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Logan, Utah 84321

Proceedings of a Summer Institute in Water Resources

VOLUME II - THE ECONOMICS OF WATER RESOURCE DEVELOPMENT AND CONSERVATION

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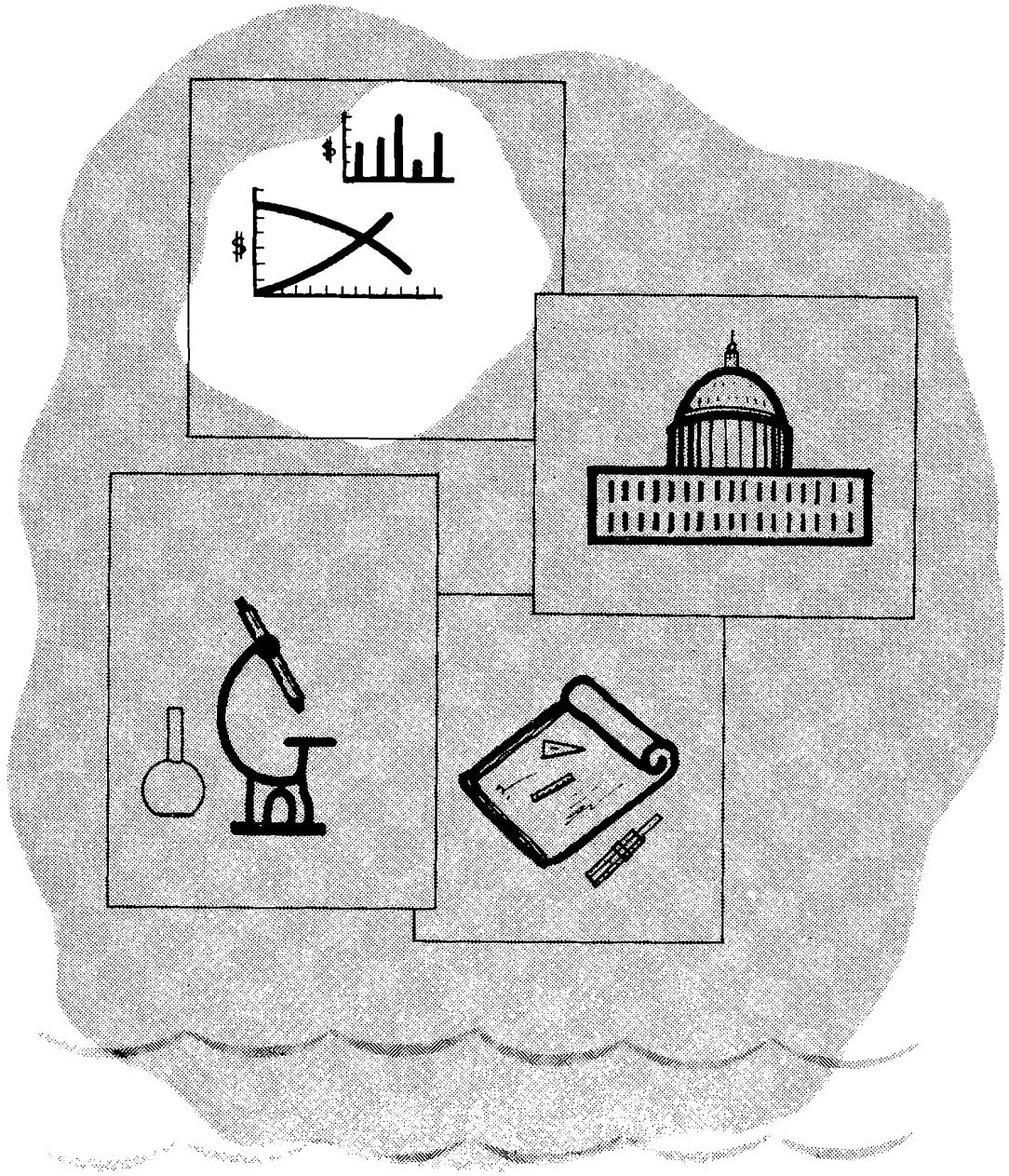

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VOLUME II

THE ECONOMICS OF WATER RESOURCE DEVELOPMENT AND CONSERVATION

Civil Engineering Department

Utah State University

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Lectures

on

THE ECONOMICS OF WATER RESOURCE DEVELOPMENT AND CONSERVATION

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Presented at the

SUMMER INSTITUTE IN WATER RESOURCES

UTAH STATE UNIVERSITY

by

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and

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FOREWORD

Recognizing the need for training of individuals to meet the rapidly rising problems connected with water resources development, Utah State University, with National Science Foundation support, organized a Summer Institute in Water Resources for college teachers. It was hoped that participants carefully selected from all regions of the country would receive additional insight and stimulation to improve and enlarge water resources training programs at their own institutions. Thus, the accelerated dissemination of such knowledge on a national scale could be facilitated.

Realizing further that the key to a successful institute of this nature lay in the excellence of its staff, efforts were made to obtain instructors with intimate knowledge and broad experience in the subject matter area they were asked to present. In nearly every case those selected willingly accepted the invitation to participate, although this meant considerable monetary sacrifice and major adjustment of busy schedules.

The subject matter treated paralleled regular offerings listed in the University catalog and is considered to be "central" or "core" to a water resources planning and management training program. One course treated the philosophical, historical, institutional, political, and legal aspects of water development. The responsibility for this course was shared jointly by Cleve H. Milligan, Charles E. Corker, and Wayne D. Criddle. The second course considered the principles of water resource economics and was presented by B. Delworth Gardner. The third course dealt with concepts of water quality management and was under the direction of P. H. McGauhey. The final course was on principles and procedures of regional resource planning and was presented jointly by Aaron Wiener, W. R. Derrick Sewell, and Harvey O. Banks.

Having assembled a distinguished and diversified staff to present some of the best current professional thinking in the topics suggested in the preceding paragraph, it was felt most appropriate to attempt to put their lectures into writing. A proceedings of the Institute would have considerable utility beyond the Institute itself. Hence, the instructors were encouraged to prepare written material for the proceedings and were given secretarial and other assistance to aid them. This material has been organized according to the four major courses and is issued in four companion volumes.

Clearly, this has been a prodigious effort which required the Institute staff and others to "go the extra mile." Special thanks and recognition are due Mrs. Dorothy Riley who not only typed the entire proceedings but also attended to many details necessary for the successful operation of the Institute.

Jay M. Bagley served as director of the Institute and assumed a general coordinating and editing role in the development of these proceedings.

PREFACE

This course is divided into two main sections: 1) economics of public policy, sometimes called "welfare economics"; and 2) evaluation of concepts, methods, and procedures used in planning and justifying water resource projects.

Professional economists will recognize that many important welfare topics have been passed over; others are merely introduced. In a short, summer session some recourse must be had to students' intuitive grasp of at least a few of the more esoteric implications. Most students possessing engineering backgrounds are able to progress very rapidly through the logical sequence of price theory propositions. Questions and personal interpretations are interspersed throughout the text, and students will find it worthwhile to work through them.

Dr. Gardner organized and presented the course. Dr. LeBaron edited notes and materials used by institute participants and wrote the text.

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PART I

I

INTRODUCTION TO THE ECONOMICS OF PUBLIC POLICY

Economic Efficiency and Rationality

Economic efficiency may be defined as the allocation of resources among competing ends in such a way that desired results are maximized. Since in actuality an infinity of desires exists, economists employ certain assumptions as first approximations to reality. For example, household members are assumed to wish to maximize utility or satisfaction from incomes, business firms wish to maximize profits, while owners of productive factors seek maximum returns. Economic theory postulates the logical set of relationships that must be satisfied to achieve these first approximations to real goals or desires. Ordinarily the maximizing decisions necessary to achieve even such generalized approximations are constrained by scarcity of resources and institutional factors.

Economic rationality is a formal attempt to link economic decisions with social and individual preferences. In the case of water resource development, a deliberate decision to establish maximization of net benefits as a social goal makes possible the analysis of public investment decisions in terms of whether expected results are likely to increase or decrease economic efficiency.

Role of Efficiency Criterion in Resources Development

Efficiency implications have been brought to bear on public works planning through the development and refinement of feasibility requirements. First introduced specifically in the Flood Control Act of 1936, these requirements were simply that project benefits must exceed estimated costs. In the early 1950's the so-called "Green Book" was adopted by the Bureau of Reclamation as a guide for feasibility procedures to be used in evaluating river basin

development. The earlier criterion was not altered, but numerous suggestions concerning measurement procedures were provided. The Corps of Engineers continued to follow rather different methods. A few years later Bureau of the Budget Circular A-47 was issued by the Executive Branch of the government in an attempt to standardize the procedures of feasibility analysis among different agencies and bureaus, especially Reclamation and the Corps of Engineers. Unfortunately, this attempt was unsuccessful. Therefore, in the early days of the Kennedy administration, Senate Document 97 was issued to various branches of government, and standardization can now be expected. Much of the latter half of this course will be concerned with an evaluation of these project feasibility procedures.

It may be interesting to speculate why evaluation of feasibility analysis has been particularly tied to water resources development. Perhaps the most important reason is that contrary to many public works projects, western reclamation developments are designed to directly augment certain scarce goods and services, notably irrigation water and electrical power. Since markets for such products have been well established for years, prices were readily ascertainable for use in the determination of project benefits. Also, exactly because the planned outputs were also produced in the private sector of the economy, it seems that some kind of economic justification should be required if federal products are to compete with those of the private sector.

Why was the flowering of feasibility analysis delayed until the decades of the 1950's and 1960's? The explanation probably lies in the condition of the economy during earlier times. In the 1930's a large portion of the nation's resources were unemployed. Under those conditions completion of government projects did not require use of resources that would have otherwise been beneficially employed. Practically any increase in employment could be assumed to represent obvious social gain. Pressures for adequate feasibility studies were absent through the early 1940's because during the war years most water developments were arrested anyway. In

the 1950's, during a period of high employment of resources, it became increasingly difficult to justify diversion of resources from the private sector for construction of public works. Diversion could be economically justified only if benefit-cost ratios could be demonstrated to be greater than unity.

Pressures for greater economic rationality also came with passage of the Full Employment Act in 1946 and the creation under this act of a Council of Economic Advisors. The Council was set up to advise the President on matters of economic policy. One effect of this act has been that economists have had greater opportunity to create within the councils of government an awareness of the importance of economic analysis.

Over the past few years, as competition for portions of the federal budget has been increasing, more and more aspects of water development have been brought under the calculus of feasibility. There are signs on the horizon that other federal activities such as foreign aid, education, recreation, highway construction, and resource conservation will also come under closer economic scrutiny. This implies that feasibility analysis is at least in part accomplishing what it was designed to accomplish.

Since feasibility analysis is essentially an investigation of the means whereby economic efficiency can be attained, the next section of the course will be devoted to an elaboration of efficiency principles.

II
METHODOLOGY OF ECONOMIC ANALYSIS

Positive Science, Normative Science, and Art

Positive science is a body of systematized knowledge concerning "what is." The object of a positive science is understanding of uniformities. The ultimate goal of positive science is development of theory or an hypothesis that yields valid and meaningful predictions about phenomena not yet observed. Positive science's work is that of demonstration, and this should be devoid of the imposition of the scientist's own value judgments as to what is good or bad, necessary or unnecessary, etc., in the analysis itself.

Normative science may be defined as a body of systematized knowledge concerning "what ought to be." The object of normative science is the determination of an ideal or goal. Normative science's work is that of persuasion and conversion where value judgments are an integral part of the analysis.

Art is a system of rules that enable the attainment of some specified end. The object of art is the formulation of rules and precepts.

The discipline of economics as applied to water resource development contains elements of all three of the above categories. Positive science is crucial in project evaluation. Normative science is important in justifying the need for greater efficiency in resource use and in project planning, and art is indispensible in project formulation and construction. The analytical power of economics, however, grows out of its development as a positive science. Because of this, primary attention will be focused on the efficiency principles of positive economics.

Ideally positive science is independent of particular ethical positions and normative judgments (9; 1st essay). Any policy conclusion must rest upon a prediction about the consequences of various alternative courses of action; this is the value of positive science: it leads to positive

propositions which can be subjected to empirical tests. This is a crucial point, because there seems to be fairly widespread agreement within our society on the goals and values that should be sought, but much disagreement concerning the most efficient means to accomplish these ends. The propositions of science can be brought to bear on means evaluation, and difficulties in choosing alternatives can be resolved.

It was stated earlier that the goal of positive science is to develop theory suitable for prediction of future events. This theoretical framework consists of two components:

1. A language (this promotes organized methods of reasoning and generally consists of a set of tautologies).
2. A body of substantive hypotheses (these are designed to abstract essential features from complex reality that aid in an understanding and explanation of real world phenomena).

A useful theory will be:

1. simple (to facilitate application);
2. general enough to explain and contribute to understanding of a wide variety of events and phenomena; and
3. testable (the hypotheses of theory must be confronted with evidence from the real world, and be subject to refutation).

The validity of a theory depends on its ability to explain and predict real world events. One cannot make judgments about the validity of a theory on the basis of the realism of the assumptions which underlie it. Simplification and generalization limit attention to essential features underlying behavior, and abstraction from all complexities of the real world which are not assumed to be important to a whole class of phenomena.

Solution of Policy Problems

As an analytical device, the following four steps constitute an approach that may be used in viewing and solving a policy problem:

1. The optimum conditions from an abstract, ideal world are stated.
2. The real world departures from this optimum are observed.
3. Hypotheses are sought to explain the discrepancies between actual and optimum conditions, and the hypotheses evaluated.
4. Policies and institutions are formulated that will aid in approaching the optimum conditions.

Means-Ends Schema

Talcott Parsons (18) has proposed a schema for studying policy issues that consists of the following components:

1. the actor (this is the action agency responsible for carrying out the policy activity);
2. uncontrollable conditions of action (economists usually refer to these as exogenous factors which are imposed from the outside and which must be accepted as given and not subject to policy manipulation);
3. controllable conditions of action (these are called endogenous factors and become the means for accomplishing policy goals);
4. ends or objectives (these constitute the future state of affairs that is desired); and
5. normative orientation of action (this consists of arriving at policy conclusions as revealed by selective standards).

III

PUBLIC POLICY AND WELFARE

Welfare Economics

Welfare economics is the branch of the discipline concerned with public policy issues. Emphasis is upon the impact of various public policies on individuals and groups. Often these impacts are so difficult to trace that the best that can be accomplished is to determine if the policy is beneficial to the aggregate community or society since decisions are made at that level. Such judgments obviously require some kind of optimizing goal. This may be stated in a number of ways such as: "maximizing social welfare," or "maximizing social net benefits," or "the greatest good for the greatest number." Most of these statements are nebulous, empty of substance, and require translation into operational terms amenable to objective measurement.

In the absence of a common denominator for measurement there can be no quantitative description and analysis of policy alternatives. "Economic value" is the common denominator most often employed for this purpose. Even with respect to social values this requires that monetary quantities be ascribed to all benefits and costs that enter into the decision calculus. This is extremely difficult, even with water resource projects, since so many costs and benefits are uninfluenced by ordinary market forces which otherwise reveal so much about economic values. For this reason, various kinds of surrogates have to be established and employed. Some values seem to defy any kind of economic quantification and it is difficult to know just how to handle such intangibles in project evaluation.

The greatest general dilemma is that almost every public works program results in gains to some citizens and losses to others. Do aggregate gains in fact offset aggregate losses? This cannot be determined merely by comparing the total value of output contributed

by a project with the total value of the resources used in an alternative project. Consideration must also be given to distribution of the product, and to allocation of costs among individuals and groups in society.

For the last 100 years economists have asked themselves whether it is possible to evaluate social gains and losses in a scientific manner. Some appreciation of suggested methods, as proposed by "classical economists," "neoclassical economists," and "modern welfare economists" can best be obtained through a brief perusal of the history of certain economic thoughts.

Resolution of the Dilemma

Classical economists. In England, where economics made most of its early progress, policy questions relating to corn laws, to foreign trade, to balance of payments, and to colonialism, were of great concern. In fact, political elements were so much a part of economic theory that early workers such as Smith, Ricardo, and Malthus were known as political economists. The results of economic analysis were often held to have normative implications.

The position of the classical economists relative to policy and community welfare received its most precise expression at the hands of Jeremy Bentham (4; especially chapters I and XII). Bentham argued that utility (the power to satisfy human wants) possessed by commodities, could be measured in cardinal numbers. Some commodities would give negative satisfaction if they produced pain rather than pleasure. Addition of all the cardinal values of the pleasures and pains associated with the commodity mix held by an individual at a given time indicated total net satisfaction. Not only could utility be thus quantified, but it was assumed to be comparable among individuals and thus could be aggregated to arrive at community welfare. This pleasure-pain calculus was then used to evaluate the desirability of given policy proposals. Proposals leading to increases in total community utility were good. Bad proposals were those leading to a fall in aggregate utility.

The neoclassical economists. Of course, no one ever managed to actually measure utility. But for a generation before and after the turn of the century economists assumed that it was possible to at least say something about whether the direction of changes in utility were positive or negative. Knowledge of the "sign" of any change, in combination with certain assumptions allowed a number of conclusions to be drawn concerning social desirability of certain economic arrangements. Developments in the theory of demand during the 1870's provided the necessary foundation for the whole process.

During that decade Stanley Jevons (11) in England, and Leon Walras (27) and Carl Menger (15) on the Continent, simultaneously hit upon the notion of diminishing marginal utility: the greater the quantity of income possessed by an individual, the smaller will be the utility produced through acquisition of additional or marginal units. Marshall (14) argued that the poor, who live close to the starvation level, of necessity used their incomes to satisfy immediate, crucial needs. The dollars spent on luxuries by the rich were not so vital since the need for food, clothing, and shelter were readily satisfied. Thus, an income redistribution associated with a transfer of wealth from the rich to the poor would result in greater community utility. Each dollar taken from a rich man would subtract less utility potential from his total purchasing power than it would add to the purchasing power of a poor man.

The Benthamite notion of additivity of individuals' utilities and the "law" of diminishing marginal utility, when considered together, clearly indicate how one could judge the superiority of one income distribution over another. Policy proposals could be partially judged good or bad on the basis of the expected changes in income distribution.[1]

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[1] Pushing this reasoning to its logical conclusion would mean that an equal distribution of income among all citizens would be the most preferred one. Even in our own society, we see evidence that society seems to prefer a more equal distribution of income than the market would permit. Thus we have progressive income taxation, unemployment compensation, minimum wage laws, and numerous other public programs which, in effect (purportedly), transfer income and wealth from the rich to the poor.

