COST-BENEFIT ANALYSIS

(1) Origins of CBA

(2) Economic basis of CBA

(3) Identifying Costs and Benefits

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(6) Discount Rate

(7) Distributional Considerations

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ORIGINS OF COST BENEFIT ANALYSIS

Cost-Benefit Analysis (CBA)

> **estimates and totals up the equivalent money value of the benefits and costs to the community of projects to establish whether they are worthwhile**

Projects may be highways and dams and or can be training programs and health care systems

Idea of this economic accounting originated with Jules Dupuit, a French engineer in 1848

British economist, Alfred Marshall, provided some of the formal concepts that are at the foundation of CBA

Practical development of CBA came as a result of the impetus provided by the Federal Navigation Act of 1936

Act required that the U.S. Corps of Engineers carry out projects for the improvement of the waterway system

> **when the total benefits of a project to whomsoever they accrue exceed the costs of that project**

Corps of Engineers had create systematic methods for measuring such benefits and costs

Engineers of the Corps did this with out much, if any, assistance from the economics profession

In 1950's that economists tried to provide a rigorous, consistent set of methods for measuring benefits and costs and deciding whether a project is worthwhile

Some technical issues of CBA have not been wholly resolved even now

ECONOMIC BASIS OF COST BENEFIT ANALYSIS

- ✰ **Positive economics** - describes, explains and predicts actual economic phenomena devoid of value judgement 'what is'

- ✰ **Normative (welfare) economics** - explicitly introduces value judgements 'what should be'

- ✰ Guiding principle of CBA - each individual's preferences must somehow count in the assessment of projects

- ✰ Rules to effect this:

    (1) Unanimity

    (2) Pareto Superiority

    (3) Majority Rule

    (4) Potential Pareto Superiority

- ✰ **Unanimity**: A is judged socially superior to B if each member of society judges A superior to B

- ✰ **Pareto Superiority**: A is judged socially superior to B if at least one person judges A to be superior to B, and no one judges B superior to A

- ✰ **Majority Rule**: A is judged socially superior to B if the majority of members of society prefer A over B

- ✰ **Potential Pareto Superiority**: A is judged socially superior to B if those who gain by choice of A over B could compensate those who lose so that, if compensation were paid, no one would be worse off than if B chosen

IDENTIFYING COSTS AND BENEFITS

✰ Classification

A. Internal v. External

B. Tangible v. Intangible

C. Direct v. Indirect

☆ Internal v. External

Internal benefits accrue directly or indirectly to the entity under study internal benefits 'captured' by the project (e.g. revenue for electricity as a result of a hydro-electric project)

Internal costs are borne by the entity under study (e.g. payment for equipment, turbines, and other inputs to hydro-electric project)

External effects (costs/benefits) 'escape' the project (also called **externalities**, **spillovers**)

External benefits are benefits received by others for which they pay nothing (e.g. aesthetic appreciation of a building)

