AEM 7500:
Resource Economics

Syllabus

Professor:	Professor C.-Y. Cynthia Lin Lawell
Office hours:	TBA, via Zoom
Teaching Assistant:	Michael Meneses (mam789@cornell.edu)
Office hours:	Mondays 6:00pm-7:00pm, via Zoom Tuesdays 1:00pm-2:00pm, via Zoom
Course web site:	Canvas (https://login.canvas.cornell.edu/)
Class time and room:	Wednesdays 7:30pm-10:30pm Eastern Time, Warren Hall 101

This Syllabus will be continually updated throughout the Semester. The Canvas course web site will always have the latest version of the Syllabus for this Semester. For the latest version of Syllabus, please see the Canvas course web site.

COURSE DESCRIPTION

AEM 7500 covers analytic methods for analyzing optimal control theory problems; analytic and numerical methods for solving dynamic programming problems; numerical methods for solving stochastic dynamic programming problems; structural econometric models of static games of incomplete information; structural econometric models of single-agent dynamic optimization problems; structural econometric models of multi-agent dynamic games; and advanced topics in dynamic structural econometric modeling including unobserved heterogeneity, identification, partial identification, and machine learning. The course also covers economic applications of these methods that are relevant to the environment, energy, natural resources, agriculture, development, management, finance, marketing, industrial organization, and business economics. These applications include firm investment, nonrenewable resource extraction, optimal economic growth, fisheries, subsistence agriculture, investment under uncertainty, optimal stopping, (S,s) policies, petroleum production, water management, environmental policy, engine replacement, nuclear energy, wind energy, land use, rural labor supply, incentive schemes, health, and education. The methods covered in the course enable one to analyze the strategic and dynamic decision-making behavior of individuals, households, organizations, firms, and countries; to analyze how different institutions and policies (and changes in these institutions and policies) affect this behavior and its outcome; and to design institutions and policies so that the decision-making behavior and outcome that are realized increase net benefits to society.

Prerequisites: Graduate-level microeconomics at least at the level of AEM 6080 and AEM 6700; and graduate-level econometrics at least at the level of AEM 6120.

Natural resource economics: AEM 7500 is a highly rigorous, technical, advanced Ph.D. course focusing primarily on teaching students frontier methods that combine dynamic optimization, game theory, and econometrics. Graduate students who would like to develop, build, further, strengthen, and/or solidify their knowledge and expertise in the foundational models, methods, intuition, and concepts in natural resource economics -- including the valuation and use of land; the extraction and management of nonrenewable resources such as minerals, rare earth elements, and energy resources; renewable and nonrenewable sources of energy; forest management; fishery economics; water and groundwater economics, management, and conservation; and sustainability -- are encouraged to also take AEM 5500 (Resource Economics), either prior to or concurrently with AEM 7500 (Resource Economics).

Companion courses: Ph.D. students are encouraged to also take the following complementary companion courses: AEM 7040 (Applied Macroeconomics), AEM 7130 (Dynamic Optimization and Computational Methods), and AEM 7510 (Environmental Economics). AEM 7040 (Applied Macroeconomics), AEM 7130 (Dynamic Optimization and Computational Methods), AEM 7500 (Resource Economics and Applied Dynamic Structural Econometric Modeling), and AEM 7510 (Environmental Economics) can be taken concurrently and in any order.

LEARNING OUTCOMES

As a result of taking AEM 7500: Resource Economics, students will be able to:

1. Use optimal control theory to solve and analyze dynamic resource economic problems.

2. Use analytic and numerical methods to solve dynamic programming problems.

3. Use numerical methods to solve stochastic dynamic programming problems.

4. Develop and estimate structural econometric models of static games of incomplete information.

5. Develop and estimate structural econometric models of single-agent dynamic optimization problems.

6. Develop and estimate structural econometric models of multi-agent dynamic games.

7. Use dynamic models and dynamic structural econometric models to solve and analyze dynamic and strategic issues relevant to the environment, energy, natural resources, agriculture, development, management, finance, marketing, industrial organization, and business economics.

8. Use dynamic models and dynamic structural econometric models to analyze firm investment, nonrenewable resource extraction, optimal economic growth, fisheries, subsistence agriculture, investment under uncertainty, optimal stopping, (S,s) policies, petroleum production, water management, environmental policy, engine replacement, nuclear energy, wind energy, land use, rural labor supply, incentive schemes, health, and education.

