Chapter #10: Natural Resource Economics

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General Overview

Natural Resource Economics addresses the allocation of resources *over time.*

Natural Resource Economics distinguishes between **nonrenewable resources** and **renewable resources**. Coal, gold, and oil are examples of nonrenewable resources. Fish and water are examples of renewable resources, since they can be self-replenishing.

Natural Resource Economics suggests policy intervention in situations where markets fail to maximize social welfare *over time*, i.e., where market forces cause depletion of nonrenewable natural resources too quickly or too slowly, or cause renewable resource use to not be *sustainable* over time (such as when species extinction occurs).

Natural Resource Economics also investigates how natural resources are allocated under alternative economic institutions.

Key Element of Dynamics: Interest Rate

One of the basic assumptions of Dynamic Analysis is that individuals are impatient. They would like to consume the goods and services that they own today, rather than saving for the future or lending to another individual. Individuals will lend their goods and services to others only if they are compensated for delaying their own consumption.

The **Interest Rate** (often called the *Discount Rate* in resource contexts) is the fraction of the value of a borrowed resource paid by the borrower to the lender to induce the lender to delay her own consumption in order to make the loan. The interest rate is the result of negotiation between the lender and the borrower. The higher the desire of the lender to consume her resources today rather than to wait, and/or the higher the desire of the borrower to get the loan, the higher the resulting interest rate. In this sense, the interest rate is an *equilibrium outcome*, like the price level in a competitive market.

Even an isolated individual must decide how much of his resources to consume today and how much to save for consumption in the future. In this situation, a single individual acts as both the lender and the borrower. The choices made by the individual reflect the individual's implicit interest rate of trading off consumption today for consumption tomorrow.

Let's consider the following example. Suppose Mary owns a resource. Mary would like to consume the resource today. John would like to borrow Mary's resource for one year. Mary agrees to loan John the resource for one year if John will pay Mary an amount to compensate her for the cost of delaying consumption for one year. (The amount loaned is called the **Principal.** The payment from John to Mary in compensation for Mary's delayed consumption is called the **Interest** on the loan.)

Suppose Mary's resource is \$100 in cash. Suppose the interest amount agreed to by Mary and John is \$10. Then, at the end of the year of the loan, John repays Mary the principal plus the interest, or \$110:

Principal + Interest = \$100 + \$10 = \$110

The (simple) **interest rate** of the loan, denoted **r**, can be found by solving the following equation for r:

$$\text{Principal} + \text{Interest} = (1 + r)\ \text{Principal}$$

For this example: $\$110 = (1 + r)\ \$100$

So, we find: $r = 10/100$ or 10%

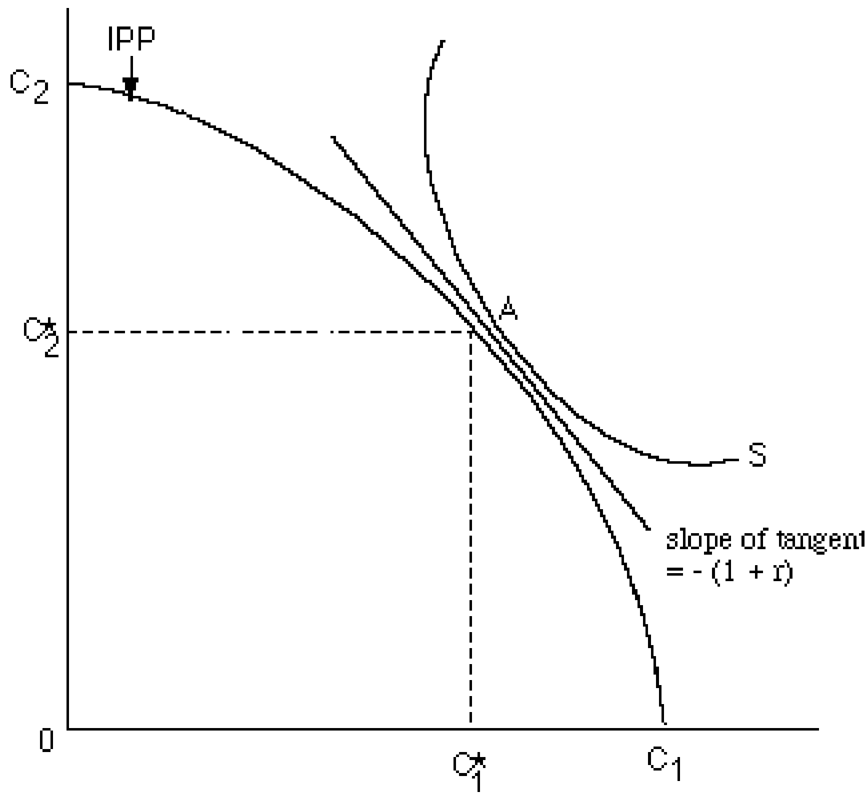
Hence, the interest rate on the loan was 10%.

