5. Dynamic Efficiency and Discounting

5.1 Introduction

- Often benefits and costs of a policy occur at different times – we need a dynamic efficiency criterion to efficiently allocate resources over time.

- Eg. Stock pollutants (cumulative pollutants) which may persist for a long time. We need to consider making investments now to prevent future damages.

5.2 Sustainability Vs. Dynamic Efficiency

- **Sustainability:** The requirement that real welfare (including environmental goods) at least remains constant is called sustainability.

- In this section we assume sustainability and discuss the social goal of **dynamic efficiency**, generating the maximum real income for both current and future generations.

5.3 Intuition of Discounting

Would you prefer $100 in real purchasing power today, next year, or are you indifferent?

By real purchasing power we mean you will be compensated for inflation.

Better to have the money immediately – you can put it in the bank and get a real return of say 3% over the year. You get an extra $3 in purchasing power at the end of the year.

Where did the bank get the $3 to give you?

- Increasing Productive Capacity of the Economy

- Real GDP grows at 2-3% per year due to the increase in productive capacity.

- This growth is the source of profits, interest, and wage increases in the economy

- Because investment is productive $100 today is worth more than $100 next year.

- To compare dollar amounts received or incurred in different time periods we put all amounts on a present value basis.

- Invest amount K_0 today at rate r. At the end of the year we have: $K_1=K_0+ r K_0$

- We should be indifferent between K_0 received today or K_1 received in a year. K_0 is the present value (PV) of K_1.

- Solving for K_0:

  PV of K1 $\equiv K_0 = K_1/(1+r)$

Formula for present value of $X to be received in T years with a real interest rate (r).

$$PV=\$X/(1+r)^T$$

Other useful formulae:

PV of a stream of equal payments 'a' received at the **end** of the year for T years:

$$PV = \frac{a}{r}(1-(1+r)^{-T})$$

PV of an amount 'a' received in perpetuity at the end of each year:

$$PV = \frac{a}{r}$$

If you get payments at the beginning of the year then the amount "a" would need to be added to the above formulas.

5.4 **Examples**

Example 1

New compact fluorescent light bulbs can dramatically reduce electricity demand to between 1/5 and 1/10 of incandescent bulbs, with substantial improvements in environmental quality. However, they cost about 15 times as much. Suppose you are a hotel manager with 1000 light fixtures, and you are deciding which bulb to put in. You are only interested in environmentally friendly products if it doesn't cost you anything.

The following table compares the cash outlays of the two products, assuming each only lasts 4 years[1]:

Option \ Year	0	1	2	3	4	Total
Fluorescents	15 k	800	800	800	800	18.2 k
Incandescents	1k	4.8k	4.8k	4.8k	4.8k	20.2 k
Fluorescent Savings	-14 k	4.0k	4.0k	4.0k	4.0k	2.0 k

Which is the better investment?

[1] In fact fluorescents last much longer than incandescents, but we ignore this for simplicity.

Example 2:

Suppose if left unchecked, carbon dioxide emitted this year would generate sufficient global warming to raise sea levels so that in 50 years New Orleans would flood.

Options:
1) Spend $15 billion today to reduce emissions enough to prevent damage,
2) In 50 years build a dyke for $15 billion to protect the city.

We want to determine whether we spend $15 billion this year to prevent $15 billion in damages to our descendants.

How much would we have to put aside today to be sure that we will have $15 billion to build a dyke in 50 years? Assume an interest rate of 3%.

This is an example of an environmental bond.
Another example is a bottle deposit. If you throw out your pop bottle, that deposit is available to fund cleanup.

If we don't want to post an environmental bond, perhaps we should spend the $15 billion today?

- Suppose per capita GDP grows at 3% per year on average due to technological progress and building of physical capital (machinery, buildings etc).
- Diverting $15 billion today from normal productive investment implies lower GDP growth.
- If used elsewhere that $15 billion investment would have grown to ________ billion in 50 years.
- Best decision for dynamic efficiency is:

- Reducing CO_2 emissions today would make sense only if it cost less than ______ billion today (the present value of the benefits (i.e. avoided costs) to be received in 2050).

Caveats

1) Assumption of complete displacement of other investments.

2) Technological spinovers from the investment in pollution control.