External costs are costs imposed on others without compensation

technological

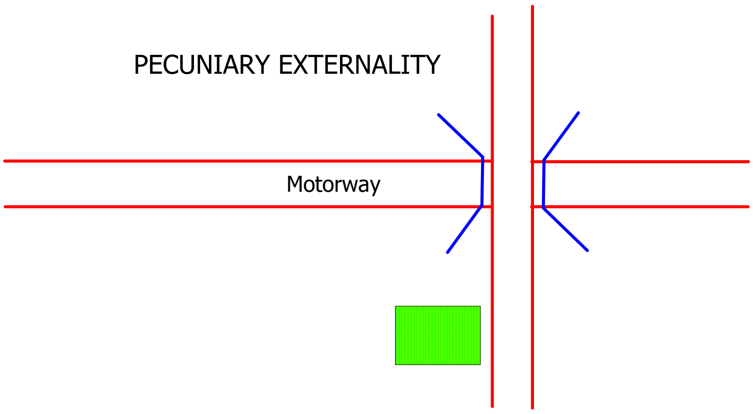
Externalities

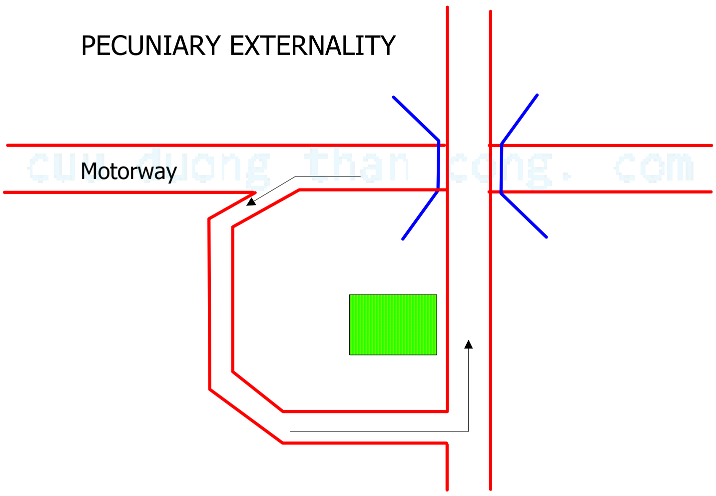
pecuniary

Technological involve **change in real consumption or production opportunities** for outsiders

Pecuniary associated with the **financial effects** of the project on others (as felt through price changes for inputs and outputs)

☆ Pecuniary externalities





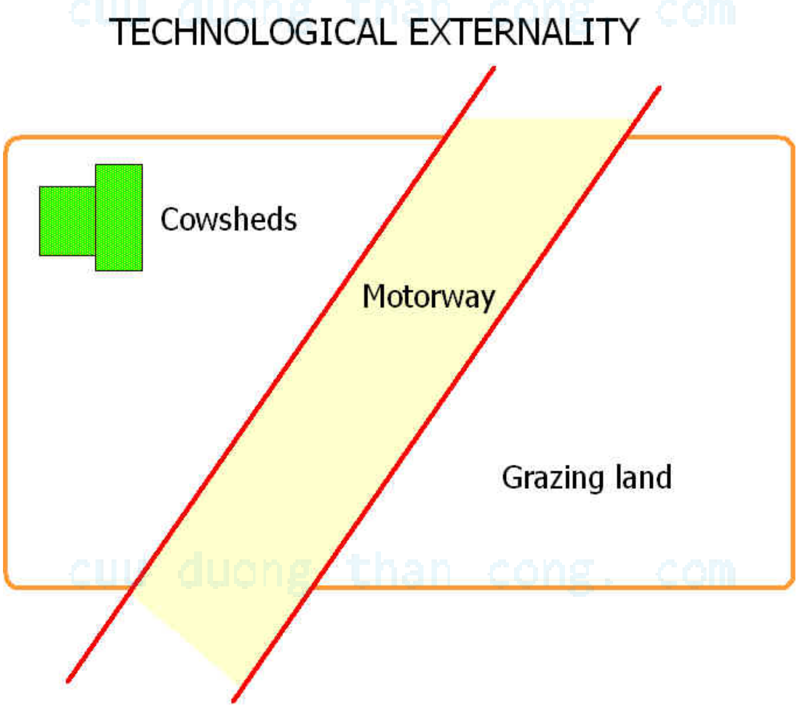
Effect pecuniary - not attributable to any change in the technical possibilities of converting inputs (land, labour, capital equipment, petrol etc.) into outputs (petrol supplies/other services to motorists)