9. Analyze the strategic and dynamic decision-making behavior of individuals, households, organizations, firms, and countries.

10. Analyze how different institutions and policies (and changes in these institutions and policies) affect this behavior and its outcome

11. Design institutions and policies so that the decision-making behavior and outcome that are realized increase net benefits to society.

12. Write and run computer programs using Matlab.

13. Find, access, critically evaluate, and ethically use information.

14. Integrate quantitative and qualitative information to reach defensible and creative conclusions.

15. Communicate and explain difficult concepts, mathematical methods, and quantitative information effectively through writing, speech, and visual information.

16. Apply concepts of sustainability to the analysis of one or more challenges facing humans and Earth's resources.

REQUIRED COURSE MATERIALS

There is no textbook for this class.

Students are required to use Excel. Cornell University students are eligible for several different options for Microsoft Office: https://it.cornell.edu/software-licensing/microsoft-office-students.

Students are required to use STATA. STATA is available on Cornell Center for Social Sciences (CCSS) servers: https://socialsciences.cornell.edu/research-support/compute-infrastructure.

Students are required to use Matlab. MATLAB student licenses are available at no cost to all registered full-time and part-time students at Cornell University and the Weill Cornell Medical College: https://it.cornell.edu/software-licensing/matlab-licensing. Matlab is also available on Cornell Center for Social Sciences (CCSS) servers: https://socialsciences.cornell.edu/research-support/compute-infrastructure

CODE OF CONDUCT

Students are expected to follow Cornell University's Code of Academic Integrity: https://cuinfo.cornell.edu/aic.cfm

COURSE COPYRIGHT

It is Cornell University policy that faculty members own the copyright of the course materials they develop. Lectures and office hours may not be audio recorded or video recorded except by the instructor. Course materials, problem sets, lecture recordings, and lecture videos should not be shared, posted, or circulated. Students are not permitted to buy, sell, post, publish, or redistribute any course materials, problem sets, lecture notes, lecture recordings, or lecture videos. Such unauthorized behavior is a violation of course copyright and constitutes academic misconduct.

TEACHING PHILOSOPHY

Students in this class will be set to a high standard of excellence. This course is very challenging, time- and work-intensive, and demanding, but also very rewarding for students who are willing to work hard and put in the time and effort to attend and actively engage synchronously in lectures and office hours, learn the difficult material, and complete and turn in all their assignments on time.

Teaching, communication, and interactions in this class will follow a high touch approach and the Socratic method. Attendance and participation in class are an integral part of this course.

Since I believe that programming is best taught individually, interactively, and through trial and error, I strongly encourage you to come regularly to office hours for help with programming and problem sets. Although there will be some instruction on Matlab during class, you will learn the most about programming in Matlab by trying out the programming yourself first and then coming to office hours with your programming questions and code.

I encourage you to ask questions and actively participate during class and office hours. I would highly recommend that you come to office hours regularly with your questions, even when there is no problem set due the next day. Between office hours and class, there will be multiple opportunities for you to ask questions before each problem set is due. The dynamically optimal strategy for learning in this class, which I encourage you to follow, is to start working on problem sets early, well before they are due, then come to office hours with your questions, then work more on the problem sets again, and come to office hours again with your questions.

Students are encouraged to ask questions and actively participate during class and office hours. I highly recommend that you come to office hours regularly with your questions. Students who come to class and office hours receive priority for my time and attention. I encourage you to actively participate in class and to come to office hours rather than send me emails when you have questions. As I believe that emails are an inferior means of teaching, communication, and interaction for this course, and as the class will instead follow a high touch approach and the Socratic method, I will not respond to a question by email if it is better addressed in person in office hours. Questions that are better addressed in person in office hours include questions relating to problem sets, questions relating to lectures, questions relating to problem set questions, questions relating to lecture material, analytical questions, empirical questions, questions about data, questions about data sources, questions about graphs, questions about Excel, and questions about Matlab. Students should not expect any individual or timely response to any emails that they send to me. This includes all forms of email and email-type messaging, including emails, emails sent via Canvas messaging, emails sent via Zoom, email replies to Canvas messages, and email replies to Zoom messages.