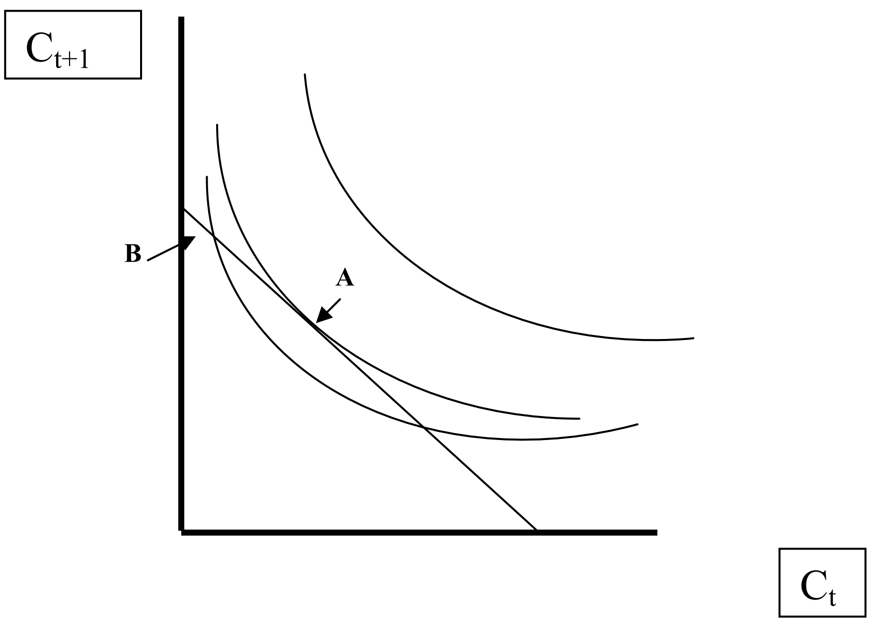
3) Choice of discount rate – what if the discount rate is 5%.

5.5 How do we choose the appropriate discount rate?

5.5.1 An individual's marginal rate of time preference

A consumer's marginal rate of time preference (MRTP): the rate at which individuals are willing to trade current for future consumption

Consider a two period example.
Consumer's problem:
Max $U(C_1, C_2)$ subject to a budget constraint.



Slope of the IC shows the rate at which the individual (Anne) is willing to trade consumption today with consumption next year and remain on the same indifference curve.

Slope of IC = marginal rate of substitution (MRS)

MRTP = MRS-1

Budget constraint: The consumer is constrained by income, *Y*.
Suppose Anne earns Y_1 in period 1 and Y_2 in period 2. If she can borrow at an interest rate of i, she could spend $Y_1 + \frac{Y_2}{(1+i)}$ in the first year, leaving no income in year 2. Or she could spend

everything in year 2 in which case she would have: $Y(_{1}(1+r)+Y_2$. Her budget constraint can be expressed as:

$$C_1 + \frac{C_2}{(1+i)} = Y_1 + \frac{Y_2}{(1+i)}$$

This says that the present value of Anne's consumption must equal the present value of her income.

If Anne is currently at Point B, she will benefit by moving to Point A because:

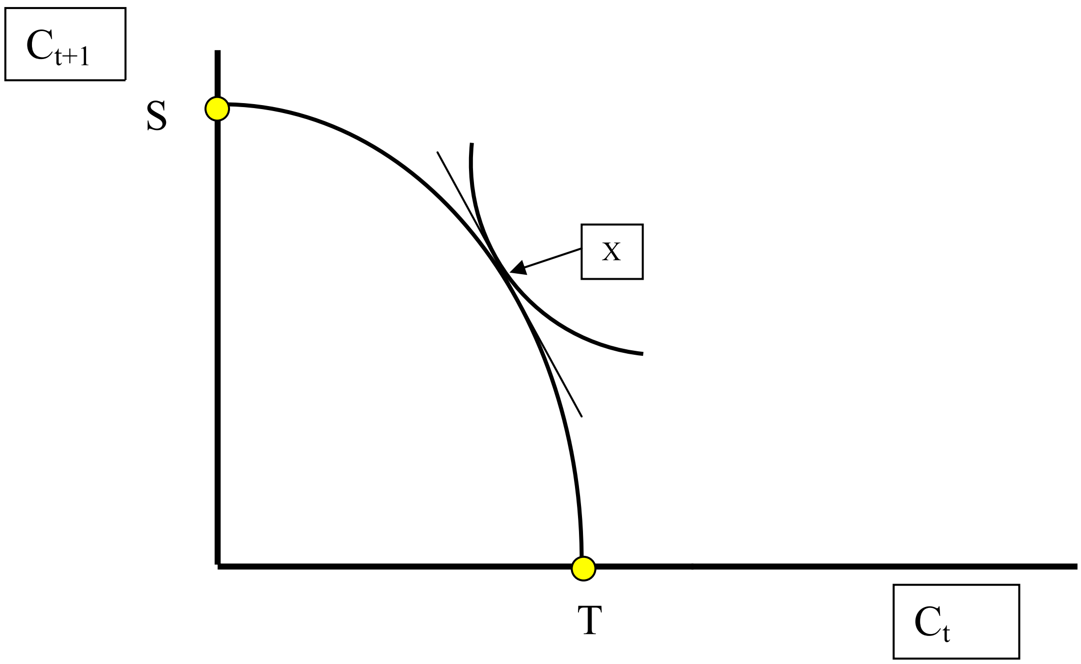
For an individual, utility is maximized when the MRTP equals to the interest rate he/she faces.