Due to enhanced profitability flowing from demand generated by motorway users

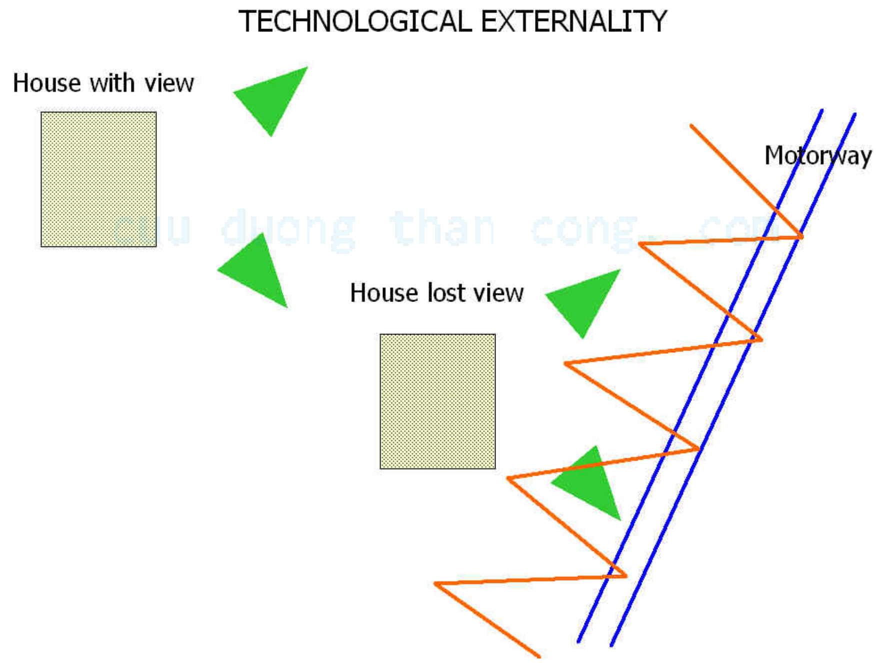
☆ Technological externalities

e.g. private hydroelectric dam - increased recreational opportunities, increased flood controls (produced incidental to the purpose of the dam - i.e. to generate electric power)

e.g. motorway - motorway <u>adversely affects</u> the <u>physical output</u> farmer can get from his land and buildings



e.g. house with view



☆ Tangible v. Intangible

Tangible benefits and **costs** are those that may be seen to be more economic in nature because they are **valued in the market place** (e.g. increased grain production from an agricultural project, earthworks for a road project)

Intangible benefits and **costs** are often more difficult to evaluate in dollar terms because they are **not priced in the market place** (e.g. odour associated with air pollutants, enjoyment of wilderness areas or recreational areas, aesthetic values, human life)

☆ Direct v. Indirect (primary v. secondary)

Direct benefits of project are **increased real values of outputs** associated with the project

(e.g. increased grain production from an irrigation project, increased electricity from a hydro-electric project, savings in travel-time from a new highway)

Indirect benefits reflect the impact of the project on the rest of the economy

'stemming from'

Indirect benefits

'induced by'

‘**stemming from**’ (forward linkage) **caused by additional activities generated by the direct outputs** (stimulative effects of direct outputs)

(e.g. net income of processors between primary product (increase in grain output) and consumers e.g. haulers, millers, bakers)

‘**induced by**’ (backward linkage) **demands induced by monetary payments for inputs to the project** (demand inducing effects of expenditures (inputs) required by the project)

(e.g. increased incomes of firms that supply the inputs to primary producers of grain)

QUANTIFYING COSTS AND BENEFITS

- ✰ To conduct an economic CBA need to know

  1) cost of project inputs

  2) the value of benefits

- ✰ At first glance this seems like a simple problem to solve

  1) total cost = number of input units x their purchase price

  2) total benefits = units of output x their market selling price

- ✰ Approach generally permissible for a **private sector financial CBA**, but not for a **public sector economic CBA**

- ✰ Public sector economic CBA requires a broader definitions of costs and benefits that may differ in some instance from private financial CBA

- ✰ Public sector economic CBA involves **gains and losses to society**

- ✰ Thus, CBA requires costs and benefits to be expressed as **social values**

Two postulates provide the philosophical basis for valuation in CBA

I. The **social value** of a project is the sum of the values of the project to the individual members of society

II. The **value** of a project to an individual is equal to his willingness to pay (WTP) for the project

I. Rejects an organic view of society in which a society is more than a collection of individuals

   Project can never be justified in CBA as for 'good of the state'