The law of diminishing marginal utility was also an important device to explain how an economy's production would be allocated to optimize consumer satisfaction, given a particular pattern of income distribution. Allocation would be optimal, in terms of maximizing total social utility, when the ratios of marginal utilities of commodity units to their individual prices were equal in all directions.[1] Situations giving rise to ratio inequalities could therefore be judged bad.

Alfred Marshall employed the concept of consumers' surplus as a welfare tool (14; Chapter VI). In Figure 1 the curve DD represents various quantities of a commodity that a consumer would be willing to take at various alternative prices during a given time period. Suppose that the market price is P_o as in Figure 1, then the quantity Q_o would be taken by the consumer. His expenditures for the commodity amount to (P_oQ_o) (the rectangular area). However, the entire area under the demand curve represents what the consumer would have been willing to pay for 0Q units (provided the seller could have sold each unit individually). Consumers' surplus, therefore, roughly represents the amount of willingness to pay over and above actual expenditures, and is understood to be an indication of the excess utility which consumers derive from the quantity obtained. All things equal, if the demand curve is steep, consumers' surplus would be greater than if the demand curve is flat. As a rough approximation, commodities that have inelastic demand curves generate large quantities of consumer surplus. Many economists have followed Marshall in using this tool to evaluate welfare implications of all sorts of economic policies.

The way this can be accomplished is not difficult to understand. If the consumers' surplus from an existing natural resource can be estimated, this value can be compared with gains in consumers' surplus

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[1] The law of diminishing returns produces an analogous model for "optimum" allocation of resources to maximize output.

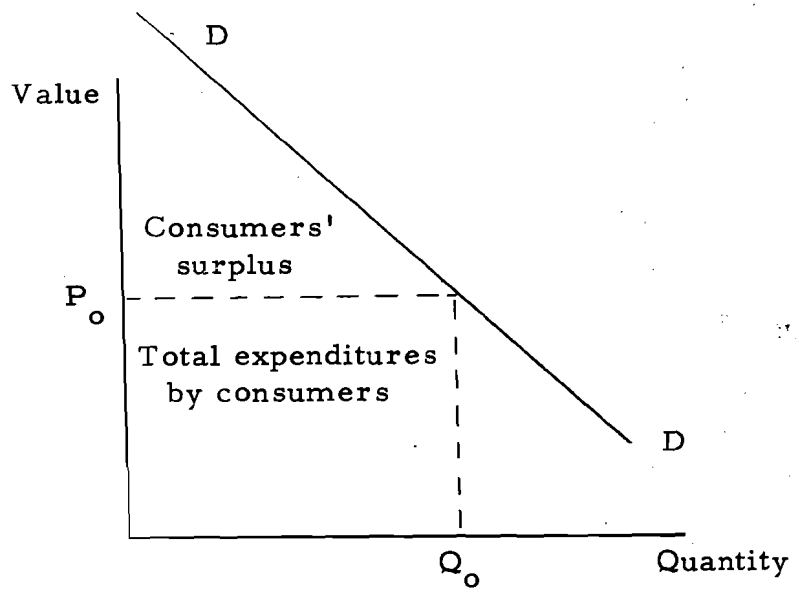

Figure 1. Illustration of consumers' surplus

that resource development would promote. Unless the net gains are expected to be positive, development may be foregone or delayed.

Marshall's successor at Cambridge University was A. C. Pigou. Pigou was more guarded in reaching conclusions concerning normative implications of economic theory than was Marshall because he believed there was some question about the logic of aggregating individual utilities into community utility. Pigou argued that the utility received by one consumer in the consumption of a commodity was a function of the consumption of other individuals. In addition, various kinds of market imperfections and considerations external to decision making units create divergencies between private costs and benefits (as revealed in market decisions) and social costs and benefits. This indicated a need for various kinds of ameliorating taxation and welfare programs (19, especially Part IV).

For all of these reasons and others, Professor Pigou moved

directly to a concept of aggregate welfare. Terming national income the social dividend, he argued that if the social dividend could be increased without worsening income distribution (that is, without injuring those individuals and groups at the lower end of the income distribution range) then aggregate welfare would be increased. Also welfare could be increased if the poor could be made better off without decreasing the social dividend. None of Pigou's work constitutes a rejection of the law of diminishing marginal utility. It is the rationale for his concern with income distribution problems and continues to provide the foundation for a theory of demand and efficient commodity allocation.

The "new" welfare economics. In the 1930's there emerged a group of economists who put forward a different viewpoint on the resolution of problems of ascertaining changes in economic welfare. This group was led by Lionel Robbins at the London School of Economics. Robbins began by denying the validity of interpersonal comparisons of utility. He argued, for example, that it cannot be determined whether taking a dollar from a rich person and giving it to a poor person would automatically increase aggregate welfare (23). Robbins and others in the so-called "new welfare school" also denied that cardinal measures of utility were possible; the best that could be said was that utility positions could be ranked in ordinal fashion. Such rankings can be displayed through the apparatus of the indifference map and certain limited welfare implications can be deduced. This group of economists was responsible for the widespread practice of judging welfare gains in terms of the "paretian criterion," which indicates that there would be a gain in total community welfare if at least one person can be made better off (by a given policy proposal) while none is made worse off (17; p. 617-18). "Better off" is measured solely in terms of opportunities to improve upon the efficiency of resource allocation. In terms of efficiency it is possible to determine the impact of policies and programs on aggregate income. Questions of good or bad income distribution must be left to one side where anthropologists, sociologists, and

psychologists may assist in evaluation. Economists have elaborated a set of efficiency conditions, satisfaction of which will indicate that allocation of resources necessary to produce a maximum of economic efficiency. The next section of this course will be devoted to a discussion of these efficiency criteria.

It is obvious, however, that the new welfare school left the discipline of economics in an extremely vulnerable position with regard to the prospects of providing definitive judgments about the goodness or badness of policy. This is because almost all kinds of imaginable policies leave some people in society better off and some people worse off. If utility is not cardinal and additive, and if interpersonal comparisons of utility are in fact impossible, then one is left in a weak position of judging good or bad policy only in terms of some of the obvious efficiency implications. If economics cannot provide definitive guides to "correct" policy, then, some have argued, observation of political processes and the ballot box could indicate welfare desires, particularly with respect to income distribution.

It can be shown, however, that political processes might be logically inconsistent, and therefore unreliable as normative guides for policy. In a democracy every man has one vote, but that vote cannot be regarded as a measure of the intensity of feeling about the issue in question. A large, almost disinterested, group of voters could select an alternative which would greatly decrease the utility of an intensely interested smaller group. It is apparent that this process could sometimes lead to adoption of programs which would reduce community welfare.

Kenneth Arrow has also shown that voting procedures can often be irrational (1). Consider three individuals, A, B, and C and their rankings of policies 1, 2, and 3 as set out in Table 1. Individuals A and C prefer alternative 1 to alternative 2. Individuals A and B prefer alternative 2 to alternative 3, and

Table 1. Inconsistencies in voting patterns

Alternative	Individual Preference Rankings		
	A	B	C
1	1st	3rd	2nd
2	2nd	1st	3rd
3	3rd	2nd	1st

individuals B and C prefer alternative 3 to alternative 1. Thus a majority prefers 1 to 2, and 2 to 3, but a majority also prefers 3 to 1. Arrow concludes that, in general, a rule for passing from individual rankings to a social ordering consistent with his "reasonable" conditions cannot be found. It is likely that some kind of a compromise is the best solution at the present time. Economic analysis, including both efficiency and income distribution implications, can (at least in a general way) indicate the economic impact of various policy alternatives; in the final analysis political processes will likely determine which policies and programs are actually implemented.

It might be well to point out, however, that benefit-cost analysis, as used by Federal agencies, is essentially an efficiency evaluation. Income distribution problems are considered hardly at all. This may be a serious omission since many kinds of government projects are proposed and built precisely because of the existence of income distribution disparities. Certain segments of the economy, and certain geographic areas are often economically depressed and require government programs. But depression is not the only situation where government action has been deemed necessary. The economic history of the United States is marked by a whole series of programs in agriculture, tariff protection for certain industries, tax concessions to meet certain contingencies, education, etc.

If public works programs are really designed to alter patterns of income distribution, then evaluations based purely upon efficiency considerations follow questionable procedures. Having said this, however, attention

must now be turned to discussion of Paretian optima. The sequence of the analysis shall treat in turn, the economic theory of the household, the business firm, and the allocation of productive services. These steps will detail the conditions that must be satisfied for efficient allocation of economic resources.

IV

THEORY OF CONSUMPTION AND CONSUMER CHOICE

In order to set forth efficiency conditions for optimal resource allocation among consumers and to consider some welfare implications, it is necessary to develop a theory of consumer choice in a market economy. The analysis proceeds in two stages:

1. Presentation of a theory of income allocation for individual households.
2. Generalization of that theory to cover optimal allocation of commodities in many households.

Indifference Maps

Imagine a simplified world of only two consumers, I and II, each having a given amount of purchasing power. Suppose incomes must be spent on only two consumable products, X and Y, both of which produce positive amounts of utility. In addition, for analytical simplicity, assume that the markets for X and Y are perfectly competitive. That is to say, each consumer can buy all of X and Y that he wishes without affecting market prices.

The first problem is to discover the optimum combination of X and Y that can be purchased by each consumer with a fixed level of income. (The optimum combination is defined as that which will maximize the utility of the consumer or members of his household.) The solution can be shown by employing the apparatus of an indifference map. On a two dimensional rectangular grid lay out increasing quantities of X on one axis and increasing quantities of Y on the other. Then take all combinations of X and Y that will produce U_o units of utility and connect all these points with a continuous curve. The result is an indifference curve because household members will be equally satisfied with combinations at various points since they all represent the same level of utility. Other indifference curves can be derived in exactly the same fashion. The

requirement in each case is that the combinations of the X and Y must all represent different levels of utility. The result will be an entire indifference map for a consumer or for the members of a household. The process can also be generalized to cover any number of commodities instead of only two.

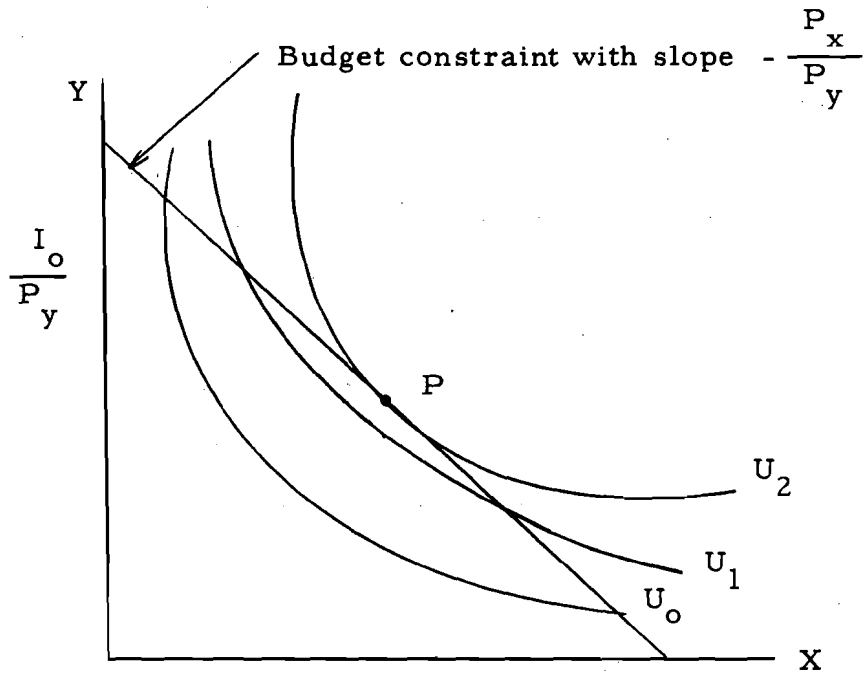

Figure 2. Indifference map and budget restraint solution of utility maximization problem

Why do indifference curves have the form shown in Figure 2? The slope of each curve is negative because as less Y is consumed, consumption of more X is necessary to offset the loss of Y in order to remain at the same level of utility. The curve is convex to the origin in response to the law of diminishing marginal utility. As more and more X is substituted for Y, the additions to total utility from each unit of X become smaller and smaller. At the same time the utility losses from giving up successive units of Y become larger and larger; in order to remain on the same indifference curve (utility level) the consumer demands more and more of X to compensate for each successive loss of a unit of Y. (If X and Y were perfect substitutes the indifference

curves would be linear.) In short, commodities X and Y substitute for each other at diminishing rates.

It will be observed that indifference curves may not intersect since this would mean that consumers could be indifferent between combinations yet simultaneously prefer one of them. (Readers should satisfy themselves on this point by making appropriate adjustments in Figure 2.)

Indifference maps indicate tastes and preferences of consumers, but reveal nothing about their purchasing power. Purchasing power may be indicated on an indifference map in the form of a budget constraint or an expenditure curve. The problem will then be to ascertain a point on the budget curve which will maximize utility for the consumer. This is equivalent to saying that consumers desire to reach the highest indifference curve possible and still remain on their expenditure curves. The conditions which must be met to fulfill these desires are perfectly straightforward once derivation of the budget constraint is understood.

Let I_o be the constant level of family income over some relevant time period. Let P_x be the price of X and P_y the price of Y. x is the quantity of X which will be taken and y the quantity of Y. If purchases are divided between X and Y then:

$$I_o = P_x x + P_y y$$

Solving for y yields:

$$Y = \frac{I_o}{P_y} - \frac{P_x}{P_y} x$$

This is the general equation for a budget constraint and is a linear relation having a Y intercept I_o/P_y, and a slope, P_x/P_y.

Examination of Figure 2 indicates that the highest indifference curve the budget constraint could possibly touch would be a curve (U_2) just tangent to the constraint. Any other point on the budget constraint must

necessarily intersect an indifference curve of lesser utility. This means that the optimal consumption allocation of X and Y is marked by the equality of the slopes of the indifference curve and the budget restraint at their point of tangency. At this point (P in Figure 2) condition

$$-\frac{dY}{dX} = -\frac{P_x}{P_y}$$

must be true. In other words optimal allocation of income between X and Y requires that the marginal rate of substitution of X and Y in the preference map of the consumer equal the inverse of the market prices for the same commodities.

In summary, the absolute amounts of X and Y taken is a function of the relative prices of X and Y. It is also apparent that as the price of X rises relative to the price of Y the slope of the budget constraint will increase. This will have the general effect of shifting the optimal consumption level in favor of commodity Y at the expense of commodity X.

Demand and Elasticity

From an indifference map it is possible to derive a demand curve which indicates quantities of a commodity which a household will take in the market at various alternative prices. Let the price of X vary and observe on the indifference map the various optimal consumption combinations of X and Y. If the results are recorded it will be found that they reveal a functional relationship between the price of X and the quantity demanded: a demand curve. A demand curve for Y or any of a number of other commodities may be obtained in the same fashion.

By the term "price elasticity" economists refer to the percentage change in quantity taken that follows a one percent change in price. Mathematically, elasticity is defined as

$$\eta = \frac{dX}{dP} \cdot \frac{P}{X}$$

where dX/dP is the derivative of X with respect to price, P is price at the point at which elasticity is measured, and X is the quantity at that point. If the demand curve has a negative slope, the sign of its elasticity will be negative. At any η value greater than one but less than infinity, the demand curve is relatively elastic. η values between zero and one are associated with relatively inelastic demand curves.

The concept of elasticity has many functional uses in dealing with policy problems. For example, if demand is elastic, a larger quantity demanded will require a relatively greater expenditure to pay for it than will a smaller quantity demanded. The reverse is true if demand is inelastic. A small quantity will be worth more in the aggregate than will a large quantity, because price increases more than proportionately to quantity decreases. This is a crucial factor in project feasibility studies because the quantity of a commodity or its close substitutes increases when the project is brought into production.

Also because elasticity is dimensionless, it means that it is possible to compare demand functions of different kinds of commodities to determine how price sensitive they are relative to each other. Figure 3 shows two demand curves, D_1 and D_2. D_1 is relatively inelastic over most of its range while D_2 is relatively elastic over much of its range. Certain comparisons are meaningful even if D_1 is for shoes and D_2 is for billy goats.

There are other elasticity concepts besides those reflecting price and quantity. Income elasticity refers to the percentage change in the quantity of a commodity demanded which results from a one percent change in income. Mathematically this is expressed as

$$\epsilon = \frac{dX}{dI} \cdot \frac{I}{X}$$

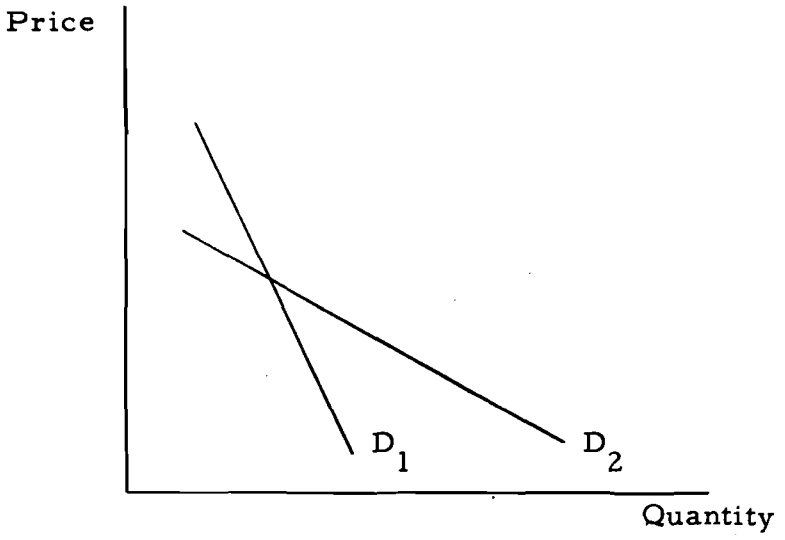

Figure 3. Demand curves with generally different elasticity characteristics

Information for computing income elasticity may also be obtained from indifference maps. In Figure 4, for example, an increase in income simply means that the budget constraint shifts to the right. This shift will in turn define a new optimal level of consumption of X and Y at P'.

