princeton University Press [Chapters 1-3, 5, 8, 10-13]
- Stokey, N.L. (1998): Are there Limits to Growth? International Economic Review, pp. 1-31
- Aghion, P., Howitt, P., and García-Peñalosa, C. (1998): Endogenous Growth Theory, MIT Press [Chapter 4]
- Acemoglu, D., et al. (2009): The Environment and Directed Technical Change, No. w15451, National Bureau of Economic Research
- Aghion, P., et al. (2012): Carbon Taxes, Path Dependency and Directed Technical Change: Evidence from the Auto Industry, No. w18596, National Bureau of Economic Research
  Lazkano, I., Nostbakken, L., and, Pelli, M. (2015): From Fossil Fuels to Renewables: The Role of Electricity Storage, Working paper

Linda Nøstbakken: Petroleum Economics

(3 lecture blocks of 45 minutes)

Lectures:

The lecture provides an introduction to the economics of nonrenewable resources, focusing particularly on petroleum economics and the global oil market. Nonrenewable resources such as oil, natural gas and other minerals, are formed by geological processes that typically take millions of years. Consequently, there is a finite amount of the resource in the ground, and once removed, we cannot replace it. The resource stock connects what we extract today with what we can extract tomorrow, and this inter-temporal dimension has big implications for extraction patterns and global oil markets.

The lecture will start with the basics – what is petroleum – before giving a descriptive overview of the development of the petroleum industry and the global oil market, from the early uses of oil until today. With this as a background, we move on to look at basic models of the oil market that takes into account that petroleum development is an inter-temporal problem. We will explain how the inter-temporal extraction path depends on the market structure and other factors. If time permits, the lecture ends with a discussion of petroleum taxation.

Literature:

- Gaudet, G. (2007): Natural Resource Economics under the Rule of Hotelling, Canadian Journal of Economics, Volume 40, Issue 4, pp. 1033-1059
- Hamilton, J. D. (2014): The Changing Face of World Oil Markets, No. w20355, National Bureau of Economic Research
- Hotelling, H. (1931): The Economics of Exhaustible Resources, The Journal of Political Economy, Volume 39, pp. 137-175

Alessandro Tavoni: International Environmental Agreements: Experimentation and Modeling

(2 lecture blocks of 90 minutes)

Lectures:

The lectures discuss international environmental agreements (IEA) in the context of experimental economics, e.g., insights from experiments about climate negotiations cooperation. Special attention will be given to the role of tipping points in catalyzing cooperation. We will focus on the basic features of IEA, followed by a more in-depth coverage of a model which unpacks the influence of lobbying on coalition formation. Then, we will review the recent experimental literature on the provision of (environmental) public goods subject to tipping points. The parallel will be drawn between the experiments and the IEA theory, and examples will be drawn from the regime shift literature (e.g., Arctic warming).

Literature:

- Barrett, S. (2005): The Theory of International Environmental Agreements, In: Maeler, K-G., Vincent, J. (Eds.), Handbook of Environmental Economics, Volume 3, Elsevier, Amsterdam, pp. 1457–1516
- Dannenberg, A., Löschel, A., Paolacci, G., Reif, C., Tavoni A. (2014): On the Provision of Public Goods with Probabilistic and Ambiguous Thresholds, Environmental and Resource Economics, pp. 1-19.

- Dietz, S., Marchiori, C., Tavoni, A. (2012): Domestic Politics and the Formation of International Environmental Agreements, Grantham Research Institute on Climate Change and the Environment Working Paper
- Grossman, G. and Helpman, E. (2001): Special Interest Politics. MIT Press, Cambridge, Mass
- Tavoni, A., Dannenberg, A., Kallis, G., Löschel, A. (2011): Inequality, Communication, and the Avoidance of Disastrous Climate Change in a Public Goods Game, Proceedings of the National Academy of Sciences, Volume 108, Issue 29, pp. 11825-11829
- Smead, R., Sandler, R. L., Forber, P., & Basl, J. (2014). A bargaining game analysis of international climate negotiations. Nature Climate Change, 4(6), 442-445.

Andries Richter: The Co-evolution of Institutions and Natural Resources

(2 lecture blocks of 90 and 45 minutes)

Lectures:

In the previous lectures students have learned how natural resources can be optimally managed, but also why strategic interactions of different users may give rise to overexploitation. However, in the real world, most cases are not as clear-cut and fall somewhere in between. Some resource systems are overexploited in the absence of strategic interactions, while others are managed sustainably even if game theory predicts massive overexploitation. Why are some resource systems trapped in a persistent state of overexploitation, while some resource users or countries can craft institutional arrangements that facilitate cooperation? To answer this question, the lecture introduces a class of models that takes the institutional context not as given, but institutions co-evolve with the resource stock. The analysis will both cover open-economy models at the country level, but also evolutionary game theory (the local level), where communities have access to a common resource.