If you would like to ask or talk to me about something, please ask or talk to me in person in class or in office hours. Similarly, if you would like individual and/or timely attention, or would like to communicate or interact with me individually, please come talk to me in person in class or in office hours.

PARTICIPATION

There are 14 lectures in this course. Students are expected to attend all 14 lectures in this course. Attendance and participation in class are an integral part of this course. Critical material and information important for the class, problem sets, and research proposal are conveyed during lecture and not via any other medium. As explained below, problem sets are based on the material covered during lecture. There is no textbook for this class, nor any other perfect substitute for the learning, discussions, and interactive activities that take place and the material, knowledge, and information conveyed during class.

Participation in this course will be graded out of 28 points total.

There will be at least 2 opportunities to earn a participation point in each of the 14 lectures (Lectures 1-14); some lectures may have more than 2 opportunities to earn a participation point. Since there will therefore be at least 28 opportunities to earn participation points during lecture throughout the semester, students who earn all the participations points in all the lectures will receive the full 28 points out of 28 points total for the participation component of the course. For any lectures that take place over Zoom, in order to earn participation points, please have your video on so that your entire face is visible, and please make sure your audio and microphone are working. Students are encouraged to continue to earn participation points, even after they have received the maximum number of participation points.

Students will receive 1 point for each of Professor Lin Lawell's office hours they attend. Students are encouraged to come to office hours regularly with their questions, even when they have already received the maximum participation points.

Before each lecture, an announcement indicating whether the upcoming lecture will be exclusively in-person or exclusively on Zoom will be posted on the "Announcements" section of the Canvas course web site.

Before each lecture that will be on Zoom, the URL to register for the Zoom meeting for the upcoming lecture will be posted on the "Announcements" section of the Canvas course web site. There will be a separate registration and a different URL for registering for each lecture and a different Zoom meeting (and a different Zoom meeting URL and Zoom meeting ID) for each lecture, so you will need to register separately and again for each lecture, even if you have registered for a previous lecture. Please register using your Cornell email that has your Cornell NetID before "@cornell.edu". Please give yourself at least 1 hour to register for the Zoom meeting in advance of each lecture, so that you are certain to be registered in time to receive the Zoom meeting information, URL, and Zoom meeting ID for joining the Zoom meeting for that lecture, and so that you can join the Zoom meeting in time for the beginning of lecture on Mondays at 7:30pm Eastern Time.

For the Zoom meetings for both lecture and office hours, please join Zoom on a device that has a camera, a microphone, and audio, so that you can see and hear and can be seen and heard; that has a large enough screen that you can see what is written on the board.

For both in-person and any Zoom lectures, please be prepared to take notes during lecture in the same way you would take notes for an in-person lecture in class (e.g., by writing in your notebook or typing on your computer).

Before each Zoom lecture, be sure to familiarize yourself with Zoom, give yourself enough time to make sure your video and audio works, make sure you have a setup that enables you to see, hear, be seen, be heard, and take notes. Please also familiarize yourself with how to electronically raise your hand in a Zoom meeting. After you join the Zoom meeting, at the bottom of the Zoom window, click on "Reactions"; at the bottom of the menu that pops up there should be a button you can click that enables you to electronically raise your hand in a Zoom meeting.

Lectures are not to be audio recorded or video recorded by anyone except the course instructor.

For lectures that take place in Zoom, in order to attend lecture and participate in class, you must have your video on so that your entire face is visible, and your audio and microphone need to be working. To ask questions during lecture, please electronically raise your hand via Zoom, and wait to be called on.

Students are encouraged to ask questions and actively participate during class and office hours, even when they have already received the maximum participation points, and even when they do not receive additional participation points for doing so.

As AEM 7500 is an advanced Ph.D. class, and as fully engaging during all lectures and working hard on all the problem sets and the research proposal will be critical for learning the technical and abstract material in this class, auditors are not permitted in this course. Students must register and enroll in this course for a letter grade.

Participation in this course will be graded out of 28 points total. Each participation point up to the maximum 28 participation points will be equally weighted, each constituting 1/28th of the total participation grade for this course.