Generally, we can find the interest rate by noting that:

$$B_1 = B_0 + r\,B_1 = (1+r)\,B_0$$

where B_0 = Benefit today, and B_1 = Benefit tomorrow

Figure 10.1: The Interest Rate is an Equilibrium Outcome



C_1 = consumption in period 1
C_2 = consumption in period 2

Delay of consumption (saving) in period 1 reduces current utility but increases utility in period 2. The inter-temporal production possibilities curve (IPP) denotes the technological possibilities for trading-off present vs. future consumption.

The curve S, is an indifference curve showing individual preferences between consumption today and consumption in the future. Any point along a particular indifference curve leads to the same level of utility. Utility maximization occurs at point A, where S is tangent to the IPP. The interest rate, r, that is implied by this equilibrium outcome, can be found by solving either of the following two equations for r:

slope of S at point A = - (1 + r)
slope of IPP at point A = - (1 + r)

Therefore, if we can determine the slope of either S or IPP at tangency point A, then we can calculate the interest rate, r. This is often done by solving the following individual optimization problem where I is the total income available over the two periods:

$$\underset{C1,C2}{Max.}\{U(C_1, C_2)\}$$

$$subject\ to:\ I = C_1 + \left(\frac{1}{1+r}\right)C_2$$

which can be written in lagrange form as:

$$= U(C_1, C_2) + \lambda\left[I - C_1 + \left(\frac{1}{1+r}\right)C_2\right]$$

FOCS:

$$\left.\begin{aligned} U_{C_1} &= \lambda \\ U_{C_2} &= \frac{\lambda}{1+r} \end{aligned}\right\} \qquad \frac{U_{C_1}}{U_{C_2}} = 1+r$$

The indifference curve is found by setting:

$$U_{C_1}d_{C_1} + U_{C_2}d_{C_2} = 0 \qquad \frac{d_{C_2}}{d_{C_1}} = \frac{-U_{C_1}}{U_{C_2}} = -(1+r)$$

The indifference curve simply indicates that the equilibrium occurs where an individual cannot improve her inter-temporal utility at the margin by changing the amount consumed today and tomorrow, within the constraints of her budget.

The Components of Interest Rates

Interest rates can be decomposed into several elements:

- Real interest rate, r
- Rate of inflation, IR
- Transaction costs, TC
- Risk factor, SR

The interest rate that banks pay to the government (i.e., to the Federal Reserve) is the sum r + IR. This is the **nominal interest rate**. The interest rate that low-risk firms pay to banks is the sum r + IR + TC_m + SR_m, where TC_m and SR_m are minimum transactions costs and risk costs, respectively. This interest rate is called the **Prime Rate**.

Lenders (banks) analyze projects proposed by entrepreneurs before financing them. They do this to assess the riskiness of the projects and to determine SR. Credit-rating services and other devices are used by lenders (and borrowers) to lower TC.

Some Numerical Examples:

(1) If the real interest rate is 3% and the inflation rate is 4%, then the nominal interest rate is 7%.

(2) If the real interest rate is 3%, the inflation rate is 4% and TC and SR are each 1%, then the Prime Rate is 9%.

Discounting

Discounting is a mechanism used to compare streams of net benefits generated by alternative allocations of resources over time. There are two types of discounting, depending on how time is measured. If time is measured as a discrete variable (say, in days, months or years), discrete-time discounting formulas are used, and the appropriate real interest rate is the "simple real interest rate". If time is measured as a continuous variable, then continuous-time formulas are used, and the appropriate real interest rate is the "instantaneous real interest rate". We will use discrete-time discounting in this course. Hence, we will use discrete-time discounting formulas, and the real interest rate we refer to is the simple real interest rate, r. **Unless stated otherwise, assume that r represents the simple real interest rate.**

From a lender's perspective, 10 dollars received at the beginning of the current time period is worth more than 10 dollars received at the beginning of the next time period. That's because the lender could lend the 10 dollars received today to someone else and earn interest during the current time period. In fact, 10 dollars received at the beginning of the current time period would be worth $10(1 + r) at the beginning of the next period, where r is the interest rate that the lender could earn on a loan.