Literature:

- Copeland, B.R. and Taylor, M.S. (2009): Trade, Tragedy, and the Commons, American Economic Review, Volume 99, pp. 725-749
- Richter, A., van Soest, D., and Grasman, J. (2013): Contagious Cooperation, Temptation, and Ecosystem Collapse, Journal of Environmental Economics and Management, Volume 66, pp. 141-158
- Richter, A. and Dakos, V. (2015): Profit Fluctuations Signal Eroding Resilience of Natural Resources, Ecological Economics 117: pp. 12-21.
- Sethi, R. and Somanathan, E. (1996): The Evolution of Social Norms in Common Property Resource Use, American Economic Review, Volume 86, pp. 766-788

Thomas Weber: Dynamic Management of Natural Resources: Regulation, Fairness, and Incentives

(2 lecture blocks of 90 minutes + 2 tutorials of 90 minutes)

Lectures:

The lectures present approaches to model resource extraction and pollution management in a dynamic setting. Elements of robust optimization and optimal control in discrete and continuous time are employed. Two applications are highlighted. The first one is on optimal dynamic information acquisition, applied to a well-established carbon-emissions control model. The problem contains a policy parameter, which allows a discussion about policy design. The second application concerns the allocation of resources using a robust notion of fairness developed by Goel, Meyerson, and Weber (2009) in a dynamic setting. It is applied to the "fair" extraction of a nonrenewable resource, which interestingly leads to a positive share of the resource for every generation. Quasi-closed-form solutions are available when the representative consumer has constant absolute risk aversion. Lastly, the lectures illustrate the importance of regulatory commitment for the implementation of first-best resource extraction or pollution-control trajectories, and the possibilities for institutional design when delegating the allocation decisions to several self-interested agents (e.g., nations or firms).

Tutorials:

The tutorials deal with applications and extensions of the lectures about information acquisition, regulatory commitment, and intertemporal fairness.

Literature:

- Arrow, K.J., et al. (2004): Are We Consuming Too Much?, Journal of Economic Perspectives, Volume 18, Issue 3, pp. 147-172
- Asheim, G.B. (2005): Intergenerational Equity under Resource Constraints, Schweizerische Zeitschrift für Volkswirtschaft, Volume 141, Issue 3, pp. 313-330
- Asheim, G.B. (2010): Intergenerational Equity, Annual Review of Economics, Volume 2, pp. 197-222
- Goel, A., Meyerson, A., Weber, T.A. (2009): Fair Welfare Maximization, Economic Theory, Volume 41, Issue 3, pp. 465-494
- Hoel, M. and Karp, L. (2002): Taxes versus Quotas for a Stock Pollutant, Resource and Energy Economics, Volume 24, Issue 4, pp. 367-384
- Nguyen, V.A. and Weber, T.A. (2015): Dynamic Information Acquisition, Working Paper, College of Management of Technology, Ecole Polytechnique Fédérale de Lausanne
- Weber, T.A. (2011): Optimal Control Theory with Applications in Economics, MIT Press, Cambridge, MA
- Weber, T.A. (2014): A Continuum of Commitment, Economics Letters, Volume 124, Issue 1, pp. 67-73

Andrea Mantovani: International Environmental Policy, Green Consumerism, and Natural Resources: static and dynamic approaches

(2 lecture blocks of 90 minutes + 2 tutorials of 90 minutes)

Lectures:

Industrial production and consumption choices heavily rely on an intensive use of both renewable and non-renewable resources and as a result polluting emissions continue to increase in many parts of the planet. The environmental consequences are already very severe, and the situation can only get worse unless immediate action is taken. This course offers an exhaustive overview of the most important policies that aim to direct global leaders facing this crucial challenge. Particular attention will be devoted to the relation between recently adopted environmental policies and other significant policies, in particular, those pertaining to competition, innovation and energy. The purpose is to provide an integrated approach capable of reconciling consumer protection, firms' competitiveness, and environmental preservation.

The first part of the course will cover static oligopoly models dealing with the difficult trade-off between competition enhancement and environment protection. We will examine the differences between Pigouvian taxation, emissions standards, markets for pollution permits and incentives for green research and development. We will cast our analysis in an international context in order to include recently emerging issues such as transboundary pollution, ecological dumping, and pollution havens.

The second part of the course will introduce differential oligopoly games modelling pollution and resource extraction. We will focus on specific dynamic aspects related to the impact of the aforementioned policy instruments on both firms' strategic interaction and consumer behavior. This will open the discussion concerning the long-run sustainability of modern production processes and consumption patterns.

Throughout the course, the concepts of *environmental quality* and *green consumerism* will be widely employed as they play a crucial role in the attempt to achieving a sustainable model of growth and development.

Last, but not least, we will consider the implications of our static and dynamic analysis on the Arctic Case, examining the projected impacts of climate change for the next decades. As Smith (2010) argued in his book: *"No doubt we humans will survive anything, even if polar bears and Arctic cod do not ...To me, the more important question is not of capacity but of desire: What kind of world do we want?"*

Tutorials:

Students will be required to present and discuss some of the most relevant papers recently published in the literature (provided by the instructor).