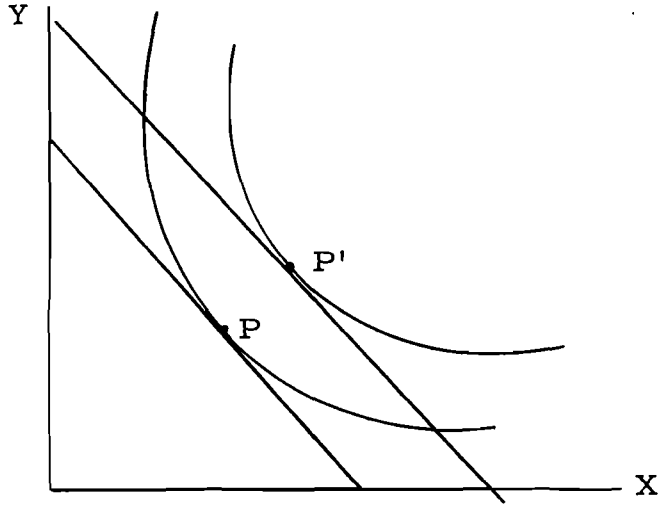

Figure 4. Indifference curves illustrating changes in consumption patterns following an increase in income

If numerous levels of income are considered, observation of related optimal allocations of X and Y will reveal a functional relationship between income and the quantity of either commodity. Figure 5 shows the relation between income and commodity X. If the quantity of X taken rises in response to an increase in income, the function will have a positive slope, income elasticity will take on a positive sign, and X is called a superior good. If the quantity taken falls in response to an increase in income, X is called an inferior good.

While mose commodities are superior, there are some with very low income elasticities, and a few might even be inferior. Certain agricultural commodities such as potatoes and beans (which are consumed in large quantities when incomes are low, but in decreasing quantities as incomes rise) may fall into the latter category.

Income/quantity relationships, and their measurement as income elasticities, are extremely useful in project evaluation. In a developing, growing economy where incomes are rising it is important to know the impact of changes in income levels on the demands for certain commodities,

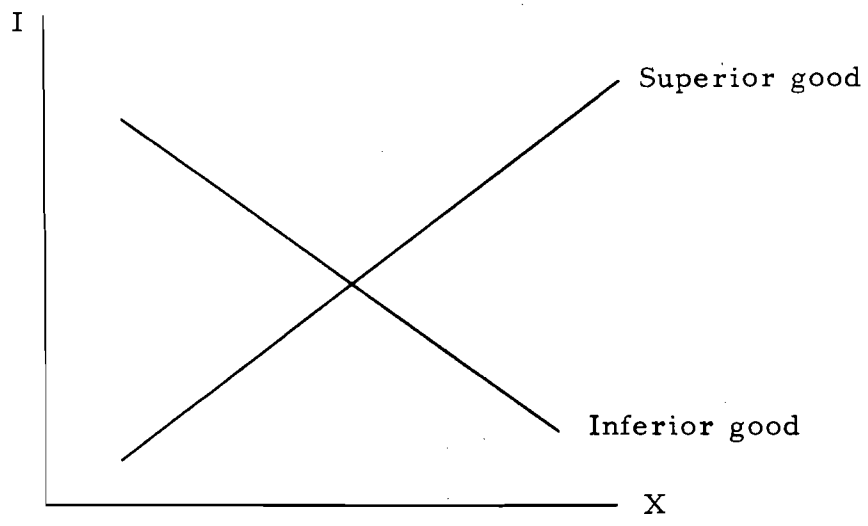

Figure 5. Possible relations between income and quantity demanded

especially those which might be produced through project development.

Some appreciation for what is called the cross demand relationship (the relationship between the relative price of one commodity and the quantity demanded of another) is also useful in feasibility studies. For example, what happens to the quantity of Y demanded as a result of a change in the price of X? Cross elasticity of demand may be defined as follows:

$$\eta_{yx} = \frac{dY}{dP_x} \cdot \frac{P_x}{Y}$$

The computed value indicates the percentage change in the amount of Y taken following a one percent change in the price of X. A geometrical representation of possibilities is shown in Figure 6. The slope of the relationship and the sign of the elasticity will depend on whether products X and Y are substitutes in consumption or complements. If they are substitutes (such as beef and pork) the expected sign of the elasticity value would be positive. That is, as the price of beef rises, beef sales fall but pork consumption increases. On the other hand, if the commodities

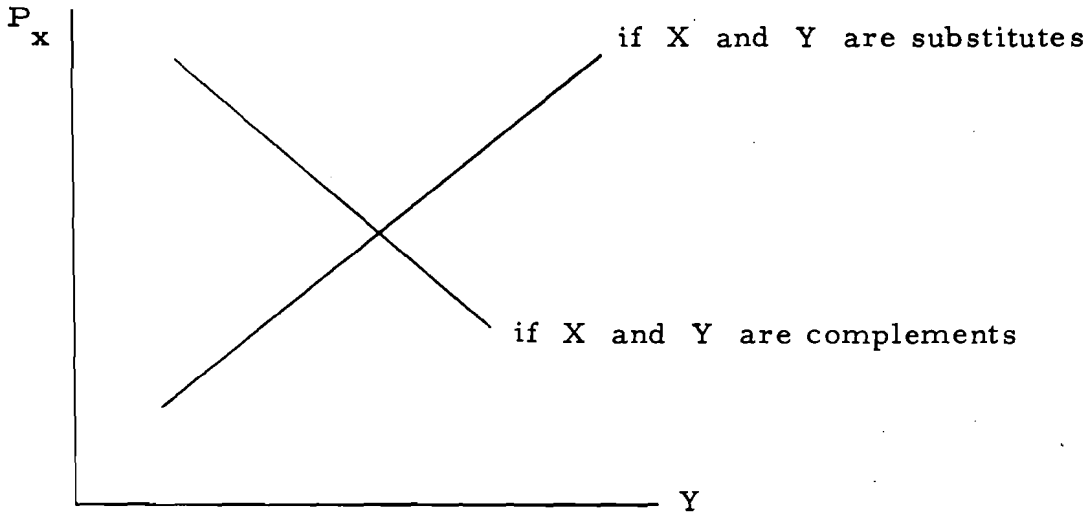

Figure 6. Possible cross elasticity of demand relationships

are complements (such as bread and butter) the expected sign of the elasticity value would be negative. As the price of bread rises, bread sales fall, and so do those of butter. Correct assessment of cross demand relationships may be very important in evaluating total market impact on the quantities demanded of substitutable and complementary commodities as a result of project induced price changes.

A number of refinements may be made in the foregoing concepts. For the present purposes, however, an especially rigorous development is unnecessary. Before leaving the area of consumption, however, the Paretian efficiency conditions for a whole economy should be explicitly set forth.

Efficient Allocation of Commodities: Many Consumers

Since optimal combinations of X and Y for any consuming unit can be determined by satisfying the equality

$$-\frac{dY}{dX} = -\frac{P_x}{P_y},$$

the role played by marginal rates of substitution and price ratios in multi-unit allocation must be considered. It will be convenient to limit attention to a two person economy, although the optimum conditions postulated can be generalized to fit any number of consumers.

The conditions which must be fulfilled to guarantee efficient allocation of resources between two consuming units, I and II, can be illustrated by means of the "Edgeworth Box" shown in Figure 7 (7). The stocks of commodities X and Y available for allocation are assumed to be fixed. Imagine that consumer's preferences can be ranked by appropriate indifference maps. The indifference map of consumer I must have X and Y axes of finite length for the stocks of each are fixed; consumer I can only obtain a certain maximum of X or Y, regardless

of the size of his income. The same can be said for consumer II. If II's indifference map is rotated 180°, and juxtaposed on I's map, the result is a rectangular "box" of fixed dimensions.

Let U_1^I and U_1^{II} be indifference curves for consumers I and II respectively, as shown in Figure 7. Suppose the initial consumption patterns of I and II are such that each is at point P.[1] The total stocks of X and Y are divided: $0^I - x^I$ plus $0^I - y^I$ to consumer I and $0^{II} - x^{II}$ plus $0^{II} - y^{II}$ to consumer Y. Can total satisfaction be increased by more efficient allocation? If the prices for X and Y are established in purely competitive markets, the answer is affirmative. Assuming competition, the two consumers face exactly the same set of relative prices, i.e., I and II both have budget constraints with the same slopes. If each consumer optimizes his utility from a given budget

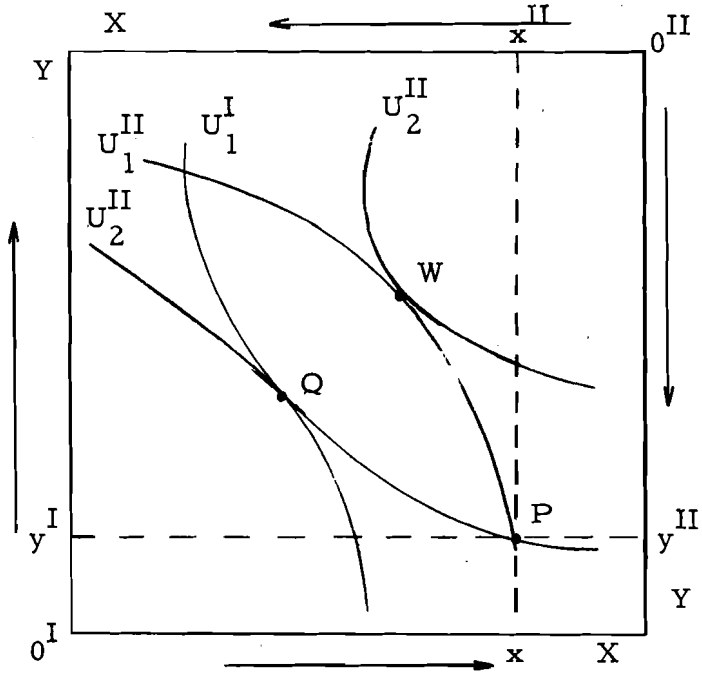

Figure 7. "Edgeworth Box" method of establishing optimum consumption patterns

[1] Note to students: Why must both be at P (or Q, R, S, or any other single point)?

where

$$-\frac{dy}{dx} = -\frac{Px}{Py}$$

then, by substitution,

$$\left(-\frac{dX}{dY}\right)^{I} = \left(-\frac{dX}{dY}\right)^{II}$$

Optimum utility for all of society can only be achieved if the marginal rates of substitution of all commodities are equal for all consumers. In graphic terms, the indifference curves must be tangent.

It is apparent that the marginal rate of substitution of X for Y is not the same for consumer I as for consumer II since the indifference curves have different slopes at point P. There will always be a gain in utility by shifting consumption about until consumers move to combinations having equal marginal rates of substitution. Movement from point P to point W in Figure 7 will satisfy the conditions of a Paretian optimum. Not only are the conditions for "efficient" individual allocations fulfilled but aggregate welfare has increased as judged by the Paretian criterion that an improvement in welfare has been made if at least one person can be made better off, while others are at least not made worse off. At position W, for example, consumer I can get on higher indifference curve U_2^I while consumer II remains on the same indifference curve, U_1^{II}.

The Paretian criterion limits movement to an area within the boundaries imposed by the indifference curves U_1^{II} and U_1^I. Only in this area can one or both consumers be made better off without the other being hurt (providing P is the initial point). The locus of all the possible points of tangency of indifference curves lying between W and Q is a portion of what is called the contract curve. Any redistribution of consumption that results in a movement toward the contract curve segment, W - Q, represents a welfare or social utility increase. But note that <u>all</u>

points on the contract curve satisfy the conditions for a Paretian optimum in consumption.

Which of the various points along the contract curve represents the "best" welfare position? It will be observed that, once on the curve, no movement can be made (along its length) which will not damage someone's position. This does not mean that a unique Paretian optimum will not be selected as consumption is made more efficient. Given the distribution of income there is one and only one Paretian optimum achievable. If another Paretian optimum is desired, an arbitrary decision about income distribution must be made. Therefore, the economist alone cannot make judgments about welfare superiority of various points along the contract curve.

In summary, an efficient allocation of consumption among consumers requires:

$$-\frac{dY^{I}}{dX^{I}} = -\frac{dY^{II}}{dX^{II}} = -\frac{PX}{PY}$$

The marginal rates of substitution of X for Y must be the same for all consumers and must equal the inverse of the ratio of the prices of the commodities. All of the foregoing assumes an economy free of monopoly or other imperfections.

V

THEORY OF PRODUCTION AND COST

Having considered the theory of demand as it relates to household and consumer markets, attention is now focused on the theory of supply. It will be shown that the supply of commodities is governed by cost relationships associated with technical production possibilities.

If it is assumed that the salient goal of the business firms is maximization of profits, three important questions must be answered relative to the production decisions of individual firms:

1. What is the optimum mixture of input factors?
2. What is the optimum amount of each input for the quantity of product to be sold?
3. What is the optimum amount of product that the firm will offer in the market?

Elementary Production Analysis

To answer the above questions, consider the following model. Let A represent the variable factors of production--these are the inputs which are increased in number as a firm chooses to expand its output of product, X. B will represent fixed factors of production--these are factors which are committed to the productive process in a given lump and are independent of the quantity of product which is produced. Suppose the quantity of factor A is increased relative to factor B. If this increase is related to increases in output, X, a production function will be generated. Any production function expresses purely engineering or technological relationships between outputs and inputs.

As a working approximation it is convenient to assume that short run production possibilities are governed by the "law of diminishing returns." Total output will increase at an increasing rate as factor A is applied relative to factor B, until an efficient combination of factors is

used. At that point the function will cease to increase at an increasing rate and will begin to increase at a decreasing rate. If the quantity of factor A applied becomes too great, a point will eventually be reached where the total product will begin to decline (point γ in Figure 8).

Average and marginal product functions may be derived from the total product function (TP). Average physical product, APP_a, is equal to X/A or total product divided by the units of variable factor which are used. As diagrammed in Figure 8, APP_a will increase until the average productivity of factor A relative to B reaches a maximum, after which it begins to decline and becomes asymptotic to the input axis (as long as the total product is positive).

Let MPP_a equal the marginal physical product of the variable input. This is the slope of the total product function or dX/dA. In Figure 8, MPP_a rises with respect to TP until the point of inflection

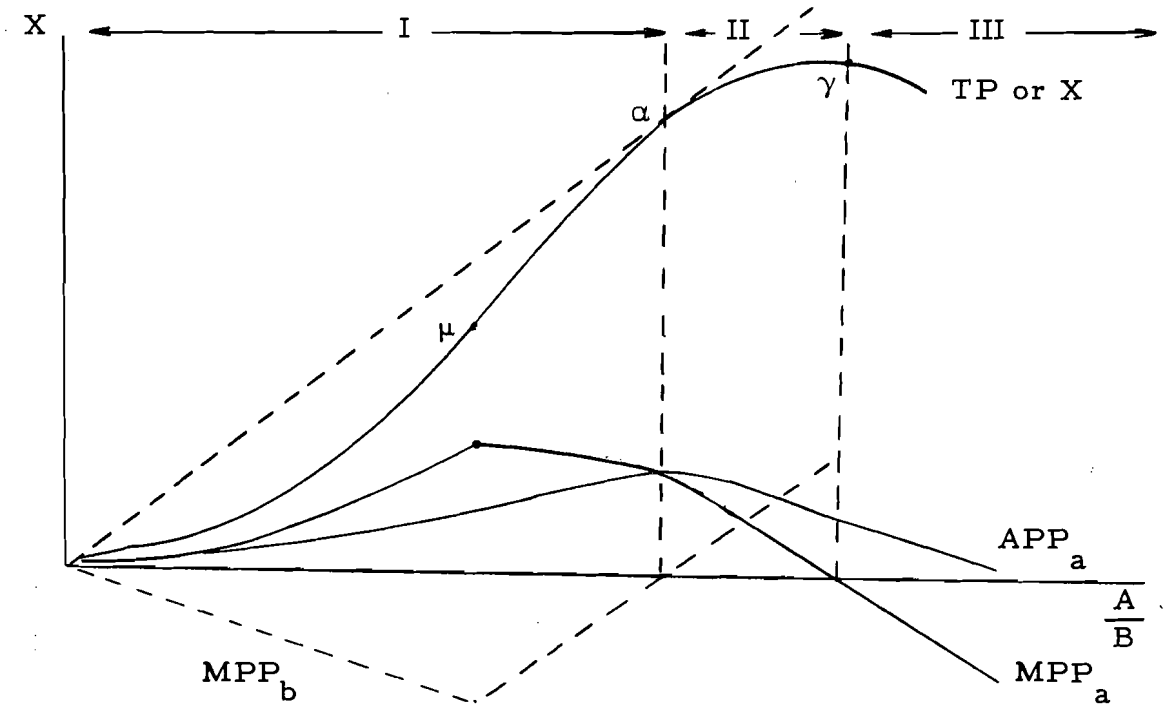

Figure 8. Generalized production function relationships (law of diminishing returns operable)

in the output function. At this point the derivative, MPP_a, must begin to decline. The value falls to zero as total physical product reaches its maximum and then becomes negative if absolute technological inefficiencies actually depress output.

An arithmetic relationship between averages and marginals requires that MPP_a will always be above APP_a as long as the average is rising, and vice versa. MPP_a will equal APP_a where the average is at a maximum. APP_a must be a maximum at a point of tangency between the TP function and a ray through the origin of Figure 8. μ is the point of diminishing marginal returns; α is the point of diminishing average returns; and γ the point of diminishing total returns.

A movement along the horizontal axis from right to left, that is, toward the origin, decreases factor A relative to factor B. Since this is the same as increasing factor B relative to factor A, a marginal physical product function can be derived for factor B in a manner analogous to the derivation of MPP_a for factor A. The marginal physical product function for B is also diagrammed in Figure 8 (MPP_b).

Knowing nothing of the costs associated with factors A and B, it is nevertheless possible to make judgments concerning production decisions purely on the basis of the technical relationships underlying TP. It is clear that rational production will be confined to stage II. Examination of Figure 8 reveals that the diagram can be divided into three sections or stages. Stage I includes output from zero to the point of maximum average product. Stage II includes output between maximum average product and the point of maximum total product. Stage III includes all output where MPP_a is negative.