PROBLEM SETS

There will be 4 problem sets in this course. Problem sets will be posted on the Canvas course web site. These problem sets are designed to familiarize students with the methods and concepts introduced in class; to help students develop the creative and critical thinking skills needed for research in the area; and to guide students toward achieving the learning outcomes for this course.

Please upload and submit your homework assignments and code in a zipped file onto the course web site before the beginning of class **by 5:00pm Eastern Time** the day they are due. No extensions will be granted.

The zipped file should be named "<*Lastname*>_<*Firstname*>_PS<#>.zip", and should include a write-up of the answers in a pdf file entitled "<*Lastname*>_<*Firstname*>_PS<#>_answers.pdf", as well as any and all Excel files, STATA data sets, STATA do files, STATA log files, and Matlab m-files each as separate files. The writeup should be in pdf format, and should include all graphs, results, tables, etc. STATA code should be in STATA do files (.do files) in plain text format. Matlab code should be in m-files (.m files) in plain text format. Please comment your code and include a "READ_ME" document that specifies how to run the code and which program does what. Include any STATA data sets as ".dta" files. For example, George F. Warren's Problem Set 1 would be in a zipped folder with the name "Warren_George_PS1.zip". Similarly, Lee Teng-hui's Problem Set 2 would be in a zipped folder with the name "Lee_Teng-hui_PS2.zip".

The online submission for problem sets is through Canvas, in the same "Assignments" section of the Canvas course web site where the problem sets are posted. There will be one item per problem set, and this item includes the problem set itself as well as the portal for submission. For example, the portal for submitting the first problem set online can be accessed by clicking "Problem Set 1" in the "Assignments" section of the Canvas course web site.

Students may submit their problem sets multiple times online if they would like. For each problem set, the last version of problem set submitted online will be counted as what you have submitted online for that problem set, and will override any previous submissions of that problem set (even if a previous version may have earned you a higher score). The last version of problem set submitted online must therefore be submitted online **by 5:00pm Eastern Time** the day it is due, regardless of whether a previous version of that problem sets was submitted on time.

If the last version of the problem set submitted online is submitted (and received) online past the **5:00pm Eastern Time** deadline the day it is due, minutes and seconds late will be rounded up to the next whole hour and 10 points will be automatically deducted for each hour the problem set is late. For example, if the last version of the problem set is submitted and received online at 6:01pm Eastern Time the day it is due, then 10 points will be deducted from the problem set score. Similarly, if the last version of the problem set is submitted and received online at 7:01pm Eastern Time the day it is due, then 20 points will be deducted from the problem set score. Likewise, if the last version of the problem set is submitted and received online at 8:01pm Eastern Time the day it is due, then 30 points will be deducted from the problem set score. If the last version of a problem set is submitted 3:00am Eastern Time or later the day it is due (i.e., if the last version of a problem is submitted more than 9 hours after it is due), or if the problem set is never submitted online, then 0 points will be given for the problem set. The deductions for late submissions are made automatically by Canvas, and are based on the clock used by Canvas. Students are encouraged to submit their problem sets well ahead of time, so that any difficulty with the submission, internet congestion, internet connectivity, time zones, and/or differences in the clock used by Canvas and their own clock, etc., will not cause their problem set submission to be submitted (and received) online past the **5:00pm Eastern Time** deadline and marked and penalized as Late by Canvas. No extensions will be granted.

Students may consult each other on problem sets, but each student must complete and write up each of his or her problem sets separately on his or her own. Each student's problem set should therefore be unique and different from problem sets submitted by other students in the class, and also different from problem sets submitted by students in previous classes or in other classes.

The 4 problem sets will be equally weighted, each constituting $1/4^{th}$ of the total problem set grade for this course.

RESEARCH PROPOSAL

A proposal for a research project that applies one of the methods introduced in class to a topic of your choosing is due at the end of the semester, in lieu of a final exam. Possible topics include (but are not limited to) issues relating to the environment, energy, natural resources, transportation, food, agriculture, development, management, finance, marketing, industrial organization, public economics, labor, macroeconomics, health, behavioral economics, and/or business economics.

The proposal should:

- Identify the research question.
- Provide motivation and background for the topic.
- Explain which method(s), lecture(s), and/or problem set(s) from this course you propose to apply to your research project, and why this is a good method to use for your topic and research question.
- Discuss the related literature.
- Identify and describe the data sources.
- Describe the model and methods to be used.
- Include acknowledgements.
- Include references (i.e., a bibliography).