II. Sanctions consumer sovereignty and the existing distribution of income

   Consumer sovereignty implies that an individual is the best judge of his own welfare

Market Prices under a wide variety of circumstances satisfy these postulates as a measure of value

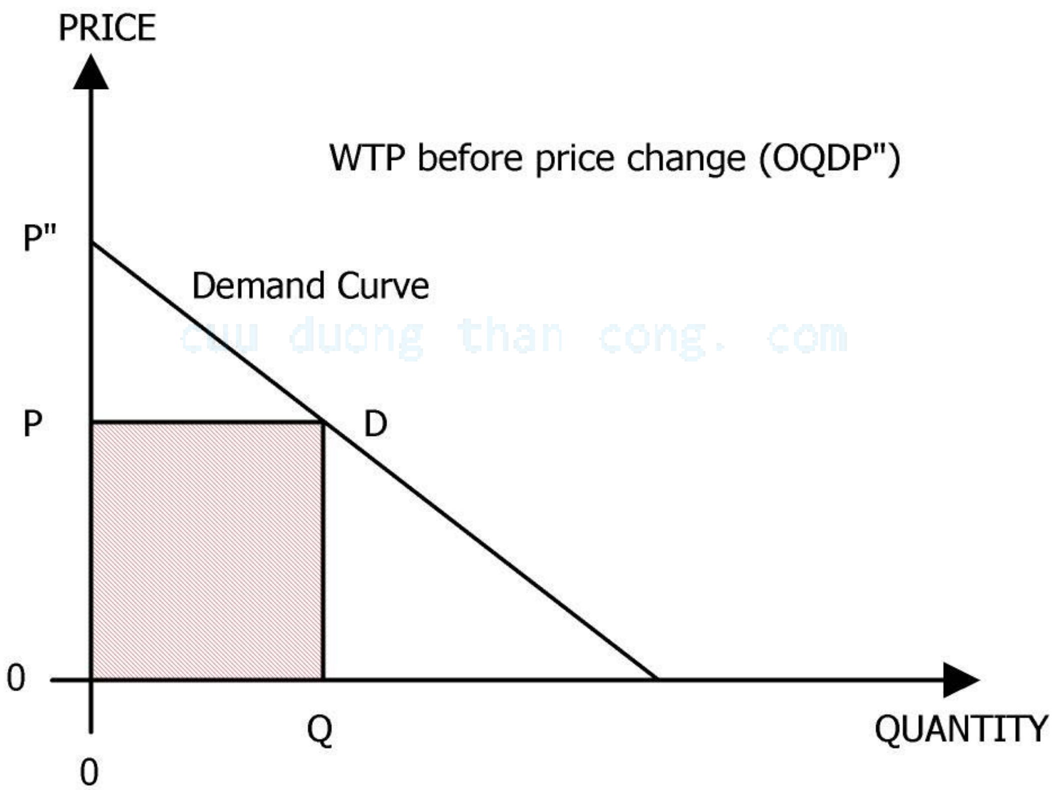
✰ Valuation of Benefits

Market prices are empirical manifestations of willingness to pay (WTP)