In stage I, MPP_b is negative. This means that additions can be made to total product by failing to use some of factor B. The output returns to B are not positive until the second stage is reached. As long as factor B costs the firm something to use, the firm will never produce in stage I. Likewise, in stage III, MPP_a is negative. This means

that total product can be increased by moving back into stage II. Insofar as factor A costs something to use, managers will never produce in stage III. Stage II must account for all rational production. It will be observed that only in stage II are the marginal productivities of both factors A and B positive.

Optimum Production

The exact point in stage II where the firm chooses to produce will depend upon economic as well as technologic considerations. A final choice requires knowledge of product prices and prices of factors. The optimum combination of A and B (i.e., the optimum production level in stage II) requires that the marginal product per dollar spent will be the same for factors A and B. This is a necessary condition for a Paretian optimum of production efficiency. Stated symbolically the Paretian criterion is:

$$\frac{MPP_a}{P_a} = \frac{MPP_b}{P_b}$$

where P_a and P_b equal prices of factors A and B respectively. Stated verbally: as long as the marginal product per dollar spent for A is greater than for B the firm should use more A and less B. This will push production further into stage II, thereby reducing the marginal physical product of A and increasing marginal physical product of B. Once an equality of the ratios is reached the Paretian condition will be satisfied. This makes possible the pinpointing of an optimum factor mix.

An alternative procedure (which will also satisfy the Paretian criterion) is to employ each factor up to that level where the marginal cost of the factor equals marginal returns to the firm. The physical return to the firm from using another unit of factor A has been defined

as MPP_a. Multiplying MPP_a by the selling price of the product X which is produced, gives the value accruing to the firm for each additional unit of A employed. This for simplicity might be called the value of the marginal product of A (VMP_a). The cost of acquiring an additional unit of A is simply the price of A if factor A is supplied to the firm from a competitive market. The optimal use of A is satisfied by the equality:

$$P_a = MPP_a \cdot MR_x = VMP_a$$

As long as $VMP_a > P_a$ factor A should be expanded in use. Within stage II, expansion of A relative to B means that MPP_a will decline until the VMP_a equals the marginal cost of A, (P_a). Precisely an analogous demonstration can and should be made with respect to use of factor B in order to obtain the Paretian condition for both factors.

The marginal physical product function for factor A has been lifted from the second stage in Figure 8, multiplied by the selling price of X, and drawn as VMP_a in Figure 9. Factor A's cost is a constant at the level, P_a, since in a competitive market a firm can purchase all of factor

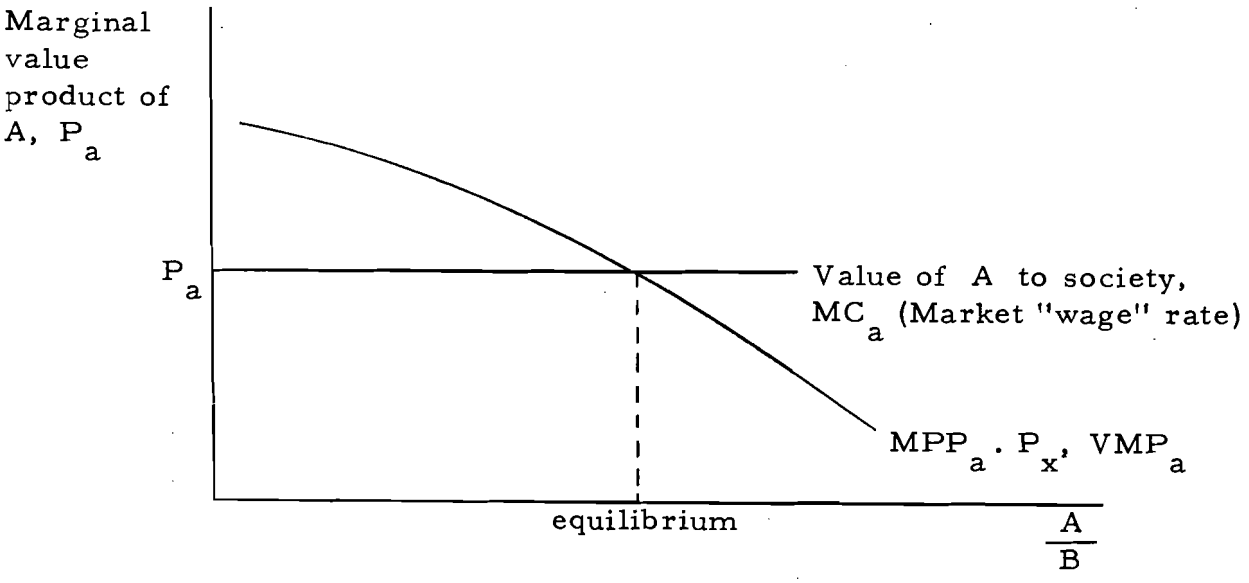

Figure 9. Equilibrium input of variable factor in production

A which it needs without paying increasingly higher prices. The point of intersection in Figure 9 satisfies the requirement that $VMP_a = P_a$. If optimum use of B requires that $VMP_b = P_b$ then:

$$MPP_a \cdot P_x = P_a \qquad (1)$$

and

$$MPP_b \cdot P_x = P_b \qquad (2)$$

Dividing both equations by P_x and (1) by P_a and (2) by P_b gives:

$$\frac{MPP_b}{P_b} = \frac{1}{P_x}, \text{ and } \frac{MPP_a}{P_a} = \frac{1}{P_x}$$

Thus,
$$\frac{MPP_a}{P_a} = \frac{MPP_b}{P_b} \text{ or } \frac{MPP_a}{MPP_b} = \frac{P_a}{P_b} \qquad (3)$$

This is the proof for the Paretian efficiency conditions set out earlier.[1]

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[1] Graphically this result can be shown in a diagram completely analogous to the indifference apparatus employed earlier. Let a and b be variable factors of production used to produce product x. Choosing any output level, say 100x, plot all the combinations of A and B which will give that number of units. An iso-product curve connects all the points representing output of 100x. Iso-product curves can be constructed for any other output level. Several output levels are imagined in Figure 10. Iso-product curves are convex to the origin because in stage II, MPP_n falls. As more A is substituted for B, MPP_a falls and relatively more of A is needed to hold output of X at the chosen level. This is because the losses in X that must be offset for reductions in B become ever greater as MPP_b rises and vice versa.

Suppose the firm has a fixed budget. If the prices for units of A and B are known, the linear cost constraint and its slope can be determined from the proof given in the case of consumption allocation (p. 19). The optimum combination of A and B is given by the tangency of the cost restraint and an iso-product curve. This is the highest production output attainable (approximately 130x) with the given budget. The

If factor supply prices are set in competitive markets, all firms producing any product utilizing inputs A and B must combine A and B so that the ratios of marginal productivities are equal between firms:

$$\frac{MPP_{ax}}{MPP_{bx}} = \frac{MPP_{ay}}{MPP_{by}} \cdots \cdot \frac{MPP_{an}}{MPP_{bn}}. \qquad (4)$$

In addition, if all firms sell outputs (X, Y, Z, ...n) in competitive markets, the most efficient allocation of resources (A, B, C, ...m) is achieved. This is the allocation that produces the maximum output possible, given resource stocks and production budgets. If all firms both buy and sell in competitive markets, then the relationships of Figure 9 can be generalized into a matrix showing the necessary conditions that must

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criterion is: $-\frac{db}{da} = -\frac{P_b}{P_a}$.

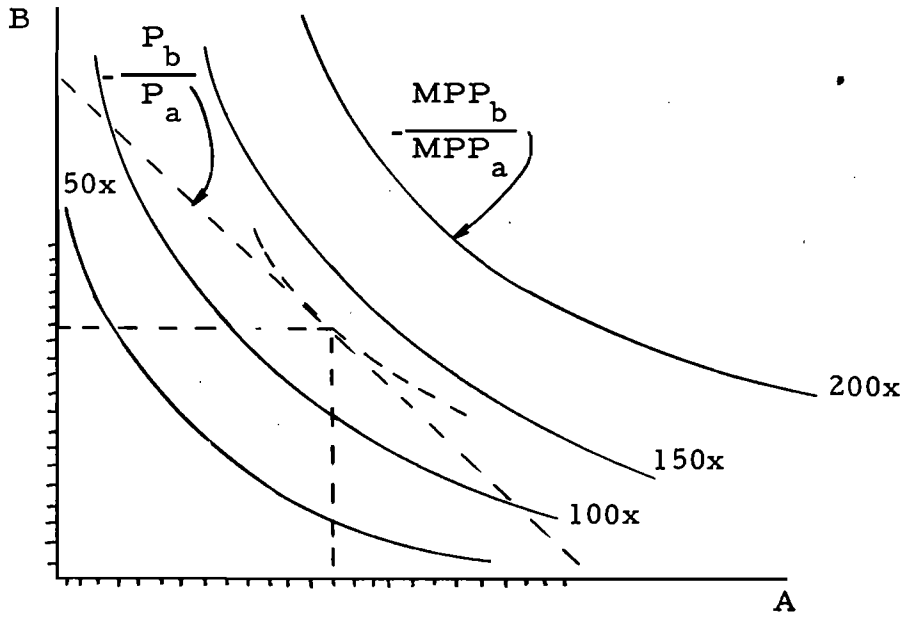

Figure 10. Iso-product determination of optimum combination of productive factors

(Students should compute the least cost budget to produce 50x; P_a = \$1, P_b = \$2. Question: What would linear iso-product curves imply? Question: What is the most significant difference between an iso-product map and an indifference map?)

prevail to insure an absolute maximum of production. The matrix shows that the value of the marginal product of any factor is equal in every use. Note that the actual relationships in the columns of the matrix are governed by whatever values are taken on by the ratios in equation (4).

$$VMP_{ax} = VMP_{ay} = VMP_{az} \ldots VMP_{an} = P_a$$
$$VMP_{bx} = VMP_{by} = VMP_{bz} \ldots VMP_{bn} = P_b$$
$$\vdots \qquad\qquad\qquad\qquad \vdots$$
$$VMP_{mx} = VMP_{my} = VMP_{mz} \ldots VMP_{mn} = P_m$$

In summary: all the production arrangements to and including equation (4) will be satisfied automatically if all firms are operated on a profit seeking basis and obtain productive factors in competitive markets. These arrangements only guarantee profit maximizing operations, however. To maximize total economic production through automatic marketing processes, competition must also be the rule on the selling side; competition must exist in all directions.

In most of the foregoing, it has been necessary to imagine existence of purely competitive markets. Numerous insights about production and cost relationships are masked if monopoly or imperfect market structures are not considered. In addition, markets for certain factors, such as labor, need special treatment. For these reasons, the theory of production will now be presented in terms of more conventional cost-curve analysis.

VI

COSTS, MARKET STRUCTURES, AND PARETIAN OPTIMALITY

Accounting Cost and Economic Cost

Production accounting costs are composed of current outlays plus some portion of the original purchase price of the fixed operating plant and facilities. The economic cost of the same productive output is the current value, to other firms, of the factor inputs used in production. Economic cost is the broader of the two concepts because it focuses attention upon alternative allocation possibilities and emphasizes the role of variable or out-of-pocket costs in making short run decisions.

Economic cost will be different for different groups: for example, the cost of the services of a famous baseball player is different to his club, to himself, and to society. The cost of water for, say, raising corn is the value of water for a different crop that might be grown on the same land. Economic costs may be different for an industry and for a firm; they may also vary geographically. All inputs, regardless of ownership, can be analyzed on the basis of economic cost. It should be noted that value in alternative uses is approximated by market prices for all economic goods having numerous alternatives.

Advantages of Using Alternative Cost Principles

The alternative cost principle is internally consistent. All inputs can be costed, even those that involve no outlay payments. Also the principle focuses attention on the relevant aspects of allocation of resources. For example, a firm can be expected to leave an industry when alternative employment of invested resources would exceed receipts from their present employment.

Economic cost will tell why resources are moving out of, say, agriculture. Irrigation water is a good example of such movement;

industry will pay more for water than will agriculture. As another example, it is often noted that firms may stay in business for long periods even though they incur accounting losses. That is, they are able to cover their operating costs and may earn little or nothing on fixed investments. This situation is an indication that such firms' investments or assets may have been overvalued.

Rent, Profit, and Depreciation

In contrast with cost, rent is a return. Economic rent is the difference between what a factor earns in its best employment and what it could earn in its next best employment, that is, its opportunity cost. While it is possible that numerous factors earn rents for a firm, from the accounting standpoint, all such rents are aggregated as the total return on the fixed investment. For a firm to be viable over the long run, returns to the fixed investment must cover depreciation and interest on capital. Any remainder is termed pure profit by economists. From an accounting standpoint all earnings over and above depreciation allowances and payments for use of non-owned capital are called profits.

If the demand for a product is very elastic, in general, a smaller amount of rent would be expected. Just as in the case of opportunity cost, rent magnitudes vary according to whether they are viewed by industry, by firms, or according to individual commodities.

Production and Product Markets

Definitions. In the short run certain production factors tend to be fixed in magnitude. They are not affected by output and often should be ignored when making profit maximizing decisions. In the long run all factors are variable, including the physical size of a firm's productive facilities and planning alternatives. The notion of long run production is a planning concept that requires consideration be given to the opportunity cost of every factor of production under consideration. Thus sunk costs

or fixed costs are commitments which the firm is unable to avoid. Quantities of variable factors change as output is altered.

$$ATC = \frac{TC}{X}$$

where ATC = average total cost, TC = total cost, and X = output units.

$$AVC = \frac{TVC}{X} = \frac{A \cdot P_a}{X} = \frac{A}{X} \cdot P_a = \frac{P_a}{APP_a}$$

where AVC = average variable cost, TVC = total variable cost, A = variable input, and APP_a = average physical product of A.

$$MC = \frac{dTC}{dX} = \frac{\Delta TC}{\Delta X} = \frac{\Delta A \cdot P_a}{\Delta X} = \frac{P_a}{MPP_a}$$

where MC = marginal cost.

$$AFC = \frac{TFC}{X}$$

where AFC = average fixed costs, TFC = total fixed costs.

$$ATC = AVC + AFC$$

Short run production. The important curves in the short run are: average total cost, average variable cost, and marginal cost. Figure 11 is an illustration of the typical relationships between short run cost curves. The generalized shapes are based upon the notion of diminishing returns. It will be recalled, from the production function analysis made earlier, that much of stage I of a technological production function is associated with increasing returns to successive, variable, outlays. This is the same as saying that costs per unit of output fall until diminishing returns set in. Then costs per unit of output begin to rise. The minimum point

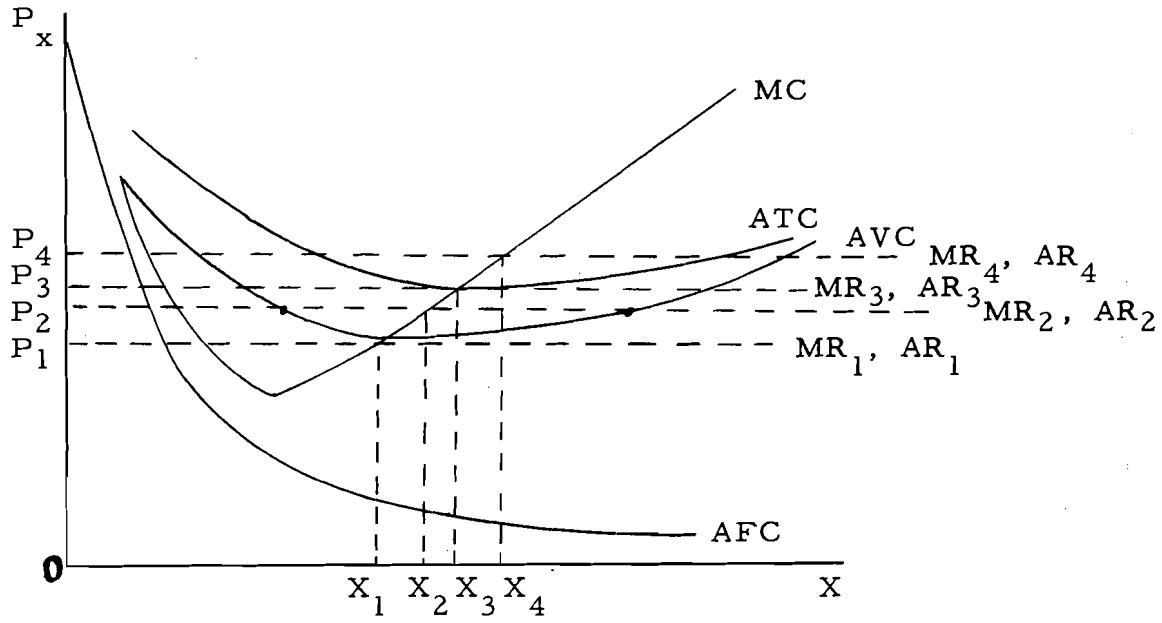

Figure 11. Short run costs and profit maximizing output (competition)

on the marginal cost curve of Figure 11, corresponds to the output associated with the onset of diminishing marginal returns on the total product curve of Figure 8. The end of stage I in Figure 8, therefore, is the point where AVC is at a minimum in Figure 11.

Suppose that all units of X can be sold at a constant price. This will be illustrated by drawing a horizontal line in Figure 11 at the appropriate price level. Suppose this level is below the point where AVC is at a minimum. This would mean that the revenue per unit would not be great enough to cover even the average or direct costs of production and the firm would have to go out of business. If production takes place at all, therefore, it must take place in stage II. This must be so, because any unit revenue higher than where AVC is a minimum, must be indicated by two intersections of the horizontal average revenue curve with the AVC curve. Only the intersection to the right of the minimum point on the AVC curve has any economic significance.

The horizontal curve of unit revenues, is really a demand curve because total revenue divided by sales equals average revenue (AR).

Individual firms face horizontal demand curves when they sell in purely competitive markets. In competitive markets, business managers have no control over the levels of selling prices. As long as market prices are constant, each unit sold returns a constant average revenue. Each successive unit sold also increases total revenues an amount exactly equal to those of the sales of previous units. Additions to total revenue are called marginal revenues (MR) and in competitive markets MR = AR.

The point where a firm maximizes profits or minimizes losses is at the output determined by the intersection of MR and MC. Output short of this intersection can be expanded because additions to total revenue will exceed additions to total costs. Output beyond this intersection adds more to cost than to revenue. Profit maximizing output under purely competitive conditions requires that MC = MR = AR.