Viewed from a different perspective, if 10 dollars were received at the beginning of the next time period, it would be equivalent to receiving only $10/(1 + r) at the beginning of the current time period. The value of 10 dollars received in the next time period is **discounted** by multiplying it by 1/(1+r).

Discounting is a central concept in natural resource economics. So, if $10 received at the beginning of the next period is only worth $10/(1 + r) at the beginning of the current period, how much is \$10 received *two* periods from now worth? The answer is $\$10/(1 + r)^2$.

In general, the value today of \$B received t periods from now is $\$B/(1 + r)^t$. The value today of an amount received in the future is called the **Present Value** of the amount.

The concept of present value applies to amounts *paid* in the future as well as to amounts received. For example, the value today of \$B paid t periods from now is $\$B/(1 + r)^t$. Note that if the interest rate increases, the value *today* of an amount received in the future declines. Similarly, if the interest rate increases, then the value *today* of an amount paid in the future declines.

For example, say you win the lottery! You are awarded after-tax income of \$1M. However, this is not handed to you all at once, but at \$100K/year for 10 years. If the interest rate is, r = 10%, net present value:

• NPV = $100K+(1/1.1)100K+(1/1.1)^2 100K + (1/1.1)^3 100K + \ldots + (1/1.1)^9 100K$.
= \$675,900
• The value of the last payment received is: NPV = $(1/1.1)^9 100K$ = \$42,410.

That is, if you are able to invest money at r = 10%, you would be indifferent between receiving the flow of \$1M over 10 years and \$675,900 today or between receiving a one time payment of \$100K 10 years from now and \$42,410 today.

The Present Value of an Annuity

An **annuity** is a type of financial property (in the same way that stocks and bonds are financial property) that specifies that some individual or firm will pay the owner of the annuity a specified amount of money *at each time period in the future*, ***forever!*** Although it may seem as if the holder of an annuity will receive an infinite amount of money, the Present Value of the stream of payments received over time is actually finite. In fact, it is equal to the periodic payment divided by the interest rate r (this is the sum of an infinite geometric series).

Let's consider an example where you own an annuity that specifies that Megafirm will pay you \$1000 per year forever. Question: What is the present value of the annuity? We know that NPV = \$1000/r. Suppose r = 0.1 then the present value of your annuity is \$1000/0.1 = \$10,000.

That is a lot of money, but far less than an infinite amount. Notice that if r decreases, then the present value of the annuity increases. Similarly, if r increases, then the present value of the annuity decreases. For example, you can show that a 50% decline in the interest rate will double the value of an annuity.

Sustainability

So, why all this talk about annuities in a resource economics class? The answer relates to **sustainability**. One definition of "the sustainability of a natural resource" is the ability to maintain a certain level of the natural resource forever. Suppose society derives some benefit each time period from a sustainably managed natural resource. Then, society will derive those benefits each time period forever. This is mathematically the same as an annuity.

Suppose society manages a small forest in a sustainable way such that we can harvest a million board-feet of timber per year from the forest forever. Society derives \$10 million per year in net benefits from the timber and the interest rate is 8%. Thus, the present value of the sustainable timber harvest from the forest is \$10 million / 0.08 = \$125 million. If society destroys the forest, society loses \$125 million in present value timber benefits. Society would need to compare this loss with the gains associated with using the land for other purposes.

The Social Discount Rate

The social discount rate is the interest rate used to make decisions regarding public projects. It may be different from the prevailing interest rate in the private market. Some reasons are:

- Differences between private and public risk preferences—the public overall may be less risk averse than a particular individual due to pooling of individual risk.

- Externalities—In private choices we consider only benefits to the individuals; in public choices we consider benefits to everyone in society.

It is argued that the social discount rate is lower than the private discount rate. In evaluating public projects, the lower social discount rate should be used when it is appropriate.

Uncertainty and interest rates

Lenders face the risk that borrowers may go bankrupt and not be able to repay the loan. To manage this risk, lenders may take several types of actions:

- Limit the size of loans.
- Demand collateral or co-signers.
- Charge high-risk borrowers higher interest rates. (Alternatively, different institutions are used to provide loans of varying degrees of risk.)

Risk - Yield Tradeoffs

Investments vary in their degree of risk. Generally, higher risk investments also tend to entail higher expected benefits (i.e., high yields). If they did not, no one would invest money in the higher risk investments. For this reason, lenders often charge higher interest rates on loans to high-risk borrowers, while large, low-risk, firms can borrow at the prime rate.