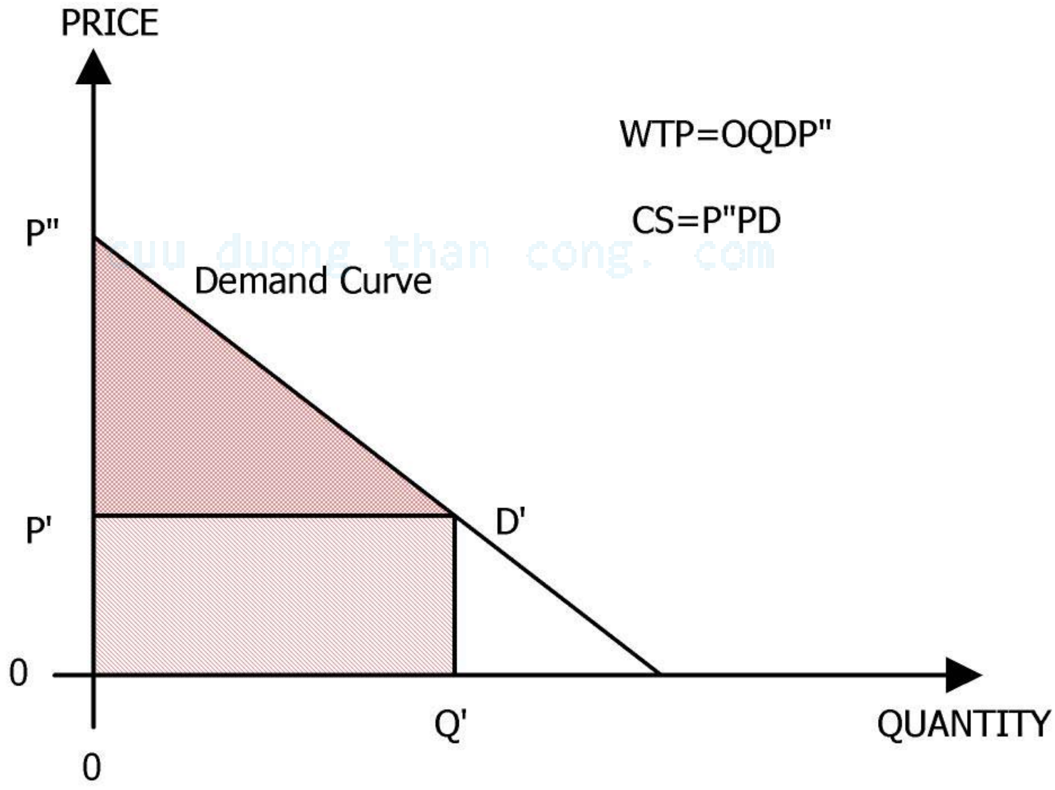
Market forces set the price of a good at P and the quantity sold at Q

Consumers pay PDQ – their effective payment - but this is not WTP

To get WTP, add **consumer's surplus** triangle P"PD



Project normally alters the price of a good (e.g. reduces price of electricity)