Literature:

- Boucekkine, R., Krawczyk, J. B., and Vall T. (2011): Environmental Quality versus Economic Performance: A Dynamic Game Approach, Optimal Control Applications and Methods, Volume 32, pp. 29-46
- Lambertini, L. (2013): Oligopoly, the Environment and Natural Resources, London, Routledge [Chapters 6,7,8,9]
- Smith, L. (2010): The World in 2050 – Four Forces Shaping Civilization's Northern Future, New York: DUTTON / Penguin Group USA Inc

For class discussion/tutorials:

- Benchekroun, H. (2008): Comparative Dynamics in a Productive Asset Oligopoly, Journal of Economic Theory, Volume 138, pp. 237-261
- Conrad K. (2005): Price Competition and Product Differentiation When Consumers Care for the Environment, Environmental and Resource Economics, Volume 31, pp. 1-19

- Damania, D. (1996): Pollution Taxes and Pollution Abatement in an Oligopoly Supergame, Journal of Environmental Economics and Management, Volume 30, pp. 323-336
- Deltas, G., Harrington, D.R. and Khanna M. (2013): Oligopolies with (Somewhat) Environmentally Conscious Consumers: Market Equilibrium and Regulatory Intervention, Journal of Economics and Management Strategy, Volume 22, pp. 640-667
- Kaufman, N. (2014): Overcoming the Barriers to the Market Performance of Green Consumer Goods, Resource and Energy Economics, Volume 36, pp. 487-507
- Lambertini, L. and Mantovani A. (2014): Feedback Equilibria in a Dynamic Renewable Resource Oligopoly: Pre-Emption, Voracity and Exhaustion, Journal of Economic Dynamics and Control, Volume 47, pp. 115-122
- Mantovani, A., Tarola, O. and Vergari C. (2014): Hedonic Quality, Social Norms, and Environmental Campaigns, Department of Economics, University of Bologna Working Paper 950
- Montero, J-P. (2002): Permits, Standards, and Technology Innovation, Journal of Environmental Econonomics and Management, Volume 44, pp. 23-44
- Sanna-Randaccio F. and Sestini R. (2012): The Impact of Unilateral Climate Policy with Endogenous Plant Location and Market Size Asymmetry, Review of International Economics, Volume 20 (3), pp. 580-599
- Sartzetakis, E.S., Xepapadeas A. and Petrakis E. (2012): The Role of Information Provision as a Policy Instrument to Supplement Environmental Taxes, Environmental and Resource Economics, Volume 52, pp. 347-368
- Tornell, A. and Lane, P.R. (1999): The Voracity Effect, American Economic Review, Volume 89, pp. 22-46

8 Group Work

Facilitating a responsible development of the Arctic is challenging for several reasons. First, there are probably few other regions in the world where the socio-economic and the natural system are so tightly coupled and changes in one subsystem has profound ramifications in the other. Second, the Arctic is one of the regions that will be affected most by climatic changes, and most of those changes will not be slow and gradual, but rapid, non-linear and abrupt. This makes the region especially vulnerable and it is urgent to take adequate actions to safeguard its unique ecosystems and the services humans derive from them. Third, the Arctic is a region of the world where borders are perceived to be fuzzy, partly because what used to have no value will have a high value in the future, but also partly due to the common pool character of the Arctic waters that entreasure a vast amount of natural resources and potentially valuable corridors for shipping routes. Biological resources, such as fisheries are especially vulnerable, both because they directly rely on the functioning of the natural system, and are prone to overexploitation due to their common pool character. At the same time these renewable resources are often vital for coastal (often indigenous communities), in particular in marginal regions. Biological natural resources not only have the potential to provide a steady flow of income and employment opportunities, they may also stabilize the very system they depend on. Importantly, common-pool resources may also serve as a livelihood of last resort, smoothing the inequitable fluctuations of a growing economy.

Literature (to be read prior to the summer school)

As a preparation to the group work all participants are strongly recommended to read the following articles:

- Chapin III, F. S., Hoel, M., Carpenter, S.R., Lubchenco, J., Walker, B., Callaghan, T.V., Folke, C., Levin, S.A., Mäler, K-G. and Nilsson, C. (2006): Building Resilience and Adaptation to Manage Arctic change, AMBIO: A Journal of the Human Environment, Volume 35, pp. 198-202
- Cole, S., Izmalkov, S., and Sjöberg, E. (2014): Games in the Arctic: Applying Game Theory Insights to Arctic challenges, Polar Research, Volume 33
- Levin, S., Xepapadeas, T., Crépin, A-S., Norberg, J., de Zeeuw, A., Folke, C., Hughes, T., Arrow, K., Barrett, S., Daily, G., Ehrlich, P., Kautsky, N., Mäler, K-G., Polasky, S., Troell, M., Vincent, J.R., and Walker, B. (2013): Social-ecological Systems as Complex Adaptive Systems: Modeling and Policy Implications, Environment and Development Economics, Volume 18, pp. 111-132

Assignments will be handed out and clarified during the Summer School