In Figure 11, if $P_x = (0, P_2)$ the firm will incur accounting losses at output $(0, X_2)$ because ATC > AR. Total losses equal $(0, X_2)$ (ATC - AR). [Students should prove that total losses will increase if any output <u>other than</u> $(0, X_2)$ is chosen.]

Suppose AR rises to $P_x = (0, P_3)$. Then AR = ATC and total revenue equals total cost. (Question: Would any accounting profits be earned?) If AR rises to $P_x = (0, P_4)$, optimum output would be $(0, X_4)$. [What is the quantity of pure profit?; prove that this quantity would be reduced if any output other than $(0, X_4)$ is chosen.][1]

A monopolist faces a negatively sloped demand curve; if he wants to increase sales, prices must be reduced. But if prices are reduced his total receipts are not increased by $\Delta Q \cdot P_2$. They are increased by

---

[1] <u>Assignment.</u>

1. Make diagram(s) to illustrate what the cost-revenue curves would look like for a competitive industry producing X in the long run.
2. Prove that profit (π) is maximized at output level (Q) where dTR/dQ = dTC/dQ.

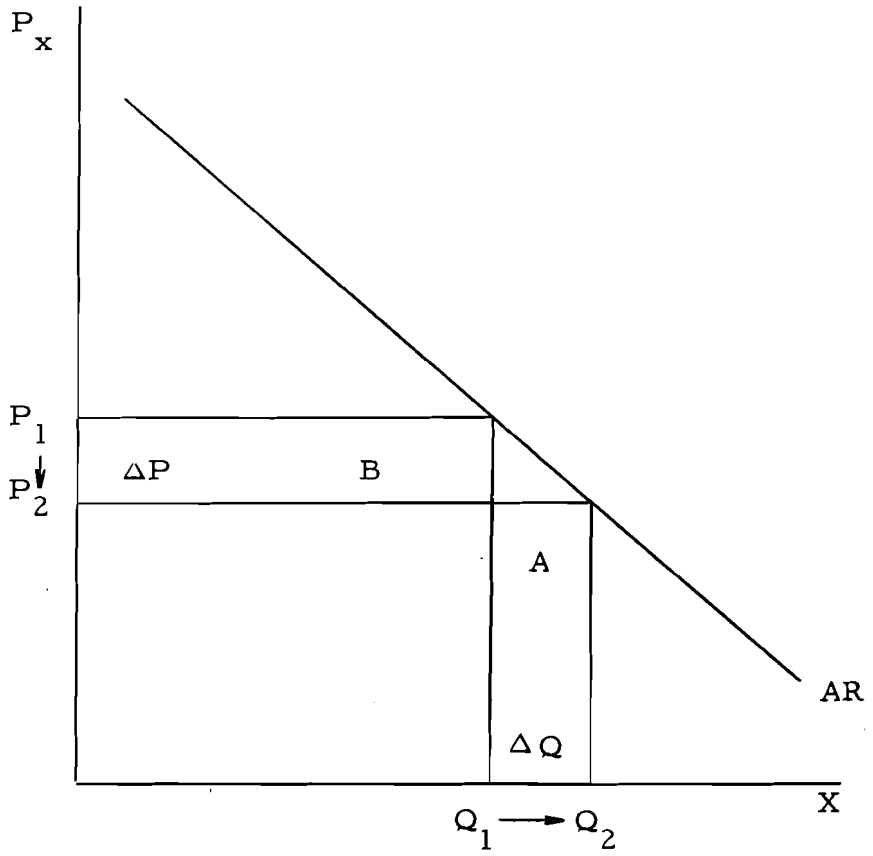

Figure 12. Graphic computation of marginal revenue (area A less area B)

$(\Delta Q \cdot P_2) - (Q_1 \cdot \Delta P)$. Marginal revenue per unit of ΔQ is evidently less than the average revenue. If the demand curve is not horizontal, there must be a separate marginal revenue function (Remember the earlier rule: if averages are falling, marginals must be below). It happens that the slope of any monopolist's MR curve is double that of the associated demand curve.

But a downward sloping demand curve doesn't change the rule for achieving equilibrium output for the firm. Under monopoly conditions, the rule still remains: adjust output until MC = MR. The profit maximizing result is diagrammed in Figure 13. The profit block has been marked. (Sketch in the economic rent accruing to the fixed factors. Suppose fixed costs were doubled, what adjustments would be necessary

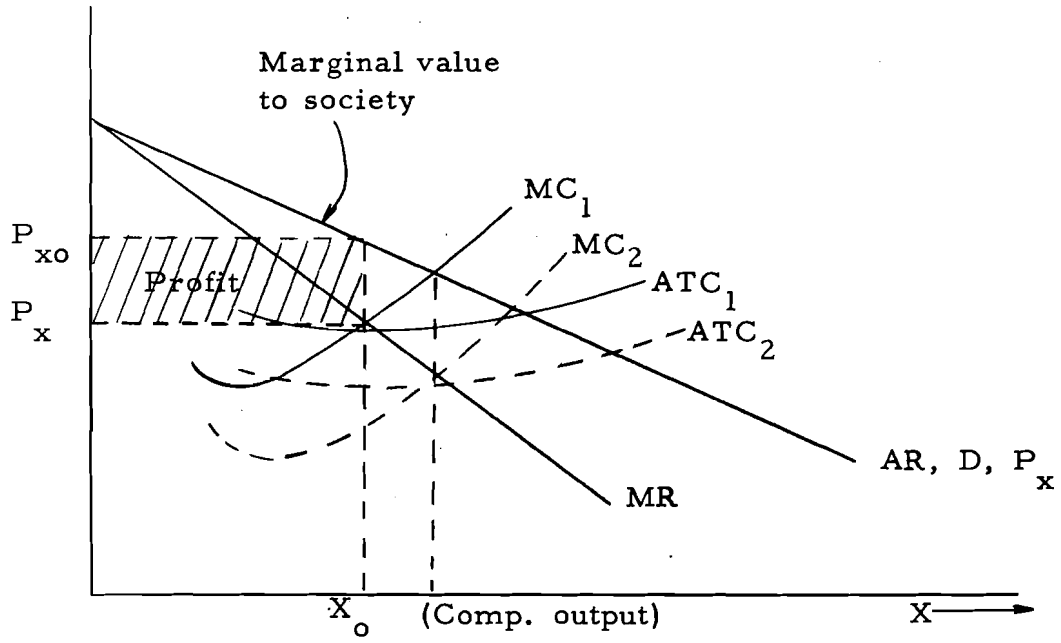

Figure 13. Profit maximizing in imperfect markets

in output? What if the cost increase converted profits into losses? Should prices be increased? Hint: do not forget elasticity implications.)

Output equilibrium where $MC_1 = MR$, although good for the firm, is not satisfactory to society because $MC_1 \neq AR$. Society wants production where $MC_1 = AR$ because this is what could be achieved under competition. And under competition (in all directions) a maximum of social output can be achieved.

Only in competition can one get a Paretian optimum. To get the firm to voluntarily expand production it is necessary that $MC_2 = MR$. To achieve this condition a marginal subsidy per unit of commodity can be given, together with the imposition of a lump sum tax on any profits that might result directly from the cost lowering operation. The MC_1 curve will shift downward with the subsidy and the optimum of the firm is shifted to the right to meet society's optimum. Paretian efficiency optimum requires prices equal to marginal costs; this implies that $MC_j = MC_k$ for any two or more firms producing X.

Long Run Equilibrium

In the short run, an equilibrium condition for a firm can be determined which reflects size of plant and all productive factors. In Figure 14, a profitable and efficient equilibrium operation is illustrated where $AR = P_{x1}$. Output X_{o1} is not efficient in the long run because other firms will be attracted by the profits and decide to enter the industry. When they do enter the industry, supplies will increase and reduce market

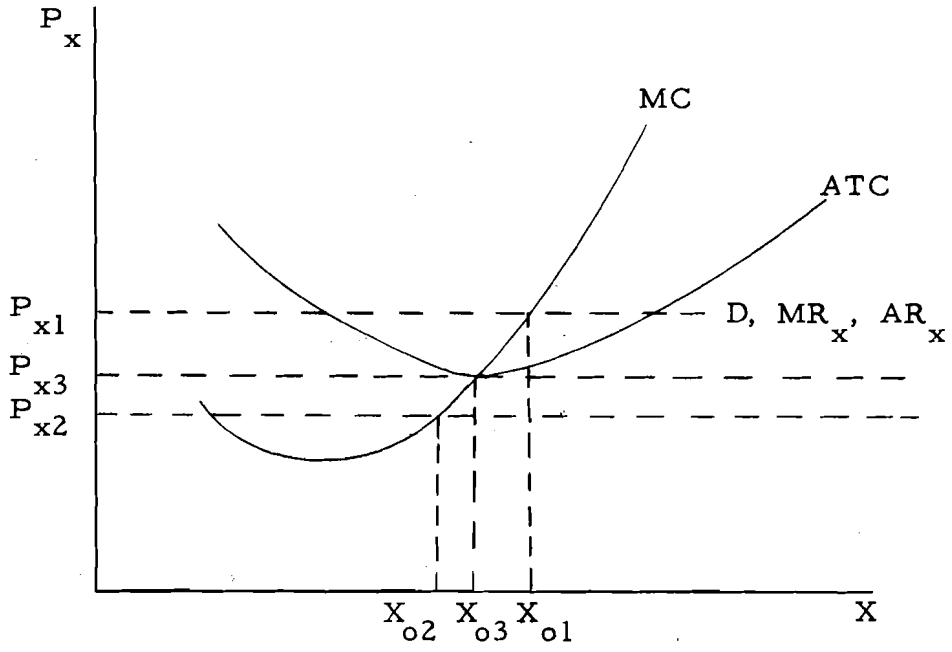

Figure 14. Competitive equilibrium in long run

prices to the level of, say, P_{x2}. At level P_{x2}, $MR_x < ATC_x$ and losses will be incurred. Some firms will therefore leave the industry and the demand curve will return to an intermediate position representing long run equilibrium at a level where $MR_x = AR_x = ATC_x = MC_x$ ($AR = P_{x3}$ in Figure 14).

Long run average cost (LRAC) can be delineated by mapping short run average cost (SRAC) curves for all potential plant sizes. What is required is an envelope of the lower portions of the SRAC family. The

resulting LRAC curve is U-shaped because as potential plant sizes increase there comes a point where management factors begin to lag or interfere with engineering efficiencies. The long run marginal cost

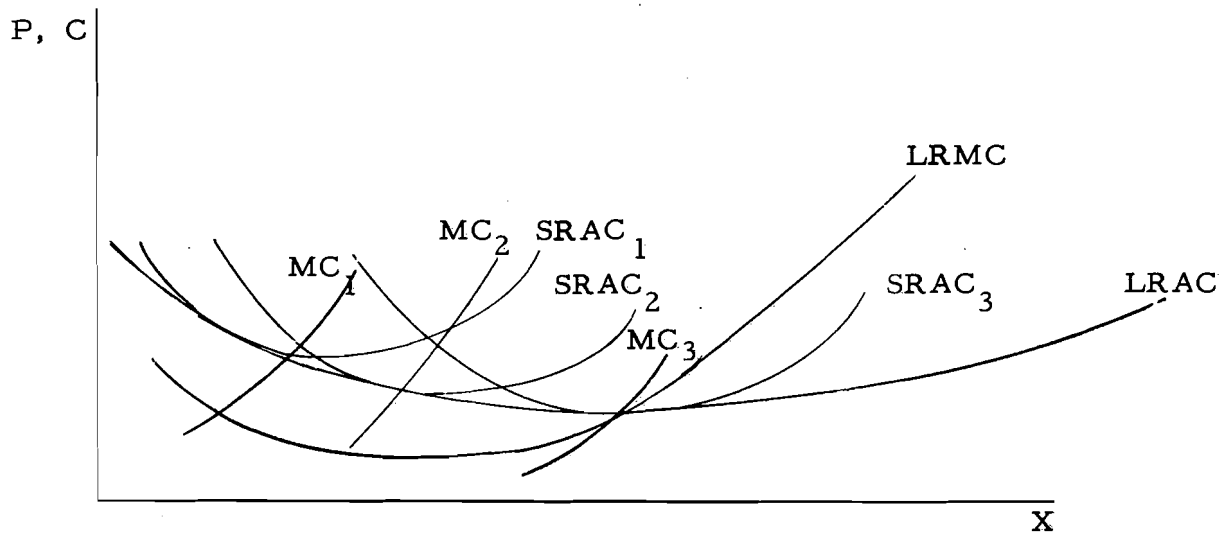

Figure 15. Construction of long run cost curves

(LRMC) curve is the first derivative of long run total costs.

$$LRMC = \frac{d(LRAC \cdot Q)}{dQ}$$

Effect of size. Often it is possible to at least gauge the long run cost structure (the scale factors) of the firms of an industry by observing the industry changes over time. For example, if small firms in the industry seem to be those going broke, this suggests increasing returns to scale (decreasing costs). If an industry contains firms of diverse sizes and all seem to be equally profitable, then constant returns to scale are implied. Most attempts at direct estimates of long run cost curves have found increasing returns to scale. A few industries may have firms large enough to have inefficient

technology and management, thereby forcing their long run cost curves to turn up. Theoretically, however, decreasing returns will eventually be reached if firms continue to expand sizes. Figure 16 illustrates the theoretically possible scale relationships.

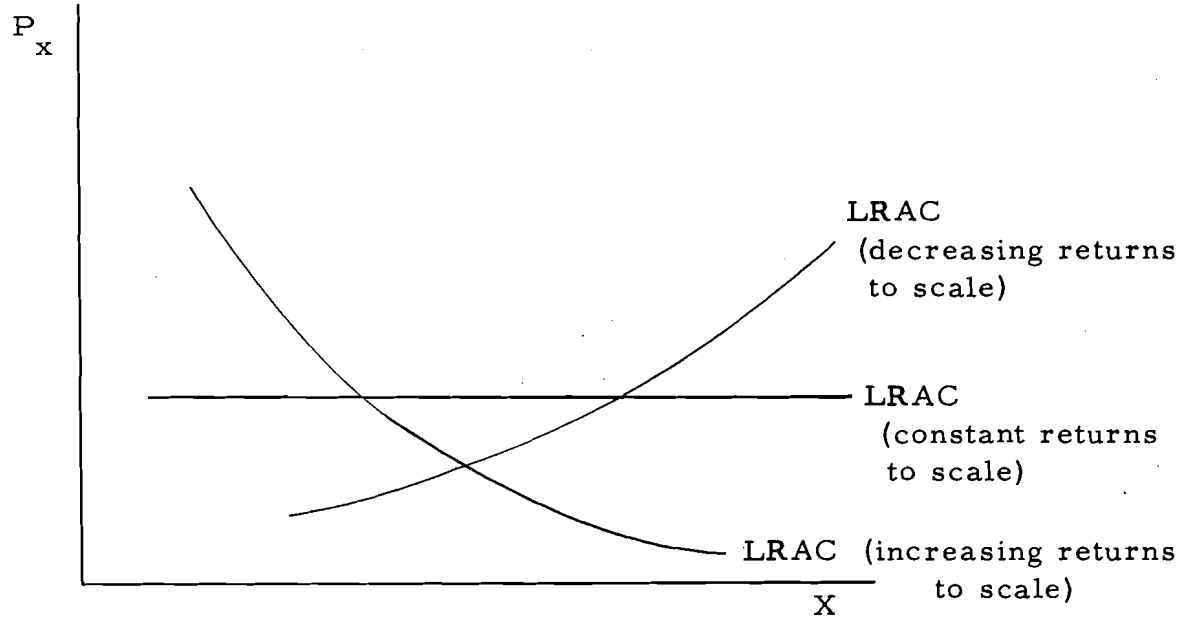

Figure 16. Observed effects of returns to scale on LRAC

Marginal cost and returns to scale. Constant returns to scale can only be associated with production functions which are linear and homogeneous of degree one. In this case $X/A = dX/dA$ for every value of X and marginal cost and average cost must always be equal.[1]

---

[1] Suppose all factor inputs receive in wages the value of their marginal products (Figure 9). Will the entire product be paid out to the inputs? or will something be left over? Indeed, is there always enough total production to "pay-off" all claims against production? If production is marked by constant returns to scale, it can be shown that the sum of marginal products will add up to the total product. This is connected with a standard mathematical result called Euler's Theorem.

To derive Euler's Theorem it may be noted that for any linear homogeneous production function, $P = g(L, C)$ there is, for any k,

$$kP = g(kL, kC).$$

The derivation of kP with respect to k,

If returns to scale are decreasing, then long run marginal costs will be above average costs. The reverse is true in the cost of decreasing returns.

Diseconomies of scale can occur both internal to individual firms and external to them. An example of an internal technological diseconomy would be when the firm got so large that management could not effectively manipulate the inputs under its control. An example of an external diseconomy might be where all the firms expand and the effect of the enlarged industry is decreased efficiency, as in the case where expansion of a number of trucking firms would lead to congestion on the highways and impose higher costs on all firms.

Economies of scale are likewise external and internal to the firm. An example of an internal economy would be when a firm, by expanding, can adopt mass production techniques and thus increase efficiency. These types of economies are very prevalent. An example of an external

---

$$\frac{dkP}{dK} = \frac{\partial g}{\partial kL} \cdot \frac{dkL}{dk} + \frac{\partial g}{\partial kC} \cdot \frac{dkC}{dk}$$

or

$$P = \frac{\partial gL}{\partial kL} + \frac{\partial g}{\partial kC} \cdot \frac{dkC}{dk}$$

Since this holds for any value of k it must hold for $k = 1$ and,

$$P = \frac{\partial g}{\partial L} L + \frac{\partial g}{\partial C} C$$

$\partial g/\partial L$ and $\partial g/\partial C$ are the marginal products of labor and capital respectively. Thus the equation states that $MPP_L \cdot A_L$ (each of whom is paid this amount) plus a corresponding total payment to capital, exactly equals the total product.

economy would be when two or more firms combine forces to provide joint facilities or services for each other than would increase efficiency.

All internal and some external "effects" must be reflected in a firm's cost curves in one of the three ways shown in Figure 16. But these effects are not always reflected in alternative costs to society. Pecuniary effects do not alter society's costs. If a firm expands production, bidding for increased labor supplies will drive up labor costs for the entire industry. But this is a pecuniary effect; society does not get any less labor services in total, even if there is some re-allocation of labor resources.

