Engineering Economy

Ch. 2 Mays, Ed., Hydrosystems Eng. Mgmt., McGraw-Hill, 1992.

Eng Eco - compare alternatives & select most economical
- need common money units
  time
  interest - time value of money

Discount factors - f(
Based on i - interest rate
n - # years
P = Present amount
A = annual amount
F = future amount

Table 2.1.1

- Future from present amount — single-payment compound amount

$$F = P(1+i)^n$$

$$F/P = (1+i)^n = (F/P, i\%, n)$$

P/F = single payment present worth

- Annual from future amount — Uniform annual series sinking fund

$$A/F = \frac{i}{(1+i)^n - 1} = (A/F, i\%, n)$$

F/A = Series compound amount

- Annual from present amount — capital recovery factor

$$A/P = \frac{i(1+i)^n}{(1+i)^n - 1} = (A/P, i\%, n)$$

P/A - series present worth factor

- Uniform Gradient Series

Benefit-Cost Analysis

Costs of the initial (cap. C) & annual (O&M)
Benefits usually annual (O&M)

$$PVB: b_0 + \frac{b_1}{(1+i)} + \frac{b_2}{(1+i)^2} \cdots + \frac{b_n}{(1+i)^n}$$

$$PVC: c_0 + \frac{c_1}{(1+i)} + \frac{c_2}{(1+i)^2} \cdots + \frac{c_n}{(1+i)^n}$$

Investment $PVB > PVC$ or $\frac{PVB}{PVC} > 1$ $\frac{PVB}{PVC} = \frac{B}{C}$

Consider multiple alternatives. What if several have $\frac{PVB}{PVC} > 1$?

Optimize — when $\Delta PVB = \Delta PVC$

marginal value of B; marginal value of C

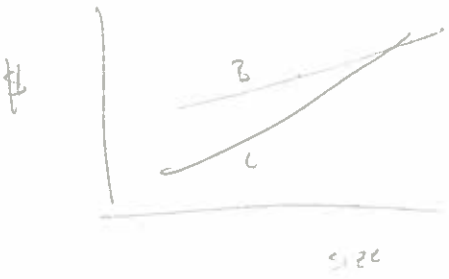
must compare Alternatives to each other

Start with lowest cost

$$\Delta_1 PVB = \Delta b_0 + \frac{\Delta b_1}{(1+i)} + \frac{\Delta b_2}{(1+i)^2} - \cdots + \frac{\Delta b_n}{(1+i)^n}$$

$$\Delta PVC = \Delta C_0 + \frac{\Delta b_1}{(1+i)} + \frac{\Delta b_2}{(1+i)^2} - \cdots \frac{\Delta C_n}{(1+i)^n}$$

$$\frac{\Delta PVB}{\Delta PVC} = \frac{\Delta B}{\Delta C} = \frac{PVB(A_j) - PVB(A_k)}{PVC(A_j) - PVC(A_k)}$$



Ex. 2.2.1

Consumer Behavior

Utility function — describes level of satisfaction to user for each alternative

select between commodities $w_1, \ldots, w_n$

$$u = f(w_1, w_2 \cdots, w_n)$$

$$n = 2 \quad u = f(w_1, w_2)$$

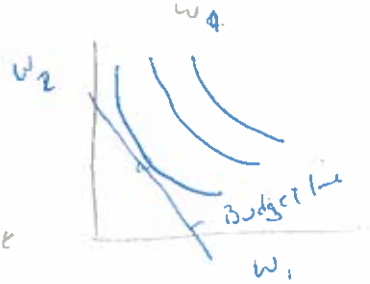
marginal utility: $du = \frac{df}{dw_1} dw_1 + \frac{\partial f}{\partial w_2} dw_2$

$-\frac{dw_2}{dw_1}$ = marginal rate of substitution

Maximization of Utility - user decisive

Budget constraint $B^\circ = P_1 w_1 + P_2 w_2$

P_1 price, P_2 price



Max utility when ratio of marginal utility = ratio of prices

$$\frac{dw_2}{dw_1} = \frac{P_1}{P_2}$$

Demand function - quantity consumer will buy as function of price & income

① substitution effect $p\uparrow \; Q_d\downarrow$

② income effect

Elasticity of demand - proportionate rate of change in quantity demanded by proportionate rate of price change

$$\epsilon_{11} = \frac{\partial w_1/w_1}{\partial p_1/p_1} = \frac{p_1}{w_1}\frac{\partial w_1}{\partial p_1}$$

more negative ↓

$\epsilon_{11} > -1$ $p_1\uparrow$, $w_1\uparrow$

$\epsilon_{11} < -1$ $p_1\uparrow$, $w_1\downarrow$

$\epsilon_{11} = -1$ $p_1\uparrow$ w_1 constant

high elasticity ≥ -1 necessities

$$\frac{\partial(p_1 w_1)}{\partial p_1} = w_1(1+\epsilon_{11})$$

Cross price elasticity $\epsilon_{21} = \frac{p_1}{w_2}\frac{\partial w_2}{\partial p_1}$