The research proposal should be at least 10 pages long, double-spaced in 12-point font, with 1” margins, and in pdf format. Please name the file “<*Lastname*>_<*Firstname*>_proposal.pdf”. For example, Barbara McClintock’s research proposal would be a pdf file with the name “McClintock_Barbara_proposal.pdf”. Similarly, Kenneth L. Robinson’s research proposal would be a pdf file with the name “Robinson_Kenneth_proposal.pdf”.

Please do not use the same proposal you have written or are writing for another course.

Please upload and submit your research proposal onto the course web site by **TBA.** Late assignments receive no credit. No extensions will be granted.

The online submission for the research proposal is through Canvas, in same the “Assignments” section of the Canvas course web site where the research proposal instructions are posted. There will be one item for the research proposal, and this item includes the research proposal instructions as well as the portal for submission. The portal for submitting the research proposal online can be accessed by clicking "Research Proposal" in the "Assignments" section of the Canvas course web site.

Students may submit their research proposal multiple times online if they would like. The last version of research proposal submitted online will be counted as what you have submitted online for the research proposal, and will override any previous submissions of the research proposal (even if a previous version may have earned you a higher score). The last version of research proposal submitted online must therefore be submitted online by **TBA**, regardless of whether a previous version of the research proposal was submitted on time.

If the last version of the research proposal submitted online is submitted (and received) online past the **TBA** deadline the day it is due, minutes and seconds late will be rounded up to the next whole hour and 10 points will be automatically deducted for each hour the problem set is late. The deductions for late submissions are made automatically by Canvas, and are based on the clock used by Canvas. Students are encouraged to submit their research proposal well ahead of time, so that any difficulty with the submission, internet congestion, internet connectivity, time zones, and/or differences in the clock used by Canvas and their own clock, etc., will not cause their problem set submission to be submitted (and received) online past the **TBA** deadline and marked and penalized as Late by Canvas. No extensions will be granted.

GRADING

Participation:	28%
Problem sets:	60%
Research proposal:	12%

As AEM 7500 is an advanced Ph.D. class, and as fully engaging during all lectures and working hard on all the problem sets and the research proposal will be critical for learning the technical and abstract material in this class, auditors are not permitted in this course. Students must register and enroll in this course for a letter grade.

As AEM 7500 is an advanced Ph.D. class and as its content is challenging, varies, is updated for each subsequent offering, and includes a research-based component, students who have already taken AEM 7500 with Prof. Lin Lawell in a previous semester and are or will be working with Prof. Lin Lawell on research may take the class again if they obtain instructor permission to do so,. Students taking the class again must register and enroll in this course for a letter grade again; are expected to fully engage during all lectures and work hard on all the problem sets and the research proposal; and are expected to demonstrate positive forward development in their knowledge, scholarship, and research.

CLASS SCHEDULE

Date	Problem Set Due (5:00pm)	Topic
Wed 1/25		**Lecture 1: Dynamic Optimization, Optimal Control Theory, and Nonrenewable Resource Extraction**

Hotelling, Harold. (1931). The economics of exhaustible resources. Journal of Political Economy, 39 (2), 137-175.

Pontryagin, Lev S., Vladimir G. Boltyanskii, Revaz V. Gamkrelidze, and Evgeni F. Mishchenko. (1962). The Mathematical Theory of Optimal Processes. New York: Wiley Interscience.

Dorfman, Robert. (1969). An economic interpretation of optimal control theory. American Economic Review, 59, 817-831.

Intriligator, Michael D. (1971). Mathematical Optimization and Economic Theory. Englewood Cliffs, NJ: Prentice Hall.

Solow, Robert M. (1974). The economics of resources or the resources of economics. American Economic Review, 64 (2), 1-14.

Stiglitz, Joseph E. (1976). Monopoly and the rate of extraction of exhaustible resources. American Economic Review, 66 (4), 655-661.

Solow, Robert M., and Frederic Y. Wan. (1976). Extraction costs in the theory of exhaustible resources. Bell Journal of Economics, 7 (2), 359-370.

Seierstad, Atle, and Knut Sydsaeter. (1977). Sufficient conditions in optimal control theory. International Economic Review, 18 (2), 367-391.