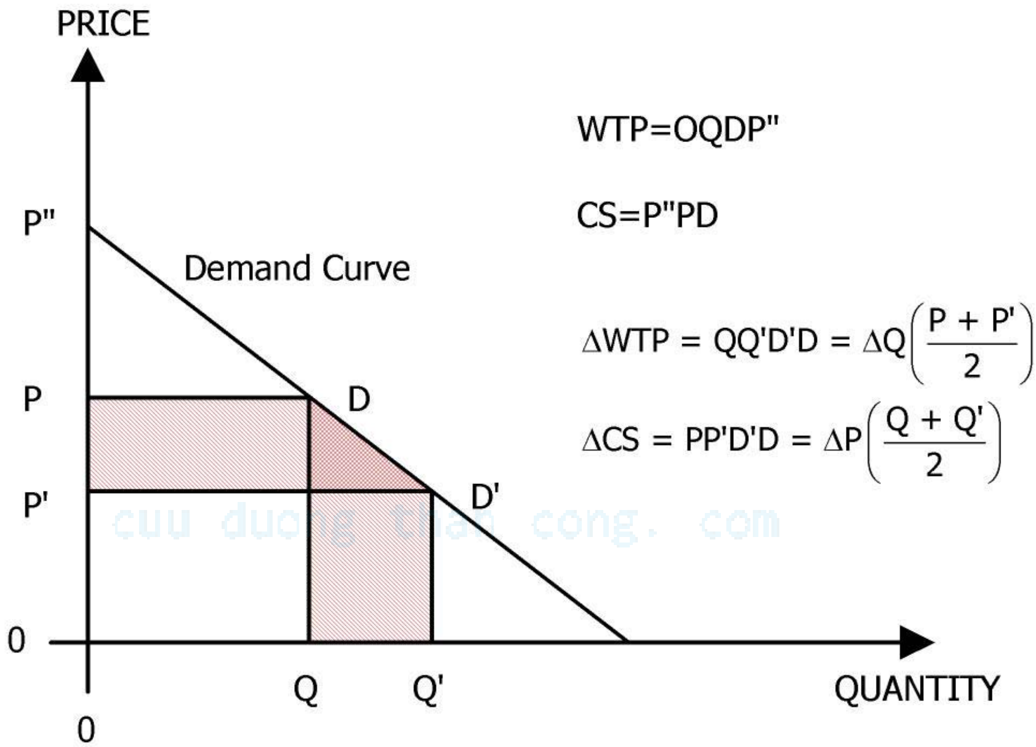


So ΔWTP important

$$\Delta WTP = \Delta Q.P' + \frac{1}{2}\Delta P.\Delta Q$$
$$= \Delta Q\left(\frac{P+P'}{2}\right)$$

Valuation of benefits is change in physical quantity (ΔQ) multiplied by price before and after investment

Change in consumer's surplus (ΔCS) is PP'D'D



If investment alters price only marginally (i.e. $P \approx P'$)

$$\Delta WTP = \Delta Q.P$$

Thus the ruling market price is the appropriate indicator of WTP per unit of output

Use of market prices needs to be qualified in a number of circumstances

✰ Valuation of Costs

Project will divert resources from an alternative use – public or private

'Costs' in CBA are **opportunity costs** i.e. **foregone benefits**

Problem is to obtain measure for WTP for foregone project

WTP for the foregone project is taken as the **monetary costs** of the selected project

Under certain circumstances, market prices are **inadequate** for representing benefits and costs

$$\text{NET BENEFITS} = WTP_i - WTP_j$$

i = project in question

j = project 'forgone'

$$\text{NET BENEFITS} = B - C$$
$$= b.p - c.p'$$

b = physical benefit (quantity of output)

p = price of output

c = physical input (quantity of input)

p' = cost of input

B = benefit from project

C = cost of project

✰ Introducing 'Time' over life span of project

$$\text{NET BENEFITS} = \Sigma_{t=0,n} B_t d_t - \Sigma_{t=0,n} C_t d_t$$

B_t = aggregate benefits in year (of project)

C_t = aggregate costs in year (of project)

d_t = discount factor (d_t becomes smaller with increasing time)

n = life span of the project

☆ Shadow Pricing

Thus in CBA, **social value** measured by WTP and **market prices** can reflect WTP

In a perfectly competitive economy, **market prices** can reflect **social cost** as well

When **market prices** do not reflect **social value**, need for **shadow** (**accounting**) **prices** arises

Also, **market prices may not exist**

E.g. services supplied publicly at zero price and **externalities** (such as noise or other pollution) not exchanged in the market

Necessitates shadow prices

DECISION CRITERIA

☆ Compounding

$$P_1 = P_0 (1 + r)$$
$$= \$100 (1 + 0.1) \quad \text{i.e. } r = 10\%$$
$$= \$100 (1.1)$$
$$= \$110$$

$$P_n = P_0 (1 + r)^n$$

$$P_5 = P_0 (1 + r)^5$$
$$= \$100 (1 + 0.1)^5$$
$$= \$100 (1.1)^5$$
$$= \$100 (1.61051)$$
$$= \$161.051$$

☆ Discounting

$$P_0 = \frac{P_1}{(1 + r)}$$

$$\$100 = \frac{\$110}{(1 + 0.1)} \qquad \text{i.e. discount rate} = 10\%$$

$$P_0 = \frac{P_n}{(1 + r)^n} \qquad (= P_n (1 + r)^{-n})$$

$$P_0 = \frac{P_5}{(1 + r)^5}$$

$$\$100 = \frac{161.051}{(1 + r)^5}$$

✰ Net Present Value (NPV)

$$NPV = \Sigma_{t=0,n} B_t d_t - \Sigma_{t=0,n} C_t d_t$$

$$d_t = \frac{1}{(1 + r)^t}$$

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

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

$$= -C_0 + \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1 + r)^t}$$

No benefits accrue in the capital construction period, $B_0 = 0$

☆ Internal Rate of Return (IRR) or Yield

IRR = rate of discounting the future that equates initial cost and the sum of future discounted net benefits (or, rate r which would make the NPV zero)