Technological effects are associated with such things as the increased production of smoke. The only costs the firm must face are for the additional factors altering production enough to increase smoke output. But laundry bills for housewives and medical bills for lung ailments may rise and physical resources that might be used otherwise must be devoted to additional cleaning and hospital care.

Decreasing cost industries. As long as AC is declining then MC $<$ AC. Optimum production in competitive selling markets is where MC = AR, and in the case shown in Figure 17 a loss is incurred. In this situation, average costs can never be recovered by relying solely upon marginal cost pricing. Average cost pricing will restrict

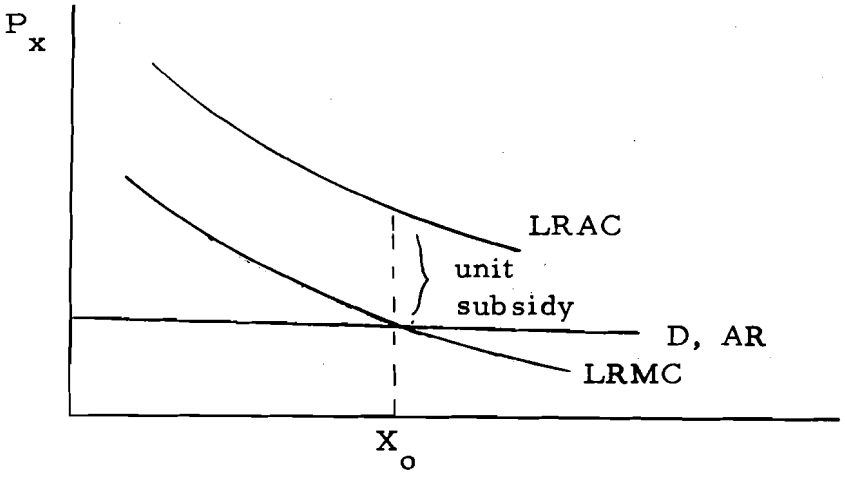

Figure 17. Unit subsidy for competitive decreasing cost industry

consumption below levels of what people are willing to pay at the margin. The losses can be subsidized; covering AC is an income distribution problem. The point in this situation is that the "natural tendency" will be for production and sales to be at the $(0, X_o)$ level in Figure 17.

In Figure 18 the decreasing cost situation is altered by the fact that the selling market is monopolized to some degree by an individual firm. This decreasing cost situation is pretty close to real life experience of many public utilities. The natural tendency is for the firm to price where MC = MR, but this is below the socially desirable output $(0, X_1)$. Thus the problem is not merely that of subsidizing losses; in addition the firm must be induced to increase output. This requires a per unit subsidy to lower marginal costs as shown in Figure 18. If average costs fall enough in the process to give rise to pure profits, a lump-sum tax may be used to recover part of the subsidy.

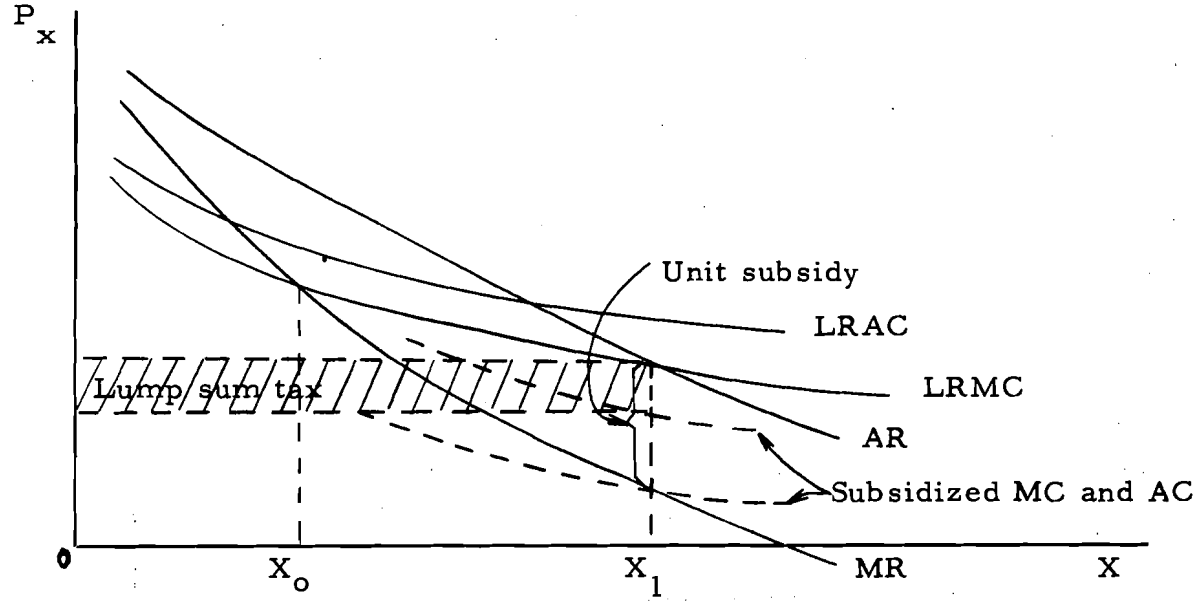

Figure 18. Tax/bounty treatment for monopolistic decreasing cost industry

Pricing of Productive Services

This section will consider the application of the Paretian optimum to factor markets. Given competition it was asserted that efficient factor allocation required $P_a = MPP_a \cdot P_x$. It was hinted earlier (p. 35) that the fact that both factor and commodity markets are involved in any production/selling arrangement may give rise to allocative restrictions. Factor and commodity markets can operate under four combinations of competition or monopoly as follows:

Table 2. Factor- product market possibilities

Case	Product	Factor	Equilibrium
1	competition	competition	$P_a = MPP_a \cdot P_x$
2	monopoly	competition	$P_a = MPP_a \cdot MR_x$
3	competition	monopsony	$MFC_a = MPP_a \cdot P_x$
4	monopoly	monopsony	$MFC_a = MPP_a \cdot MR_x$

Case 1: competition (factor) - competition (product). Value of the marginal product of A equals MPP_a times the net increase in revenue from sales of additional units of X. Since X is sold in competitive markets, $MR = P_x$. Supplies of factor A are assumed to be purchased in competitive markets. This means that additional units of A can be obtained at constant unit prices. The additional or marginal factor costs (MFC) equals the average supply price (P_A) or wage rate (W).

In connection with the equilibrium condition illustrated in Figure 19 it should be noted that the marginal unit of factor A receives the entire value of its marginal product.

Case 2: competition (factor) - monopoly (product). A profit maximizing firm will not equate $VMP_a = P_a$ in this market situation.

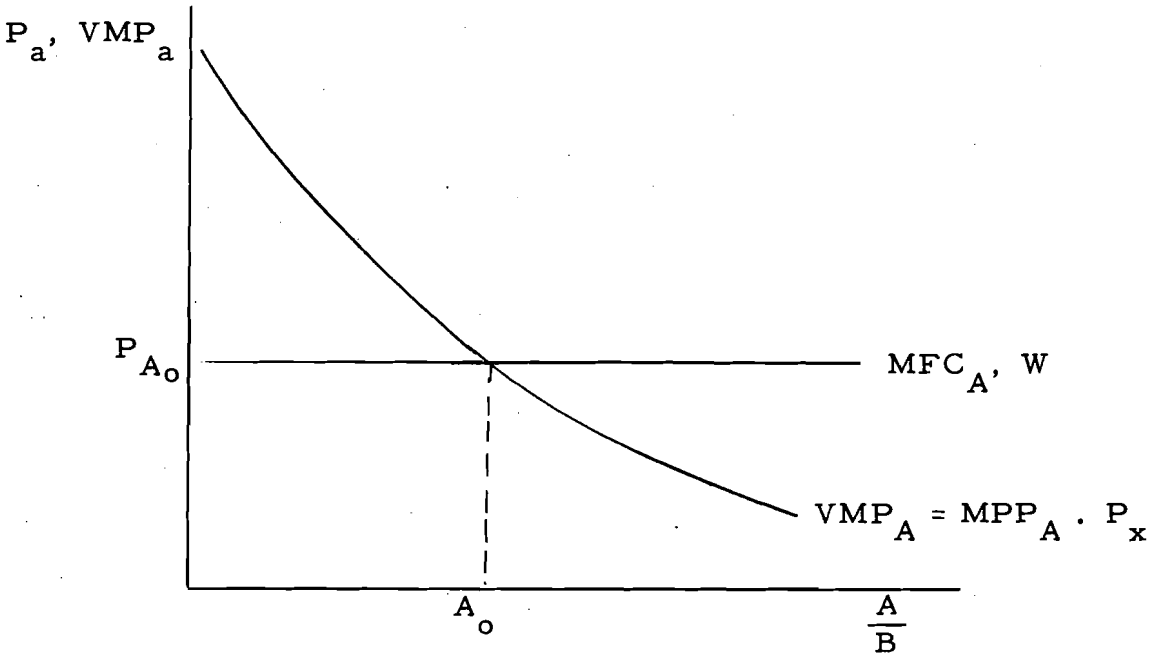

Figure 19. Productive services equilibrium: case 1

When sales are made in a monopolistic market, the value of MPP_a to the firm is governed by marginal revenues, not average. Thus the value is obtained by multiplying $MPP_a \cdot MR_x$.[1] The result is termed marginal revenue product (MRP). This nomenclature change is a reminder that the analysis is no longer in terms of competitive selling. (Students should prove that $MRP = P_a$ is equivalent to $MC = MR$).

In Figure 20, the Paretian conditions are not satisfied at input

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[1] The empirical problem of ascertaining values for MR is minimized somewhat by existence of the following relationship:

$$MR = P_x \left(1 + \frac{1}{e}\right)$$

where e = elasticity of demand with negative algebraic sign. Many economic questions can be answered only after estimates of demand functions have been made. The econometric techniques employed to estimate demand parameters also supply elasticity values. Once price elasticities are available, computations of marginal revenues is simple. The equilibrium condition in case 2 can thus be written:

$$MPP_a \cdot P_a \left(1 + \frac{1}{e}\right) = P_a.$$

level $(0 - A_o)$ even though the value of marginal product (Q, A_o) is paid to A. A sufficient condition for an optimum would also require that employment not be restricted to the $(0 - A_o)$ level. The analogous employment level under competition would be $(0, A_1)$. It is in the sense of restricted employment that the factors are exploited. (Question: Can the factors earn pure profits for the firm if they do receive wages equivalent to VMP_a? If so, how much?)

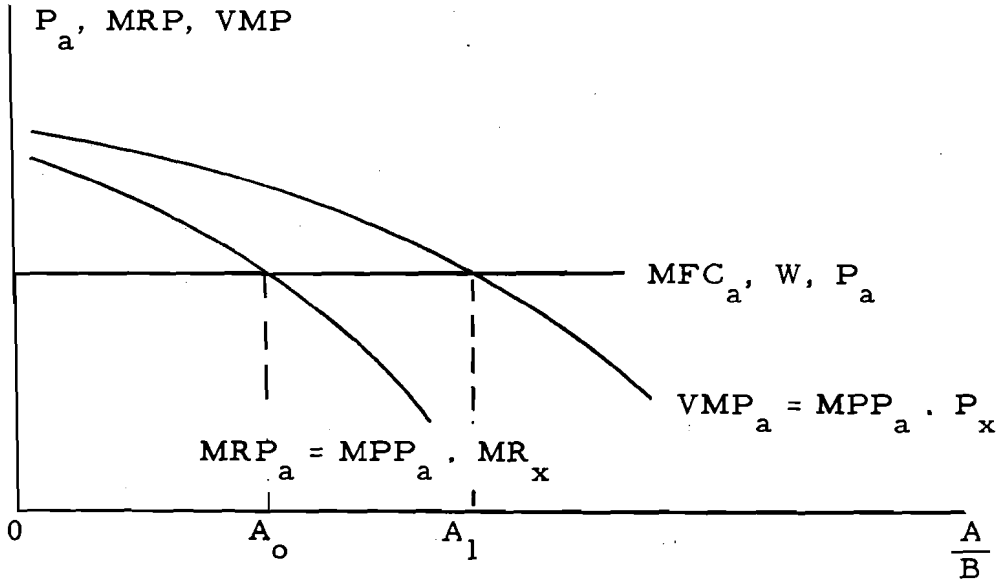

Figure 20. Productive services equilibrium: case 2

Case 3: monopsony (factor) - competition (product). Equilibrium for the firm is shown at factor input $(0, A_o)$ in Figure 21. The marginal factor cost of A (MFC_a) must be set equal to VMP_a to maximize profits.[1] Benefit to the firm from using the marginal unit of A is the value of the marginal product, depicted as distance (A_o, Q) in Figure 21.

[1] From the previous footnote, $MFC_a = P_a(1 + \frac{1}{E})$ where E = elasticity of supply of factor A with a positive algebraic sign.

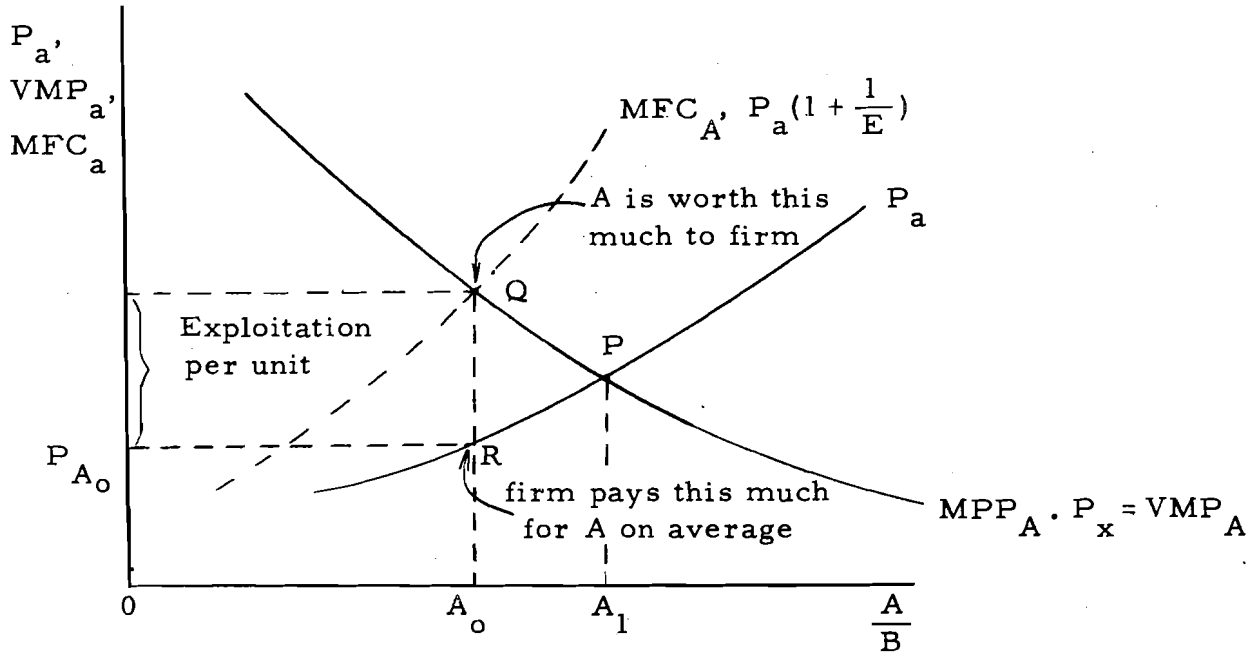

Figure 21. Productive services equilibrium: case 3

Equilibrium for the firm cannot be efficient in the Paretian sense. The socially desirable employment level of A would require expansion to $(0, A_1)$. Since wage returns to A are (A_o, R), the value (R, Q) is a measure of the price exploitation the factor bears due to existence of monopsony in the factor market (only a single purchaser of factors).

Case 4: monopoly (product) - monopsony (factor). Equilibrium for the firm is still where $MFC_a = MRP_a$. In this particular instance factor exploitation is increased due to additional influence of a monopoly selling market. Value of output to society at level $(0, A_o)$ is (A_o, P). Wage payments to factors are only (A_o, R). (Figure 22)

If Paretian conditions could be fulfilled, production associated with $(0, A_1)$ inputs would be forthcoming and the return to A would equal the marginal sacrifice of factor effort. It is clear that competitive markets on both sides of the productive process are a prerequisite to attainment of a Paretian optimum.

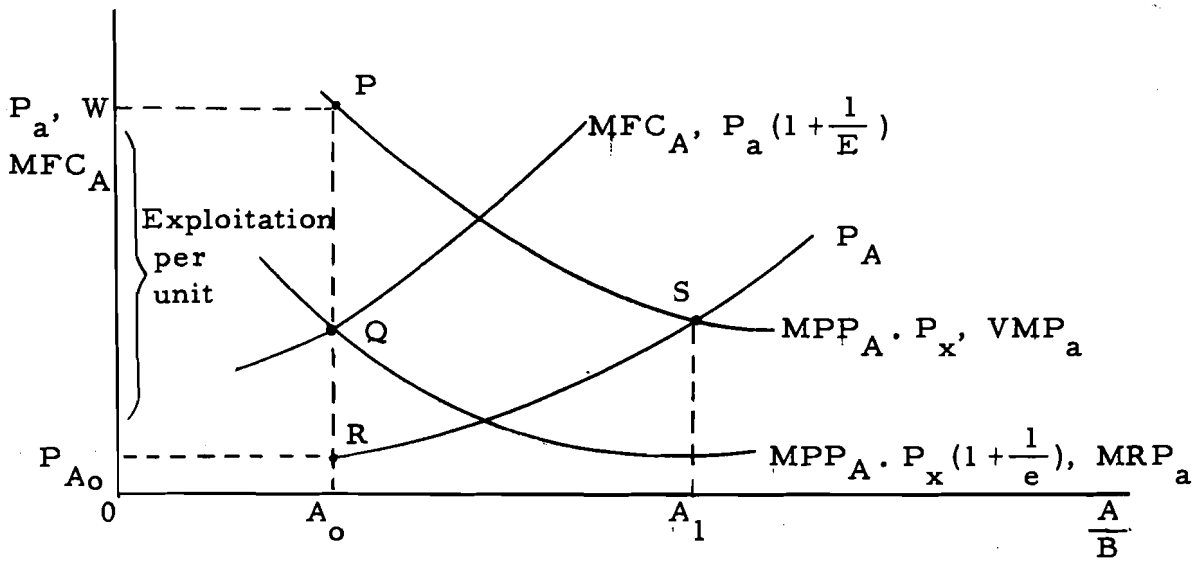

Figure 22. Productive services equilibrium: case 4

Labor as a Market Force

Labor as an economic commodity will be examined in the same framework as that of other factor markets. What amount of labor, in equilibrium, will be offered at the going market rate? Four somewhat ficticious assumptions will be employed while examining this question:

1. Labor can be supplied on a 24-hour basis.
2. There are no institutional impediments to the employment of labor.
3. Perfect competition exists.
4. Predictions can be made with certainty.