Theory of the Firm — used for hydrosystems

Firm – technical unit which produces commodities

Theory of Firm

- allocation of resources for production
- determine level of production
- response to change in price for inputs & outputs

Production function

$$q = f(x_1, x_2, \cdots, x_m)$$

(q: product; $x_1, \ldots, x_m$: inputs)

assume technical efficiency max output from each combination

Ex. q = corn x_1 = irrigation H_2O x_2 = fertilizer

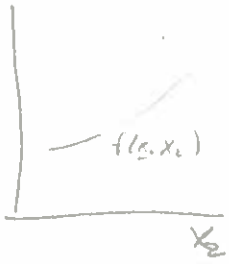
$$q = f(x_1, x_2)$$

Input, output levels → rate of use or production/time

Long run → all inputs vary

Short run → some is fixed

Total Product $TP(x_2) = q = f(\underline{x}_1, x_2)$ ($\underline{x}_1$: fixed)



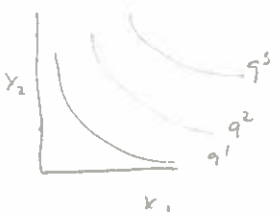
Average Product $AP(x_2) = \frac{q}{x_2} = \frac{f(\underline{x}_1, x_2)}{x_2}$

Marginal Product $MP(x_2) = \frac{\partial q}{\partial x_2} = \frac{\partial f(\underline{x}_1, x_2)}{\partial x_2}$

Ex 2.4.1 calculate MP

Isoquant

$q^0 = f(x_1, x_2)$ (q^0: constant)



Rational operation → where $MP(x_1)$ & $MP(x_2)$ are > 0

Rate of Technical Substitution $RTS = f(\text{slope of isoquant})$

$$= -\frac{dx_2}{dx_1} = \frac{MP(x_1)}{MP(x_2)}$$

Rat

Optimal Inputs – 2 variable

cost function $C = r_1 x_1 + r_2 x_2$ (price)

$$\frac{dx_2}{dx_1} = -\frac{r_1}{r_2} \Rightarrow RTS = -\frac{dx_2}{dx_1} = \frac{r_1}{r_2} = \frac{MP(x_1)}{MP(x_2)}$$

rearrange $\frac{MP(x_1)}{r_1} = \frac{MP(x_2)}{r_2}$ $\frac{MP}{\text{dollar cost}}$ same for all inputs at optimum

Expansion Path – crossing Isoquants at optimal combinations $g(x_1, x_2) = 0$

Cost in Short Run – 2 variable
x_1 fixed x_2 variable

$q = f(x_1, x_2)$ $\quad g(x_1, x_2) = 0$

$C = r_1 x_1 + r_2 x_2$

Costs associated w/ x_1 are **fixed cost** FC

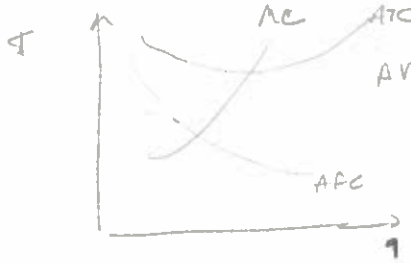
Total variable cost – spent on x_2

Total Cost = TVC + TFC

Average Total Cost $ATC = \frac{TC}{q}$ $\quad AFC = \frac{TFC}{q}$

$AVC = \frac{TVC}{q}$

Marginal cost $MC = \frac{\Delta TVC}{\Delta q}$



Total Revenue $TR = pq$
$MP = \Delta TR / \Delta Q$
Profit maximized when
$MR = MC$

Costs in Long Run – all variables
long run AVC = envelope of short-run AC curves

Demand Curve

Demand for commodity w_j depends on P_j, other product prices, & budget B^0

$$D_i = D_i(P_1, P_2 \dots, P_n, B^0)$$

only P_j variable

$$D_i = D_i(P_j)$$

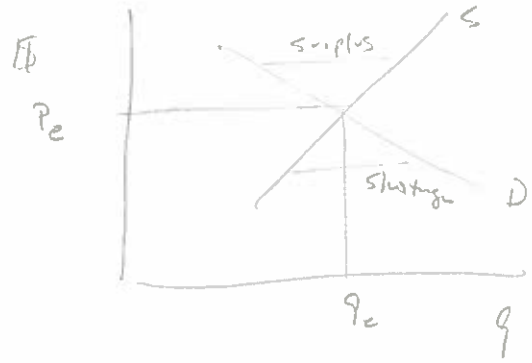
Aggregate demand $D = \sum_i D_i(P)$

Marginal revenue $MR = \frac{d(TR)}{dq} = P$ if $TR = Pq$

MR curve = Demand Curve

Supply function = part of MC above AVC

Long run optimum $\Rightarrow MC = P$



Benefit-Cost Analysis

I. Project Evaluation

A. Feasibility Tests

1. Engineering feasibility - performs function?
2. Economic feasibility - benefits > costs?
3. Financial feasibility - sufficient funds?
4. Political feasibility - approval secured?
5. Social feasibility - users in favor?
6. Environmental feasibility - No laws broken?