IRR is some r such that

$$C_0 = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t}$$

The rate of return r is not necessarily unique

Also, IRR assumes a single discount rate over the life of the project

If IRR exceed some predetermined value (the social discount rate), then the project is deemed to be acceptable

- ✰ Benefit-Cost Ratio

$$\frac{B}{C} = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}}$$

- ✰ B/C ratio useful when several independent projects are to be chosen, given a capital constraint

- ✰ The can rank projects by their respective B/C ratios, implementing successively lower projects until the capital budget is exhausted or until B/C ratio reaches one

- ✰ Fatal flaw when used to compare two or more projects: the B/C ratio gives the (discounted) benefits per dollar of (discounted) cost

- ✰ Thus the smaller of two projects may have a higher B/C ratio, yet yield a smaller total net benefit

- ✰ E.g. consider two projects, each of life span 1 year

(r = 5 percent)

Project	B_0	C_0	B_1	C_1	B/C	NPV
A	0	1	2	0	1.9	0.9
B	0	5	8	0	1.5	2.6

PROJECT (A)

$$\frac{B}{C} = \frac{2/(1 + 0.05)}{1} = 1.9, \quad NPV = -1 + \frac{2}{(1 + 0.05)} = 0.9$$

PROJECT (B)

$$\frac{B}{C} = \frac{8/(1 + 0.05)}{5} = 1.5, \quad NPV = -5 + \frac{8}{(1 + 0.05)} = 2.6$$

A superior to B on B/C ratio whereas B superior to A on NPV

However, B yields greater net benefits to society

B/C ratio sensitive to the definition of benefits and costs (i.e. will effect the magnitude of the B/C ratio)

Positive benefit ≡ negative cost, but B/C ratio depends on whether the magnitude added to the numerator (benefits) or the denominator (costs)

e.g. reduction of pollution

= [positive benefit] or [negative cost]?

B = present value of project benefits

C = present value of project costs

X = present value of cash flow (either added benefit or reduced cost) not included in B or C

If X classified as benefit, the B/C = (B + X)/C

If X classified as cost, the B/C = B/(C - X)

Assuming project acceptable if B/C ≥ 1

$$(B + X)/C \geq 1 \Rightarrow B + X \geq C$$

$$B/(C - X) \geq 1 \Rightarrow B \geq C - X$$

$$B \geq C - X \Rightarrow B + X \geq C$$

Thus classifying a cost as a negative benefit or a benefit as a negative cost has no impact on project acceptability

DISCOUNT RATE

✰ Rate of discount is a crucial parameter in NPV calculations, e.g.

Project	Initial Cost	Year 1	Year 2	Year 3
A	-100	220	12.1	13.3
B	-100	0.0	0.0	266.0

Project A has large initial return tapering off over time

Project B has net benefits occurring only in the terminal year

Project	NPV at 1 percent	NPV at 10 percent
A	143	120
B	158	100

Project B has net benefits occurring only in the terminal year

Project B is superior to A at discount rate 1 percent, but A is superior to B at discount rate 10 percent

☆ Two major conceptual approaches to the discount rate

(1) relates to society's valuation of future benefits (including those enjoyed by future generations) compared with the benefits available now

(2) concerned with the possibility that the resources required will be drawn out of alternative uses in the private sector of the economy

(1) **social time preference rate** [STP]
(2) **social opportunity cost rate** [SOC]

Under perfect competition STP = SOC

- ✰ Controversy developed in CBA around the choice of proper discount rate to use in present value calculations

- ✰ Controversy is not only over numerical values per se but also the very concept of what the discount rate ought to measure

- ✰ Correct discount rate (**social discount rate**) is the rate which, when applied to future costs and benefits, yield their actual **present social values**, the **rate at which society as a whole is willing to trade off present for future costs and benefits**