Pindyck, Robert S. (1978). The optimal exploration and production of nonrenewable resources. Journal of Political Economy, 86 (5), 841-861.

Pindyck, Robert S. (1980). Uncertainty and exhaustible resource markets. Journal of Political Economy, 88 (6), 1203-1225.

Pesaran, M. Hashem. (1990). An econometric analysis of exploration and extraction of oil in the U.K. Continental Shelf. Economic Journal, 100 (401), 367-390.

Kamien, Morton I., and Nancy L. Schwartz. (1991). Dynamic Optimization. 2nd Edition. New York: Holland.

Farzin, Y. Hossein. (1992). The time path of scarcity rent in the theory of exhaustible resources. Economic Journal, 102, 841-851.

Farzin, Y. Hossein. (1995). Technological change and the dynamics of resource scarcity measures. Journal of Environmental Economics and Management, 29, 105-120.

Young, Denise, and David L. Ryan. (1996). Empirical testing of a risk-adjusted Hotelling model. Resource and Energy Economics, 18, 265-289.

Withagen, Cees. (1998). Untested hypotheses in nonrenewable resource economics. Environmental and Resource Economics, 11, 623-634.

Chermak, Janie M., and Robert H. Patrick. (2001). A microeconometric test of the theory of exhaustible resources. Journal of Environmental Economics and Management, 42, 82-108.

Weitzman, Martin L. (2003). Income, Wealth, and the Maximum Principle. Cambridge, MA: Harvard University Press.

Lin, C.-Y. Cynthia, and Gernot Wagner. (2007). Steady-state growth in a Hotelling model of resource extraction. Journal of Environmental Economics and Management, 54 (1), 68-83.

Livernois, John. (2008). On the empirical significance of the Hotelling rule. Review of Environmental Economics and Policy, 3 (1), 1-20.

Lin, C.-Y. Cynthia. (2009). Insights from a simple Hotelling model of the world oil market. Natural Resources Research, 18 (1), 19-28.

Slade, Margaret E., and Henry Thille. (2009). Whither Hotelling: Tests of the theory of exhaustible resources. Annual Review of Resource Economics, 1, 239-260.

Gao, Weiyu, Peter R. Hartley, and Robin C. Sickles. (2009). Optimal dynamic production from a large oil field in Saudi Arabia. Empirical Economics, 37 (1), 153-184.

Lin, C.-Y. Cynthia, Haoying Meng, Tsz Yan Ngai, Valeria Oscherov, and Yan Hong Zhu. (2009). Hotelling revisited: Oil prices and endogenous technological progress. Natural Resources Research, 18 (1), 29-38.

Conrad, Jon M. (2010). Resource Economics. 2nd Edition. Cambridge, UK: Cambridge University Press.

Ghoddusi, Hamed. (2010). Dynamic investment in extraction capacity of exhaustible resources. Scottish Journal of Political Economy, 57 (3), 359-373.

Kaiser, Harry M., and Kent D. Messer. (2011). Mathematical Programming Models for Agricultural, Environmental and Resource Economics. Hoboken, NJ: John Wiley and Sons, Inc.

Ghandi, Abbas, and C.-Y. Cynthia Lin. (2012). Do Iran's buy-back service contracts lead to optimal production?: The case of Soroosh and Nowrooz. Energy Policy, 42, 181-190.

Leighty, Wayne, and C.-Y. Cynthia Lin. (2012). Tax policy can change the production path: A model of optimal oil extraction in Alaska. Energy Policy, 41, 759-774.

Smith, James L. (2013). Issues in extractive resource taxation: A review of research methods and models. Resources Policy, 38, 320-331.

Stroebel, Johannes, and Arthur van Bentham. (2013). Resource extraction contracts under threat of expropriation: Theory and evidence. Review of Economics and Statistics, 95 (5), 1622-1639.

Smith, James L. (2014). A parsimonious model of tax avoidance and distortions in petroleum exploration and development. Energy Economics, 43, 140-157.

Zhang, Wei, and C.-Y. Cynthia Lin Lawell. (2017). Market power in nonrenewable resource markets: An empirical dynamic model. Land Economics, 93 (1), 74-86.

