Economics 659: Real Options and Investment under Uncertainty
Course Outline, Fall 2013

Professor: Margaret Insley
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Office Hours: MW 3 -4 pm
Class time and location: T/Th, 3:30-4:50 pm, EV3 4408
Class Number: 3920

COURSE DESCRIPTION
This course considers the application of option concepts from finance to valuing real assets and investment opportunities. The focus is on using real options theory and methodology to determine to the optimal timing of investment expenditures characterized by uncertainty and irreversibility. We consider the implications of real options theory for the firm’s decision to invest, as well as for industry equilibrium. The course begins with an introduction to stochastic processes, Ito’s Lemma, the Black-Scholes equation, contingent claims analysis and dynamic programming. Numerical methods to solve simple option value problems will be presented, such as binomial trees and Monte Carlo simulation. Applications will focus on problems in natural resource and environmental economics, such as the optimal timing to exploit a mining asset or install pollution control equipment and, time permitting, other applications in economics.

BACKGROUND REQUIRED
Knowledge of microeconomic theory, basic calculus and linear algebra and some experience with differential equations are required. Assignments require some programming in Matlab, which students are expected to learn on their own.

EVALUATION

<table>
<thead>
<tr>
<th></th>
<th>Weighting in final grade</th>
<th>Important dates:</th>
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<tbody>
<tr>
<td>Assignment 1</td>
<td>7%</td>
<td>Due on Thurs Oct 10</td>
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<tr>
<td>Midterm</td>
<td>20%</td>
<td>Thurs Oct 31 in class</td>
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<tr>
<td>Assignment 2</td>
<td>8%</td>
<td>Due Thurs Nov 21</td>
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<tr>
<td>Project</td>
<td>20%</td>
<td>Paper choice due: Thurs Oct 17; Write up due: Mon Dec 2; Presentations will be scheduled towards the end of term.</td>
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<tr>
<td>Final exam</td>
<td>45%</td>
<td>TBA</td>
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Project: The goal of the project is for students to read and evaluate a journal article which applies real options theory and methodology, and to summarize the article in a class presentation. Students will choose a paper from a list provided early in the term. Each student will present a summary and analysis of their chosen paper to the class. A brief report (approximately 5-7 pages, double spaced) discussing the paper will be handed in by the deadline specified above. Paper selections must be approved by the instructor by Oct 17.

The project will be marked out of 50, with 25 for the written discussion, 20 marks awarded for the presentation, and 5 marks for questions asked during class presentations of your classmates. (You will be responsible for asking questions after one or two your classmates’ presentations.) The oral presentations will be scheduled sometime in November and/or December. Some presentations may need to be scheduled outside of class time. More instructions regarding the project will be handed out during the term.


OTHER REFERENCES (Where possible I will place these on reserve in the Porter library.)


Trigeorgis, Lenos (1996) Real Options, Managerial Flexibility and Strategy in Resource Allocation, MIT Press. (available online through the library)
## TENTATIVE LIST OF TOPICS AND SCHEDULE
This list of topics and readings may be adjusted during the term depending on interest and timing. Additional readings may be assigned throughout the term. A * indicates a required reading.

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Topic</th>
<th>Readings</th>
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| Sept 10/12 1-2 | I. Introduction  
1. Traditional investment theory versus the options approach  
2. Introduction to financial options  
3. A two period real options example  
4. Extending the example to more periods | • *Dixit & Pindyck, Ch 1 and 2  
• Trigeorgis Ch1  
• Hull, Chapter on the mechanics of options markets |
| Sept 17/19 3-4 | II. Stochastic processes and Ito’s lemma  
1. Introduction to stochastic processes  
2. The Wiener process  
3. Random walk representation of Brownian motion  
4. Ito processes | • *Hull, Chapters on Wiener Processes and Ito’s Lemma, the Black Scholes Merton Model  
• * Dixit and Pindyck, Chapter 3  
• *Forsyth, Sections 2.5 and 2.6  
• Various chapters in Neftci  
• Various chapters in Ross |
| Sept 24/26 5-6 | III. Dynamic optimization under uncertainty  
1. Dynamic programming and the Bellman equation | |

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<table>
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<tr>
<th>Date</th>
<th>Time</th>
<th>Topic</th>
<th>Supplemental Reading</th>
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| Oct 1/3 | 7-8   | 2. Contingent claims approach to valuing a risky asset, Black Scholes equation and risk neutral valuation | • * Dixit and Pindyck, Chapters 4  
• Trigeorgis Chapters 2 and 3 |
| Oct 8/10 | 9-10  | 3. Capital asset pricing model  
4. Valuing a forward contract | Assignment 1 due on Oct 10  
* Any introductory corporate finance text |
| Oct 15/17 | 11-12 | IV. Simple models of investment valuation and optimal investment timing  
1. A basic investment problem when the value of the project follows GBM  
2. Comparative statics for the stochastic case | Paper choice due on Oct 17  
* * Dixit and Pindyck, Chapters 5 and 6 |
| Oct 22/24 | 13-14 | 3. A more realistic investment problem |  |
| Oct 29/31 | 15-16 | Midterm – Oct 31  
4. Extensions of these basic investment problems |  |
| Nov 5/7 | 17-18 | V. Introduction to numerical methods for solving real option problems | * Forsyth, pages 19 – 21 and 37-41  
* Hull, Chapter on Basic Numerical Procedures |
| Nov 12/14 | 19-20 | VI. Industry Equilibrium  
1. Competitive Industries | * Dixit and Pindyck, Chapters 8 |
| Nov 19/21 | 21-22 | 2. Imperfect competition Assignment 2 due (Nov 21) | * Dixit and Pindyck, Chapter 9 |
| Nov 26/28 | 23-24 | Presentations, course evaluation, finishing up lecture material as needed | Paper write-up due Dec. 2 |
EXAMPLES OF PAPERS USING A REAL OPTIONS APPROACH

The real options approach can be applied in many different contexts. Below is a sampling of papers, focusing mainly on those analyzing environmental and natural resource topics. These papers may be chosen for your project. (Note each paper may be chosen by one student only.)

An overview of the real options literature containing many more references is found in:

Another useful review is found in:

1) Some earlier papers


2) **Natural resource investments**


c) Jon Conrad and Koji Kotanis, When to Drill? Trigger Prices for the Arctic National Wildlife Refuge, *Resource and Energy Economics*, 27(4), 273-86, November 2005. Also see the comment and erratum on this article:


3) **Environmental investments**


4) **Real estate**


5) **Other**


Academic Integrity: Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo are expected to promote honesty, trust, fairness, respect and responsibility.

Discipline: A student is expected to know what constitutes academic integrity, to avoid committing academic offences, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about “rules” for group work/collaboration should seek guidance from the course professor, academic advisor, or the Undergraduate Associate Dean. When misconduct has been found to have occurred, disciplinary penalties will be imposed under Policy 71 – Student Discipline. For information on categories of offenses and types of penalties, students should refer to Policy 71 - Student Discipline, http://www.adm.uwaterloo.ca/infosec/Policies/policy71.htm

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70 - Student Petitions and Grievances, Section 4, http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm

Appeals: A student may appeal the finding and/or penalty in a decision made under Policy 70 - Student Petitions and Grievances (other than regarding a petition) or Policy 71 - Student Discipline if a ground for an appeal can be established. Read Policy 72 - Student Appeals, http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm

Academic Integrity website (Arts): http://arts.uwaterloo.ca/arts/ugrad/academic_responsibility.html

Academic Integrity Office (University): http://uwaterloo.ca/academicintegrity/

Accommodation for Students with Disabilities:

Note for students with disabilities: The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.