DISTRIBUTIONAL CONSIDERATIONS

✰ CBA formalised in terms of maximising net benefits and in this respect

(a) individual preferences count

(b) existing distribution of income sanctioned

- ✰ Consider a society of four individuals: A. B, C, D

  A, B, C gain $100 each from a project

  D loses $200

  Benefits = $300, Costs = $200

  Net benefits = $300 - $200 = $100 and the project is potentially worthwhile

✰ Conventional CBA sets a weight of unity to each $1 of benefit (or cost) regardless of who receives that benefit or who suffers the cost

$$\text{Net benefit} = a_A B_A + a_B B_B + a_C B_C + a_D B_D$$

B_A = benefits to A, ...

a_A = weight given to individual A, ...

Means that the existing income distribution is assumed optimal

Fact that D might be very poor and A, B, C equally very rich is immaterial to conventional CBA

☆ Deriving Distributional Weights – weights other than unity

a_i = weight attached to ith income group

Then, $a_i = \bar{Y}/Y_i$ where

$\bar{Y}$ = average income (of the nation, community ...)

Y_i = income of ith group

$$a_i > 1 \text{ if } Y_i < \bar{Y}$$

$$a_i < 1 \text{ if } Y_i > \bar{Y}$$

Consider example - assume groups A, B, C, D have the same number of persons

Group	A	B	C	D	Net Benefit
Y_i	200	250	100	50	
B_i	+100	+100	+100	-100	+200
a_i	0.75	0.60	1.50	3.00	
a_iB_i	75	60	150	300	-15

$$\text{Net Benefit} = \sum_t \sum_i \frac{a_i(B_{it} - C_{it})}{(1 + r)^t}$$

☆ Problem of using $a_i = \bar{Y}/Y_i$ is that a hypothetical change from Y_i to $\bar{Y}$ would in fact be accompanied by a change in the individual's expenditure pattern (determined by the income elasticity of demand) for the goods in question)

$a_i = \bar{Y}/Y_i$ approximates each individual's 'income equalised' WTP if the income elasticity of demand is unity

☆ In a situation where the elasticity is not unity

$$a_i = \left(\frac{\bar{Y}}{Y_i}\right)^b$$

where b is the income elasticity of demand

Weights a_i have nothing to do with what is or is not 'deserved' by each of the groups

To adjust for 'deservingness'

$$a_i' = \left(\frac{\bar{Y}}{Y_i}\right)^{v}$$

v = some judgemental weighting about 'deservingness'

Combining the two procedures

$$a_i'' = \left(\frac{\bar{Y}}{Y_i}\right)^{b+v}$$

SENSITIVITY ANALYSIS

In expression for NPV

$$NPV = \sum_{t=0}^{n} \left\{ \frac{\sum_i B_{it} - \sum_i C_{it}}{(1+r)^t} \right\}$$

Each B_{it} and C_{it} will be an estimate

Reliability of NPV will depend on accuracy of these estimates

In CBA, many measurements non-physical (e.g. WTP)

All deal with the future (thus, predictions)

NPV not a precise figure

If difference between NPVs for two projects is small and degree of error large, then decision-maker may select either or neither

Variance of an estimate should supplement the mean

Analyst’s attempt to gauge degree of error in estimates fall under heading of **sensitivity analysis**

Subjective approach quickest but least rigorous

E.g. after calculating NPV, analyst might suggest that figure subject to error of ± 10%

Selective approach to sensitivity analysis involves explicit series of calculations

E.g. varying a parameter (cost or benefit) considered subject to error by selecting high and low value and calculating NPV

Has advantage of **objectivity**, but unsuited for more than a few parameters

E.g. for 10 parameter, 20 NPVs for each project, in addition to best estimate

For two projects, 42 NPVs

Really need to calculate all possible combinations for worst, medium, best for each parameter

Thus for 10 parameters, 3^{10} (= 59,049) NPVs for each project

And have not incorporated on the chance of one of the bottom 10^3 outcomes actually happening