Anderson, Soren T., Ryan Kellogg, and Stephen W. Salant. (2018). Hotelling under pressure. Journal of Political Economy, 126 (3), 984-1026.

Conrad, Jon M., and Daniel Rondeau. (2020). Natural Resource Economics: Analysis, Theory, and Applications. Cambridge, UK: Cambridge University Press.

Benchekroun, Hassan, Gerard van der Meijden, and Cees Withagen. (2020). OPEC, unconventional oil and climate change - On the importance of the order of extraction. Journal of Environmental Economics and Management, 104, 102384.

Meier, Felix D., and Martin F. Quaas. (2021). Booming gas -- A theory of endogenous technological change in resource extraction. Journal of Environmental Economics and Management, 107, 102447.

Bertone Oehninger, Ernst, and C.-Y. Cynthia Lin Lawell. (2021). Property rights and groundwater management in the High Plains Aquifer. Resource and Energy Economics, 63, 101147.

Pelzl, Paul, and Steven Poelhekke. (2021). Good mine, bad mine: Natural resource heterogeneity and Dutch disease in Indonesia. Journal of International Economics, 131, 103457.

Pommeret, Aude, Francesco Ricci, and Katheline Schubert. (2022). Critical raw materials for the energy transition. European Economic Review, 141, 103991.

Cairns, Robert D., and John M. Hartwick. (2022). Reconciling Hotelling resource models with Hotelling's accounting method. Energy Journal, 43 (5).

Ekeland, Ivar, Wolfram Schlenker, Peter Tankov, and Brian Wright. (2022). Optimal exploration and price paths of a non-renewable commodity with stochastic discoveries. NBER Working Paper No. 29934. URL: https://www.nber.org/papers/w29934

Ghandi, Abbas, and C.-Y. Cynthia Lin Lawell. (2023). On the design of oil production contracts: Insights from a dynamic model. Working paper, Cornell University. URL: http://clinlawell.dyson.cornell.edu/Iraq_TSC_paper.pdf

Lin Lawell, C.-Y. Cynthia. (2023). Market power in the world oil market: Evidence for an OPEC Cartel and an oligopolistic non-OPEC fringe. Working paper, Cornell University. URL: http://clinlawell.dyson.cornell.edu/oil_mkt_conduct_paper.pdf

Kheiravar, K.H., Lin Lawell, C.-Y.C., and Jaffe, A.M. (2023). The world oil market and OPEC: A structural econometric model. Working paper, Cornell University. URL: http://clinlawell.dyson.cornell.edu/world_petroleum_mkt_dynamic_game_paper.pdf

Wed 2/1

Lecture 2: Dynamic Programming

Bellman, Richard. (1957). Dynamic Programming. Princeton: Princeton University Press.

Stokey, Nancy L., and Robert E. Lucas, Jr. (1989). Recursive Methods in Economic Dynamics. Cambridge, MA: Harvard University Press.

Conrad, Jon M. (2010). Resource Economics. 2nd Edition. Cambridge, UK: Cambridge University Press.

Conrad, Jon M., and Daniel Rondeau. (2020). Natural Resource Economics: Analysis, Theory, and Applications. Cambridge, UK: Cambridge University Press.

Wed 2/8

Lecture 3: Numerical Dynamic Programming and Introduction to Matlab

Stokey, Nancy L., and Robert E. Lucas, Jr. (1989). Recursive Methods in Economic Dynamics. Cambridge, MA: Harvard University Press.

Judd, Kenneth L. (1998). Numerical Methods in Economics. Cambridge, MA: MIT Press.

Conrad, Jon M. (2010). Resource Economics. 2nd Edition. Cambridge, UK: Cambridge University Press.

Ghandi, Abbas, and C.-Y. Cynthia Lin. (2012). Do Iran's buy-back service contracts lead to optimal production?: The case of Soroosh and Nowrooz. Energy Policy, 42, 181-190.

Leighty, Wayne, and C.-Y. Cynthia Lin. (2012). Tax policy can change the production path: A model of optimal oil extraction in Alaska. Energy Policy, 41, 759-774.

Conrad, Jon M., and Daniel Rondeau. (2020). Natural Resource Economics: Analysis, Theory, and Applications. Cambridge, UK: Cambridge University Press.