Criteria for Evaluating Alternative Allocations of Resources Over Time

Net Present Value (NPV) is the sum of the present values of the net benefits accruing from an investment or project. Net benefit in time period t is B_t - C_t, where B_t is the Total Benefit in time period t and C_t is the Total Cost in time period t.

The discrete time formula for N time periods with constant r:

$$NPV = \sum_{t=0}^{N} \frac{(B_t - C_t)}{(1+r)^t}.$$

Net Future Value (NFV) is the sum of compounded differences between project benefits and project costs.

The discrete time formula for N time periods with constant r:

$$NFV = \sum_{t=0}^{N} (B_t - C_t)\ (1+r)^{N-t}.$$

Internal Rate of Return (IRR) is the interest rate that is associated with zero net present value of a project. IRR is the x that solves the equation:

$$0 = \sum_{t=0}^{N} \frac{(B_t - C_t)}{(1+x)^t}$$

The Relationship Between IRR and NPV:

- If $r < IRR$ then the project has a positive NPV
- If $r > IRR$ then the project has a negative NPV
  (it is not worthwhile to invest in a project if you can get a better rate of return on an alternate investment).

To familiarize us with this concept let's consider the following situations:

- *Two period model:* If we invest \$I today, and receive \$B next year in returns on this investment, the NPV of the investment is: -\$I + \$B/(1 + r). Notice that the NPV declines as the interest rate r increases, and vice versa.

- *Three period model:* Suppose you are considering an investment which costs you \$100 now but which will pay you \$150 next year.

  If r = 10%, then the NPV is: -100 + 150/1.1 = \$36.36
  If r = 20%, then the NPV is: -100 + 150/1.2 = \$25
  If r = 50%, then the NPV is: -100 + 150/1.5 = \$0

- Consider the "stream" of net benefits from an investment given in the following table:

Time Period:	0	1	2
B_t - C_t:	-10066		60.5

The NPV for this investment is:

$$NPV = -100 + \frac{66}{(1+0.1)^1} + \frac{60.5}{(1+0.1)^2} = 10$$

The IRR for this investment is the value of x that solves:

$$0 = -100 + \frac{66}{1+x} + \frac{60.5}{(1+x)^2}$$

$$==>100 = \frac{66}{1+x} + \frac{60.5}{(1+x)^2}$$

$$==>100x^2 + 134x - 26.5 = 0.$$

$$==>x = \frac{-134 \pm \sqrt{(134)^2 + 400 \;\; 26.5}}{200}$$

$$==>x = \frac{-134+169}{200} = .175$$

That is, if the individual has a discount rate of $r < .175$, then she should invest in the project because it yields a higher return than simply loaning the principal amount at r.

***Problem with Internal Rate of Return**:* You may not get a unique answer For example, consider an income flow where you pay "a" in period 0, receive "b" in period 1, and pay "c" in period 2. To derive the internal rate of return z, solve:

$$-a + \frac{b}{(1+z)} - \frac{c}{(1+z)^2} = 0.$$

- Suppose a = 10, b = 30, c = 20, then:

$$-10(1+z)^2 + 30(1+z) - 20 = 0.$$

Using the quadratic formula:

$$1+z = \frac{b \pm \sqrt{b^2 - 4ac}}{-2a} = \frac{30 \pm \sqrt{100}}{20} = \frac{30 \pm 10}{20}$$

(1 + z) = 1 or 2 ==> z = 0 or 1.

Hence, the IRR calculation does not give us a unique answer.

Benefit-Cost Analysis

Benefit-cost analysis is a pragmatic method of economic decision-making. The procedure consists of the following two steps:

- ***Step 1**:* Estimate the economic impacts (costs and benefits) that will occur in the current time period and in each future time period.

- ***Step 2**:* Use interest rate to compute net present value or compute internal rate of return of the project/investment. Use internal rate of return only in cases in which net benefits switches sign once, meaning that investment costs occur first and investment benefits return later.

A key assumption of benefit-cost analysis is the notion of *potential* welfare improvement. That is, a project with a positive NPV has the potential to improve welfare, because utility rises with NPV.

Some issues in benefit-cost analysis to consider include:

- How discount rates affect outcomes of benefit-cost analysis. When discount rates are low, more investments are likely to be justified.
- Accounting for public rate of discount vs. private rate of discount.
- Incorporating nonmarket environmental benefits in benefit-cost analysis.
- Incorporating price changes because of market interaction in benefit-cost analysis.
- Incorporating uncertainty considerations in benefit-cost analysis.