If all consumers face the same interest rate, all consumers will have the same MRTP.

5.5.2 Rate of return on investment

Consider a two period model with consumption and production in a hypothetical country with a group of individuals. Assume this country does not trade with other countries.

Consumption possibility frontier shows all possible combinations of current and future consumption if the economy uses all of its resources efficiently. Also shown is a social indifference curve.



Suppose we have T resources in period 1, which we can consume or invest. If we consume all in period 1 we will have none in period 2.
If we nothing in period 1 we will have S to consume in period 2.

S>T because:

The slope of the CPF represents the MRT.
MRT-1 = rate of return on investment (r)

Show the optimal level of consumptions and investment in period *t* and the level of consumption in period *t*+1.

The slope of the SIC is the MRS for society as a whole. MRS-1 = the social marginal rate of time preference (SMRTP). At point X we denote the SMRTP as p_X

At the optimum $1+ p_X = 1+r_X$, or $p_X = r_X$

These rates will also equal the economy wide market interest rate, *i*. If all individuals can borrow and lend at rate *i*, then the MRTP for all individuals will equal *i*.

In this restrictive model, we have $p = r = MRTP = i$

The appropriate discount rate is therefore the market rate of interest.

5.6 The social rate of discount in the real world

- In reality there is more than one interest rate.
- Taxes, risk, transactions costs - All lead to a divergence between the rate of return on investment and the rate at which consumers are willing to trade current and future consumption.
- Also future generations do not participate in today's capital markets
- What discount rate should governments use in making decisions about policy and spending?
- There are several different approaches that can be used.
- In this course we will examine the optimal growth rate method.

5.6.1 The Optimal Growth Rate Method for determining the Social Rate of Time Preference

Two arguments for a positive discount rate:

1) **Pure Time Preference (ρ)**: the degree of "impatience" in consumption defined by the extra amount a person will give up of future consumption in order to have that consumption now. This is reflected in the consumers MRTP discussed earlier. In the real world we would look at the real after-tax return on savings.

Ramsey and Pigou (in the 1930s) argued that ethically the social time preference rate should be zero, irrespective of the preferences of individually now living.

2) Real Income Growth (g)

If future generations will be better off than us, we are entitled to discount their income in order to "level the intergenerational playing field."

Note: we should look at growth in true real income adjusted to be a better measure of economic well being than GDP. Goodstein calls this net national welfare (NNW).

- Considering both these factors we have

$SRTP = \rho + \theta g$

Where θ is the (absolute value of the) "elasticity of marginal utility" – the percent change in marginal utility for an additional unit of consumption.

- Empirical estimates of θ range from 1 to 1.5, meaning that when per capita income rises by 10%, the marginal utility of an additional unit of consumption falls by 10 to 15%

- If per capita income is expected to grow at 2% annually over the long term, and if we set $\rho=0$, that implies SRTP of 2% to 3%.

5.6.2 Other possible ways of determining the discount rate

- Rate of return on private investment, r
- Rate at which individuals are willing to substitute consumption today with consumption next year, MRTP
- Government borrowing rate
- Shadow Price of Capital
  - Convert all costs and benefits to their corresponding changes in consumption, and then use the SRTP to discount – need to find the "shadow price of capital"

The book *Cost-Benefit Analysis* by Boardman, Greenberg, Vining and Weimer has a good discussion on these alternatives.