In Figure 23 consider the indifference curve for a given level of utility, U_o, relating total income and hours worked per week. This and other indifference curves can be constructed by connecting combination points of hours and income that produce given levels of satisfaction.

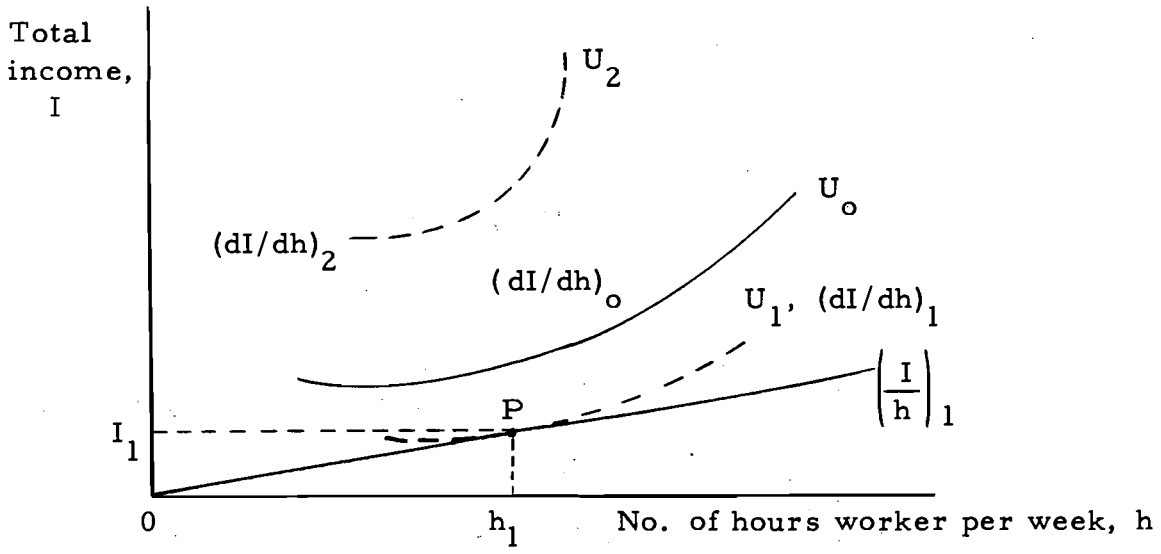

Figure 23. Indifference curve for labor

Indifference, U_o, has a positive slope because more incentive is needed as the work week increases; the derivative of the slope is positive due to the increasing marginal disutility of work.

If a certain wage rate is offered, it can be depicted by a linear function having slope $(I/h)_1$ as in Figure 23. The equilibrium point will be at P which is the point tangent to the highest level of utility (U_1) for the curve. Thus, $(0, h_1)$ hours of labor will be offered at the market wage rate $(I/h)_1$. Optimum hours of labor for an individual to supply are determined by an equality of the marginal rate of substitution of income for labor with the wage rate $dI/dh = I/h$.

In Figure 24 the effect of an increase in income has been plotted. Equilibrium moves from P to R. Again, as when the demand for commodities was considered, the movement from P to R is the net result of two disparate tendencies. As wages rise there is some tendency to substitute earnings for labor; there is a tendency to move from P to Q. The "income effect" creates a tendency to move from Q to R.

Again, just as in the case of demand, the substitution effect is virtually certain to lead to positive increases (in hours). Due to the necessary slopes of indifference curves in the labor supply case, however, the chance that income effects will swamp out substitution effects is enormously increased. Thus, the net effect of a wage increase could be a reduction in labor offerings.

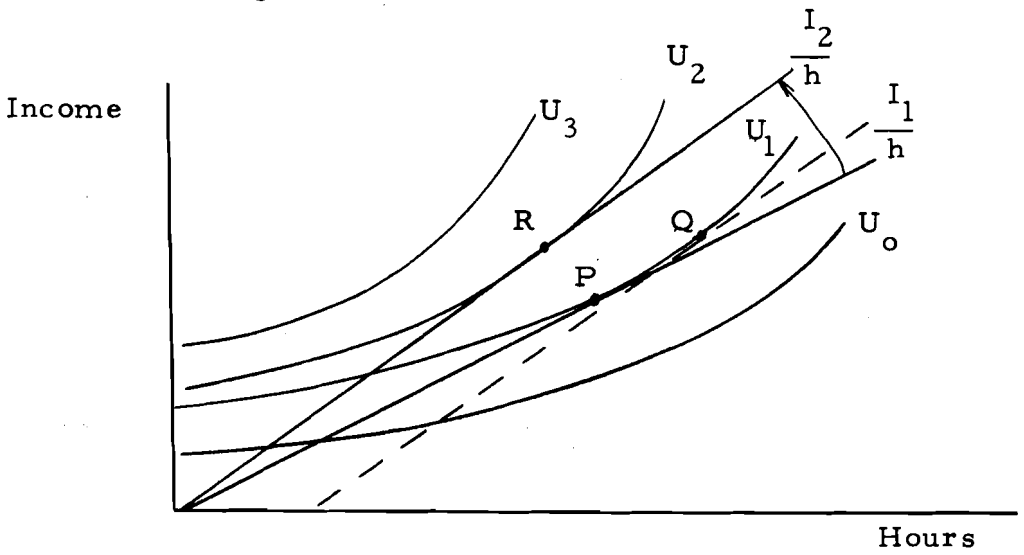

Figure 24. Income and substitution effects in a labor supply market

If the locus of all possible points of tengency of indifference curves and various wage rates is drawn, a labor supply curve will be defined. The shape of this function may be as shown in Figure 25.

The general shape of the supply curve of Figure 25 indicates that leisure may be both inferior and superior, depending upon the level of income. Or, another interpretation can be made in terms of marginal utility. After a certain income plateau is reached, the marginal utility of income sharply declines, and the marginal disutility of labor increases. (Questions: What might happen to agricultural employment levels if a minimum wage is enforced? What might union wage bargaining do to employment of members? Do union goals such as maximum employment, maximum wages per man, or maximum total union wage receipts have

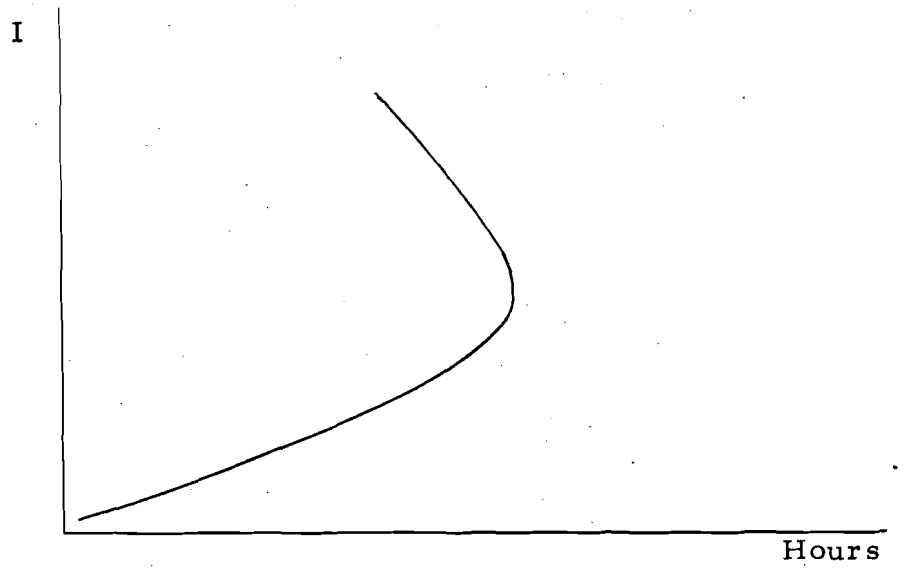

Figure 25. Labor supply curve indicating influence of leisure as a superior good

any bearing on your answer?)

Optimum supply of labor to numerous employers requires that

$$\left(\frac{dI}{dh}\right)_i = \left(\frac{dI}{dh}\right)_j = \cdots \left(\frac{dI}{dh}\right)_n = \frac{I}{h}$$

This can only be achieved in competitive markets, because only such markets force all labor suppliers to adjust to a common wage rate.

VII

SUMMARY OF NECESSARY CONDITIONS FOR PARETIAN OPTIMUM

1. In Consumption:

$$-\frac{dY_1}{dX_1} = -\frac{dY_2}{dX_2} = \cdots = \frac{dY_n}{dX_n} = \frac{P_x}{P_y}$$

2. In Production:

Product market - $(MC_x)_1 = (MC_x)_2 = \cdots = (MC_x)_n = P_x$; Also for all other products, Y, Z, ... M.

Or,

$$\frac{MPP_{ax}}{MPP_{bx}} = \frac{MPP_{ay}}{MPP_{by}} = \cdots = \frac{MPP_{an}}{MPP_{bn}} = \frac{P_a}{P_b}.$$

Factor market - $P_M = MPP_M \cdot P_n$ for all factors.

3. Factor Supply:

MRS between factor benefit and factor sacrifice must be equal for all suppliers of a given factor.

VIII

KALDOR COMPENSATION CRITERION

According to the Paretian criterion one can always increase welfare by moving toward the contract curve (within the confines of the indifference curves passing through a position off the curve). Thus in the Edgeworth box diagram of Figure 26 there is no question that there is an increase in welfare in moving from point A to point E, since II is no worse off and I is better off.

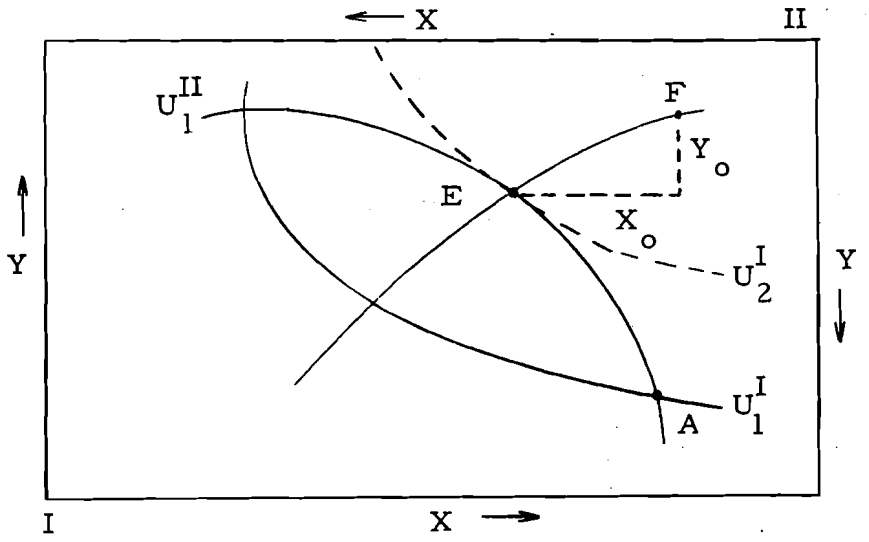

Figure 26. Logic of compensation criterion

To compare A to F in Figure 26 is an income distribution problem. Kaldor (34, 35) suggested that <u>any</u> point on the contract curve is superior to any point off. Thus while II is worse off at F than at E, a series of compensating payments, x_o and y_o, from I to II will put I and II back at E (I still better off on U_2^I) while the project is able to operate at F. Therefore all positions on the contract curve are superior to positions off, if compensation is paid from gainers to losers.

The Kaldor criterion leaves Paretian conditions stronger because they are satisfied at any point along the contract curve.

IX

GENERAL THEORY OF SECOND BEST

Professors Lipsey and Lancaster (38) are responsible for the general theory of the second best. This states that a complete Paretian optimum requires fulfillment of all marginal conditions simultaneously; a constraint or imperfection in the economy which prevents fulfillment of one condition makes all other Paretian conditions no longer desirable even though they may be attainable.

There are three negative corollaries to this theory as follows:

1. There is no apriori way to judge between situations if there is a departure from the complete Paretian optimum.
2. It is not true that a situation in which more but not all of the optimum conditions are fulfilled is more desirable than a situation in which fewer are fulfilled.
3. In a situation where there are many constraints, the removal of one of the constraints which pushes the economy closer to a Paretian optimum does not mean that welfare is improved or that it is not improved; the answer cannot be determined.

Perhaps the best example of attaining a second best optimum might be found in times of less than full employment. If there is a lack of consumer demand or an institutional rigidity exists that results in unemployment, it may be desirable to reallocate employment until the marginal rate of substitution of labor for income is equal for both the previously employed group and previously unemployed group. In Figure 27, if A is the previously unemployed group and B is the employed group, it may increase the overall utility of both A and B by forcing B to work fewer hours while A picks up the slack until the above criterion is satisfied. This will prevent group B from operating at its Paretian optimum, but group A is better off.

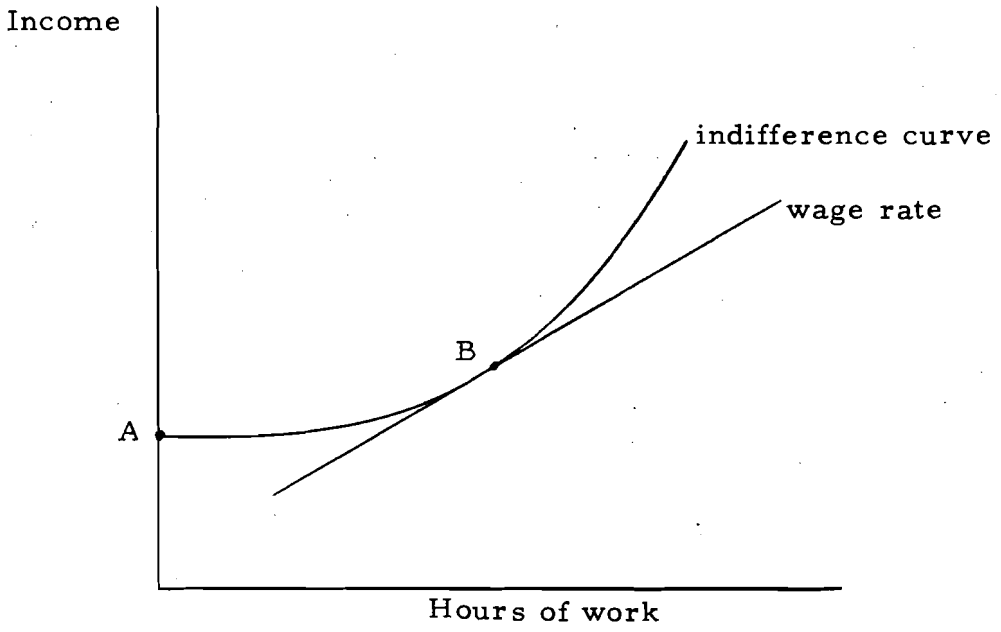

Figure 27. Reallocation of work to satisfy second best optimum

As a result of the appearance of the general theory of the second best there is some controversy over the assertion that Paretian optimums will produce economic efficiency. Actually mobility and degree of imperfections in the economy govern how much departure there is from a Paretian optimum. Whether an increase in welfare results as the economy approaches the Paretian condition cannot be predicted with certainty; the "feeling" that welfare will increase may only be intuitive.

X

FREE MARKET PHILOSOPHY AND THE PARETIAN OPTIMUM

Milton Friedman (8) has argued strongly in favor of minimal governmental interference in the economy. His thesis is that the market offers several distinct advantages over a command economy:

1. In a voluntary exchange every individual believes he is better off than if someone else made the allocation.
2. There is no coercion and therefore freedom is maximized.
3. The market offsets political power.
4. The market can reduce the range of issues that need to be solved by political means--and the market does not require a cumbersome structure and overhead.
5. Political action requires conformity, but the market may produce wide diversity.

Many persons would feel, with respect to 2 that markets are not entirely free of coercion. Those who have experienced run-away inflation or live lives dominated by specific markets that cannot be avoided (certain labor markets in areas where labor mobility is virtually nil) are cases in point. And persons only receive the benefit of Friedman's fifth argument if they have the wherewithal to select meaningful alternatives. Friedman discusses freedom in terms of absence of constraints (thereby leaving himself open to the charge of espousing a paradox). Economic constraints constitute a lack of freedom. Freedom needs a broader definition, such as in terms of the total number of alternatives to choose from.

There are five general areas where government must function, according to Friedman:

1. Protection (from each other and from foreign nations)
2. To preserve law and order
3. To enforce contracts

4. To foster competitive markets
5. To help individuals accomplish jointly what may be difficult individually.

A complete application of Friedman's philosophy is impossible due to the existence of three major classes of market imperfections: imperfect possession, imperfect foresight, and monopoly.

Imperfect Possession

Weak property rights. The beneficial use of many resources is threatened by theft, enticement, expropriation or other means. When such conditions are present, owners will invest short of the optimum. Unclear water laws may inhibit development due to uncertainty of future rights. The expectation that the federal government may continue to cut grazing permits on the public lands will likely reduce investment in range improvement practices below the optimal level.

While recognizing that property rights are not God given, respect for them tends to promote conservation. Conversely, strong drives for conservation may overturn property rights and be self-defeating.

Fugitive resources. In many cases, resources are subject to private appropriation only if they can be captured, e.g., fish or precious minerals. The odds are that such situations lead to duplication of capture effort. In the case of oil, for example, there is inducement to over-rapid depletion and even reduction in total yield. The pattern of exploitation in the sea fisheries reveals how investment can get out of hand relative to reasonable expectations of success. Possibly the greatest recent example of flagrant overinvestment is provided by the fever in search and promotion activities accompanying the "Uranium Boom" of 1954.

Neighborhood effects and externalities. These are unborn costs imposed by some resource users on others that do not get evaluated in the market. An example mentioned earlier is smoke and other air

pollutants. Others are: congestion mutually imposed by urban road users, or the deterioration of water quality caused by one group which increases social costs of re-use.