Miftakhova, Alena, Karl Schmedders, and Malte Schumacher. (2020). Computing economic equilibria using projection methods. Annual Review of Economics, 12, 317-353.

Renner, Philipp, and Karl Schmedders. (2020). Discrete-time dynamic principal–agent models: Contraction mapping theorem and computational treatment. Quantitative Economics, 11 (4), 1215-1251.

Bayer, Christian, and Ralph Luetticke. (2020). Solving discrete time heterogeneous agent models with aggregate risk and many idiosyncratic states by perturbation. Quantitative Economics, 11 (4), 1253-1288.

Paarsch, Harry J., and John Rust. (2020). Implementing Faustmann-Marshall-Pressler: Stochastic dynamic programming in space. In Áureo de Paula, Elie Tamer, and Marcel-Cristian Voia (Eds.), The Econometrics of Networks (Advances in Econometrics, Vol. 42, pp. 145-174). Emerald Publishing Limited, Bingley.

Ghandi, Abbas, and C.-Y. Cynthia Lin Lawell. (2023). On the design of oil production contracts: Insights from a dynamic model. Working paper, Cornell University. URL: http://clinlawell.dyson.cornell.edu/Iraq_TSC_paper.pdf

Wed 2/15	PS 1 due (5:00pm)	**Lecture 4: Using Matlab to Solve Dynamic Programming Problems**

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Wed 2/22

Lecture 5: Investment Under Uncertainty, Optimal Stopping, and (S, s) Policies

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Feb. Break

----- *February Break* -----

Wed 3/1

Lecture 6: Structural Econometrics and Generalized Method of Moments (GMM)

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Wed 3/8

Lecture 7: Estimating Structural Econometric Models of Static Games

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Wed 3/15	PS 2 due (5:00pm)	**Lecture 8: Using Matlab to Estimate Structural Econometric Models**

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Lecture 9: Dynamic Structural Econometric Models

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Wed 3/29

Lecture 10: Applications of Dynamic Structural Econometric Models

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----- *Spring Break* -----

Wed 4/12	PS 3 due (5:00pm)	**Lecture 11: Structural Econometric Models of Dynamic Games**

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Wed 4/19

Lecture 12: Applications of Structural Econometric Models of Dynamic Games

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Wed 4/26

Lecture 13: Advanced Topics in Dynamic Structural Econometric Modeling

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Wed 5/3	PS 4 due (5:00pm)	**Lecture 14: Using Dynamic Structural Econometric Models in Research**

TBA	Proposal due (TBA)	***Research Proposal due by TBA***

SUMMARY

Date	Problem Set Due (5:00pm)	Topic
Wed 1/25		**Lecture 1: Dynamic Optimization, Optimal Control Theory, and Nonrenewable Resource Extraction**
Wed 2/1		**Lecture 2: Dynamic Programming**
Wed 2/8		**Lecture 3: Numerical Dynamic Programming and Introduction to Matlab**
Wed 2/15	PS 1 due (5:00pm)	**Lecture 4: Using Matlab to Solve Dynamic Programming Problems**
Wed 2/22		**Lecture 5: Investment Under Uncertainty, Optimal Stopping, and (S, s) Policies**

Feb. Break		*----- February Break -----*
Wed 3/1		**Lecture 6: Structural Econometrics and Generalized Method of Moments (GMM)**
Wed 3/8		**Lecture 7: Estimating Structural Econometric Models of Static Games**
Wed 3/15	PS 2 due (5:00pm)	**Lecture 8: Using Matlab to Estimate Structural Econometric Models**
Wed 3/22		**Lecture 9: Dynamic Structural Econometric Models**
Wed 3/29		**Lecture 10: Applications of Dynamic Structural Econometric Models**

Spring Break		----- *Spring Break* -----
Wed 4/12	PS 3 due (5:00pm)	**Lecture 11: Structural Econometric Models of Dynamic Games**
Wed 4/19		**Lecture 12: Applications of Structural Econometric Models of Dynamic Games**
Wed 4/26		**Lecture 13: Advanced Topics in Dynamic Structural Econometric Modeling**
Wed 5/3	PS 4 due (5:00pm)	**Lecture 14: Using Dynamic Structural Econometric Models in Research**

TBA	Proposal due (TBA)	***Research Proposal due by TBA***

updated February 28, 2023