B. Economic Feasibility

1. Need for government in w.r. planning
   a. Overcome allocation deficiencies
   b. Coordinate multi project systems
   c. Provide financial resources

2. Problems with govt.
   a. Lack of market incentives
   b. Political motivation - "pork barrel"

3. Solution - B/C analysis
   a. Force objective evaluation
   b. Encourage improved fund allocation

C. Defining Benefits and Costs

1. First define goal(s) and alternative actions
   a. Benefits measure effectivenes of action
   b. Costs measure effectiveness of sacrificed action

2. Differences in B/C analysis and private firm analysis:
   a. Public viewpoint incorporates all costs and all benefits. External economies/diseconomies need evaluating.
   b. Discount rate may be lower than that used by private firms.
   c. Government planner should try to evaluate true economic worth of input and output.
   d. Govt. planner must dirive equivalent market values through demand analysis.

D. Benefit-Cost Categories - 4 main classes:

1. Tangible (market) benefits - those resulting from consequences to private parties which can be assigned monetary value.

   a. Primary benefits - value obtained from project-produced goods and services.
      Direct benefits - accrued to those who put project output to its intended use.
      Indirect benefits - realized economic consequences of technological external effects.
      Land-enhancement benefits - when more productive land use is made possible (other than direct benefits)

reduce flood damage
from increase
value of electric power
lowflow tr... water quality
also benefits
navigation

b. Secondary benefits - value added to activities influenced by the project through economic rather than technological linkages.

"Stemming-from" benefits - linkages that increase the net income of those who process project output. cotton used for clothing - each processor

"Induced-by" benefits - result from backward production linkages that increase income for those providing goods and services. farm implement sales to save the cotton

c. Employment benefits - increased enployment from new jobs created.

d. Public benefits - other goals achieved and evaluated by value judgements or relative desirability. economic stabilization, income redistribution, environmental quality

2. Intangible (extramarket) Benefits - cannot be assigned monetary value, eg. health improvements, env. aesthetics, historic preservation.

3. Project Construction - requires private parties to bear costs as well as realize benefits.
Benefits - costs = net benefit

a. Associated costs - private investment to produce or utilize project output. purchase machinery for new crops

b. Induced costs - adverse consequences of project construction, eg. cost of downstream flood control.

4. Cost of Project Installation - placed in denominator of B/C ratio. Includes construction cost, O&M, and replacement.

II. Benefit-Cost Measurement - use "with-and-without" principle. built or not built

A. Direct Primary Benefits

1. **Market value of output**
2. **Cost of producing output by alternative (least-costly)**

B. Indirect Primary Benefits

1. **Develop checklist of potential project technological external effects and assess each one; then sum results for total benefit.**
2. **Estimate on the basis of % of direct benefits.**

C. Land-Enhancement Benefits

1. **Develop substantial evidence that land use will change.**
2. **Evaluate extent of change.**

D. Secondary Benefits

1. **National - include with primary benefits.**
2. **Regional, state or local - additional B/C ratio.**
3. **Include explanation of secondary benefits in planning reports.**

E. Employment Benefits

1. **Wages paid to those otherwise unemployed.**
2. **Increase in wages to those underemployed.**
3. **New investment opportunity**
4. **Input-output analysis**

F. Income-Redistribution Benefits - Establish, by tax bracket,

1. **Cost of project among those providing funds to pay for project**
2. **Money spent on installation, and**
3. **Tangible efficiency benefits.**

G. Other Public Benefits - depends on type of benefit.

Improved facilities, property taxes

H. Intangible benefits - Documentation. if not valued

I. Associated and Induced Costs - depends on type.

For investment to utilize output — adverse consequences

J. Project Installation Costs - Includes construction, engineering/administration, right-of-way, easements, relocations, etc.

K. O&M, Replacement - Includes personnel, equipment, supplies, energy costs, etc.

III. Value of Benefit-Cost Analysis

A. Project formulation

B. Adequacy of Measurement

C. Reasons for Using B/C

1. **Restrains abuse of political process**
2. **Promotes scientific understanding of physical and social problems**
3. **Helps broaden repayment base**
4. **Helps obtain dependable repayment contracts**
5. **Helps make public districts and special taxes more palatible.**