Two features should stand out from these examples.

1. Increased costs associated with such external effects are technological. That is, additional costs must be borne by society in the form of production below what would otherwise be possible;
2. The resources involved are treated by users as "common property." Actual use often takes place in an atmosphere of "If I don't get it, someone else will."

In attempts to correct for certain external effects, the government (Friedman argues) tends to err as much as private markets do in ignoring their presence. He does concede that some government regulation may be desirable.

Imperfect Foresight (Risk and Uncertainty)

Social risk. Use and development of natural resource may turn out to be more or less valuable than expected. Therefore, on an ex post basis, such use may have been bad. But results can go either way. The real question is whether private market decisions are any worse than government decisions.

If the resource in question is a small part of a private person's wealth, so that marginal utility of money is invariant if the asset is lost, there should be no difference in the rate of utilization between the social optimum and private optimum

Some argue in favor of government planning because the time horizon is purported to be longer. Private development need not be deficient in this respect. Corporations have a perpetual existence at stake, and private interests are often motivated to leave wealth to their posterity.

Private risk. Loss of possession through expropriation is a reason for government action. But other risks, according to S. Ciriacy-Wantrup (5), are due to: 1) irrationality; 2) extra-market values; 3) uncertainty; and 4) habit patterns. Since (1) and (4) are not considered by Friedman, Wantrup's extensions are of some interest.

By irrationality Wantrup means that private actions are not consistent with private goals. They do not reflect learning over time. Habit patterns are intertwined with irrationality. Similar actions are consistently repeated over time without recourse to rational thought processes. In this situation society might gain by government sponsored education, and policies designed to conserve otherwise wasted resources.

Public vs. Private Sectors and Monopoly

The most glaring deficiency of the private sector is limited objectives (most of which are tied to profits). Thus, externalities are often neglected: water and air pollution are prominent examples today. Some firms have begun to internalize externalities, however, because they recognize a responsibility to the public in addition to their responsibility to stockholders and employees. The government is more apt to consider externalities in its planning, but it can be limited by its policies and bureaucratic structure. The Corps of Engineers in its zeal to promote flood control projects, and thus its own growth, is a good example. This type of weakness leaves open the question of whether government planning will promote greater overall utility than private planning.

There are incentives for private firms to keep themselves informed on a broad perspective, their economic life depends upon it. The market is better able to take care of inefficiencies than political processes, but monopoly may reduce the competitive pressures to weed them out. Despite oligopolistic growth, however, it is possible to argue that today's markets are even more competitive and less tolerant of

economic inefficiency than ever before. Their comprehensiveness and the increased knowledge of both buyers and sellers have made them so.

There are situations where competition is not desirable, however. Where there are economies to scale and where needless duplication would result because of the natural situation (such as power transmission, telephone service, or railroads) then monopoly production should prevail. In place of market forces some kind of government regulation and intervention is necessary to protect the public welfare.

To summarize: when there is a common property resource, when monopoly exists, and when externalities are important, and if private enterprise is valued, then there must be some form of control. Beyond that it is open to question. Government intervention can only go so far without impairing the health of the private sector.

Decentralization is better than centralization, other things equal. People have more flexibility to adjust or move if they do not like a situation. If large doses of monopoly appear some governmental intervention in fostering private markets is necessary. Friedman argues that of the two, private monopoly is better than government because it is less likely to last over the long pull.

PART II

XI

GREEN BOOK (30)

Motivation for Green Book

In 1946 the Federal Interagency River Basin Committee appointed a subcommittee for the purpose of formulating mutually acceptable principles and procedures to determine benefits and costs for water resources projects. The "Green Book" presents the conclusions and recommendations resulting from a series of studies by that subcommittee.

The series of studies upon which the Green Book is based was divided into the following major parts.

A. Analysis of current practices in economic evaluation

B. Objective analysis and analysis of special problems

C. Conclusions and recommendations

Comparison of then current practices among government agencies indicated important, fundamental differences in their concepts of economic evaluation. Agencies differed in such concepts as:

1. Economic effects attributed to differences in measurement procedures
2. Differences in the liberality with which costs were measured as compared with benefits.

Section B was designed to provide a systematic, consistent, and theoretically sound framework for the economic analysis of river basin projects and programs irrespective of current practices or legislative and administrative limitations.

Section C contained the recommended set of criteria for benefit-cost analysis which participating agencies could employ to select those projects which would lead to most effective development of individual river basins.

Basic Assumptions and Principles

Analysis in Chapter 2 proceeds from four main assumptions:

1. The most effective use of economic resources is made if they are utilized in such a way that the amount by which benefits exceed costs is at a maximum. (This criterion takes precedence over benefit-cost ratio or any other basis.)
2. A project should be designed to include each separable segment or increment of scale of development which will provide benefits at least equal to the cost of the segment or increment.
3. The project, and any separable segment selected to accomplish a given purpose should be more economical than any other alternative means, public or private, for accomplishing the purpose of that project.
4. Economic analysis should provide data which can ultimately be used for arraying a number of justified projects in the order of their economic desirability.

Basis for evaluation of benefits and costs. The Interagency Committee recognized the limitations inherent in reflecting public values solely in monetary measures but concluded that there is no other suitable framework for evaluating the effects of public works projects in common terms. Accordingly it was recommended that project effects were to be gauged in the light of market prices. Intangibles, such as scenic values, which are considered impossible or difficult to express in monetary terms, were to be considered and described in a way that would clearly indicate their importance and influence on project formulation and selection.

Cost-benefit terminology.

Project costs are the values of the goods and services used for the establishment, maintenance, and operation of the project.

Associated costs are the values of the goods and services needed over and above those included in the cost of the project itself to make

the immediate products or services of the project available for use or sale.

Primary benefits are the values of the immediate products or services resulting from the measures for which project costs and associated costs are incurred.

Secondary costs are the values of any goods and services which are used on the cost side as a result of the project. These may be such things as the costs of transporting wheat, elevator and milling costs, etc.

Secondary benefits are the values added over and above the values of immediate products or services of the project as a result of activities stemming from or induced by the project.

Primary and secondary benefits. Individual projects should be credited with the difference between total primary benefits and benefits that could be expected to be realized by applying the associated costs for other purposes if the project were not undertaken. Benefits foregone are, in the usual case, assumed to be equal to the market value of the goods and services used. Therefore, the primary benefits attributable to a project are equal to the total primary benefits less associated costs.

No secondary benefits are attributable to the project unless it can be shown that there is an increase in such benefits as a result of the project as compared with conditions to be expected in the absence of the project. Secondary benefits can accrue, for example, under the following conditions:

1. Goods and services equivalent to the project surplus can be made available to secondary activities at less cost than would have been possible in the absence of the project.
2. Net secondary benefits may be creditable to projects when it is expected that goods or services used in activities stemming from or induced by the project would have lower use value in the absence of the project.

3. Secondary activities can obtain the project surplus without an increase in market price.

Suppose that project produced "surplus" or additional wheat could be made available to millers at the prevailing market price of $2.00 per bushel. If conditions were such that in the absence of the project equivalent additional production of wheat by other means would have to be sold to millers at $2.10 to cover costs, a benefit of 10 cents per surplus bushel would be credited to the project.

Economic limitations on scale of project development. This section considers implications for project scales resulting from a decision to maximize the benefit-cost ratio, rather than to maximize the difference between benefits and costs, or to equate total benefits and total costs. There is a rather clear reference to the principle that total benefits exceed total costs by a maximum where marginal cost equals marginal return, and that this is the best scale.

In comparing relative economic value of justified projects, the ratio of benefits to costs reflects both benefit and cost values and is the recommended basis for ranking projects. (The process of formulating such ratios can be very tricky even in cases where the required original investment in alternative projects is equal. See Appendix on this point.)

Measurement of Benefits and Costs

Chapter 3 takes up price levels, interest rates, risk allowances, period of analysis, particular problems of measurement (including treatment of tangibles and intangibles), adjustments for levels of economic activity, costs of affected public facilities, acquisition of land, and improvements, taxes, displaced facilities, extension of useful life, and consequential damages.

The most convenient and widely recognized basis for comparisons of benefits with costs is the monetary unit, but to make these equivalent

on a time basis discounting and adjustments for price levels are necessary.

Price levels. Measurements should be concerned with real costs and benefits. Real costs to society if resources are used for project construction is measured by the amount of other goods and services for which such resources could be exchanged at the time when they are to be used. Similarly for benefits. (Unless expected benefits will command more goods and resources than represented by project costs the cost-benefit ratio will be less than unity, regardless of monetary values exhibited by the ratio. Future monetary values must be corrected for expected purchasing power.) The problem is that no one can foresee what future price levels will be. It is suggested that the most satisfactory approach would require use of prices estimated as they are expected to be at the time when costs are incurred and benefits received. As a practical matter this would mean applying prices, current at the time of investigation, to project investment costs (assuming the latter are to be incurred shortly after project authorization). Benefits and other costs would be expressed in terms of the best judgment of price levels expected to prevail at the time when these benefits and costs materialize. (In a sense the suggested procedure amounts to utilization of an average expected price level. But it is obvious that in a situation where inflation is the general rule that this will grossly overstate benefits compared to costs since the greater proportion of the benefits come in the future when price levels are inflated. In the 1958 edition deflation for upward price level changes is advocated.) Various price projections by agencies of government might be used, with application of special adjustments to the section of the country where the project is planned if prices are consistently on one side of the national average in that locality.

Interest rates, discounting, and risk allowances. Values attached to benefits and costs at the time of accrual can be made comparable only through conversion to an equivalent basis for time and degree of certainty

of occurrence. Discounting and risk allowance provide a means for giving monetary expression to differences in the time and certainty of occurrence of benefits and costs.

In established money markets, interest rates for loans and investments reflect both time and risk elements. Adjustment for risk takes account of the hazards and uncertainties that intervene between the commitment or investment of resources and the accrual of benefits. (The difference between risk and uncertainty is explained and the statement made that risk allowance be governed by appropriate factors; reflections for uncertainty must be based on judgments.)

Regarding discounting, it is argued that the interest rate on investments such as long-term government bonds would appear to be a reasonably satisfactory measure of the interest return with minimum risk opportunities available for capital investment. (The 1958 edition suggests that risk allowance on government projects be similar to that prevailing in similar private projects.) Although such a rate may not fully reflect a justifiable preference of society for present goods, it still provides a measure of the yield of other opportunities for capital investment that are foregone by society if resources are invested in government projects. It is freely admitted that there may be risks in government projects that do not get reflected in the government borrowing rate; nevertheless, the Committee advocates use of the government borrowing rate, which was 2 1/2 percent in 1950. (They continue to suggest use of the government rate in 1958, rounded to the nearest one-fourth of one percent.)

Period of analysis. The Committee makes a distinction between economic and physical life. Physical depreciation, obsolescence, changing requirements for project services, and time discount in allowances for risk and uncertainty may limit the present value of future project services. The economic life of a project is determined by the point in time at which the effect of the foregoing factors is to cause the costs of continuing the project to exceed the additional benefits to be expected from continuation. The

economic life is generally less than the physical life of the project and is never more than the estimated physical life.

It is recommended that the period of analysis of 100 years be considered as the upper limit on economic life. If it is known that the expected economic life of the project is less than 100 years, the actual estimates should be used.

Measurement Problems

Treatment of tangible and intangible effects. Tangible effects of a project are defined as those measurable in monetary terms, and the intangible effects are those which cannot be measured in monetary terms. Some tangible effects cannot be evaluated directly on the basis of market prices, but their values may, in some cases, be derived or estimated indirectly from prices established in the market for similar or analogous effects.

Intangible effects need to be described with care and should not be overlooked or minimized merely because they do not yield a dollar evaluation. (It is interesting that recreation and wildlife are placed in this category.)

Adjustments for levels of economic activity. During times when labor and other economic resources are fully employed, market prices of construction resources represent an adequate measure of the value of benefits foregone. But during times of relatively low economic activity construction resources lack alternative uses. This situation may warrant adjustment of the usual market price evaluation of project costs. (As long as unemployment is a cyclical phenomenon, attempting to make adjustments in data would be the same as trying to out-guess the business cycle. Have to assume full employment in long-run.)

Due to the practical difficulties of summing up the numerous factors involved, it is suggested that the advantageous effects of the use of unemployed labor in public works can be approximated by estimating the

reduction in unemployment compensation or relief payments made possible if the project is undertaken. The necessary adjustment could be made by decreasing project costs or increasing project benefits by this amount. (This could not be a correct procedure unless it could be assumed that relief payments are an accurate measure of the social usefulness of the resources.)

Treatment of costs of affected public facilities. Project cost for acquiring privately owned land and property should include both the market price to be paid for the property plus the discounted value of any annual payments on bonded indebtedness, if any, applicable to that property on account of public facilities.

Acquisition of land improvements. When land and improvements are acquired for project purposes the acquisition costs including legal fees and administrative expenses are normally included as project costs.

Treatment of taxes. There are two aspects of tax receipts that need special consideration in the economic analysis of proposed projects:

1. Changes in tax revenues of local government units affected by the project which are not fully balanced by changes in governmental expenses of the same units.
2. The effect of taxes on the value of benefits that could be obtained for the same cost from an alternative source (as in the case of electric power).

A tax adjustment problem arises when an adversely affected taxing district cannot benefit from the increased tax returns in other areas which may have their tax basis raised by a project.

When market prices are used to evaluate project benefits, the Green Book suggests the following:

> To the extent that taxes are reflected in the market prices of goods and services, such taxes, whether on income or property, will have been considered in estimating the value of goods and services produced by water resource development projects. No deductions for taxes

> in market prices should be made since this would reduce the value of benefits below the actual appraisal of the market as indicated by consumers' preferences or willingness to pay.

(Thus the project costs should include all increases in costs of governmental services resulting from the project. Advantageous effects such as an increase in the net property tax revenues should be deducted as an offset from associated costs. When the benefits of a federal project are evaluated on the basis of the cost of producing similar products from an alternative private source, the estimate of private costs should include taxes that would be payable.)

Displaced facilities. Displaced facilities are those whose present use is abandoned because the project facilities provide essentially the same purposes. It is recommended that the value of services that would have resulted from displaced facilities less their operation and maintenance costs should be subtracted from the total value of project services of the same kind to determine benefits attributable to the project.

Extension of useful life. A project may have the effect of extending the useful life of a non-project structure or facility. The benefit creditable to a project for such extension of life is the difference in the net value of goods or services provided by the affected facility with and without the life extending measures. Such benefits may be measured in terms of the value of the increased goods or services provided or in terms of reduced costs of providing such goods or services.

Consequential damages. Consequential damages are uncompensated losses resulting directly from a project and should be a part of the project development costs.

Cost Allocation for Multiple Purpose Projects

Most of the material in the latter chapters of the Green Book is simply a summary of how these procedures can be related to the various

functional areas of water resource development such as irrigation, power, flood control, etc. Only chapter 6 will be reviewed here because it contains interesting views on project cost apportionment. Cost allocation is the process of apportioning project costs among the various purposes served by the project. The objective of cost allocation is to distribute project costs equitably among the purposes served.

The "separable costs--remaining benefits" method of cost allocation is supposed to provide an equitable distribution of the costs of a multiple purpose project among the purposes served. The method consists of

1. Determining the separable costs of including each function in the multiple purpose project.
2. Determining an equitable distribution of costs incurred for several purposes in common.

Separable cost for each project purpose is the difference between the cost of the multiple purpose project and the cost of the project with the purpose omitted. In effect, separable costs are computed from a series of project cost estimates, each representing the multiple purpose project with one purpose omitted.

Residual costs are defined as the difference between the cost of the multiple purpose project as a whole and the total of the separable costs for all project purposes. Residual costs thus represent a remaining joint cost attributable to all or several purposes. From total benefits for each purpose separable costs are deducted to give remaining benefits, then residual costs are distributed in proportion to the remaining benefits for each purpose. The distribution of residual costs in proportion to the excess of benefits over separable costs assigns to each purpose an equitable share of project savings.

(Assuming that project B/C ratios are above unity, this method implies that separable costs give rise to benefits on a 1:1 basis while residual costs must give benefits greater than 1:1. One might argue

that those people who receive the most benefits should in fact pay the highest proportion of the costs. In fact, this is what taxes based on ability-to-pay amount to. The procedure is equivalent to taxing away the rent on intramarginal resources of all kinds in order to make net returns equal. Intuitively, this may seem to be just, but the procedure is arbitrary and has no strong economic rationale.)

XII

BUDGET CIRCULAR A-47 (29)

Background

An executive order requiring cost-benefit estimates to be placed before the Bureau of the Budget for review has existed since 1943. The succeeding decade was marked by conflict between the executive branch and Congress. Finally, on the last day of the Truman administration, Bureau of the Budget Circular A-47 was issued (December 31, 1952). It was hoped that the suggested standards and procedures would encourage 1) priorities for projects yielding the greatest value to the nation, and 2) effective resource development at minimum necessary cost.

The Circular set forth standards and procedures to be used by the executive branch in reviewing proposed water resource project reports and budget estimates submitted in accordance with existing requirements. While the aim was to encourage adoption of more uniform agency policies and standards, it was specifically noted that differences of opinion among the agencies would continue. The Circular neither meant to restrict the content of agency reports nor to determine the position which agencies might take with respect to substantive issues.

The Circular contains a rather long list of definitions for "project," "program," "benefits," "primary benefits," "secondary benefits," all of which follow the lines established by the Green Book. "Economic costs" are defined to include all of the financial costs of the program excepting investigating, surveying, and planning costs incurred prior to authorization, and all other identifiable expenses, and liabilities which are incurred as a result of constructing, operating, or maintaining a program or project. "Financial costs" include all of the monetary outlays made in connection with the program or project and interest costs connected therewith. (When applied to irrigation, financial costs

shall not include interest on the irrigation construction cost.) "Construction costs," "operation and maintenance costs," "net revenues," and "reclamation" are defined along conventional lines.

Information for Inclusion in Project Reports

The following categories of information are required in the project reports. A description of the need for the production or services that would result from the project. A concise but complete estimate of all the benefits and all of the economic costs of undertaking the program or project. (Wherever appropriate benefits and economic costs shall be expressed in monetary terms.) All data relating to the financial feasibility and to the allocation and reimbursement of financial costs prepared in accordance with the standards set forth. (This shall include the net effect of the project on the federal treasury.) The source, nature, and adequacy of the basic information available and used during the preparation of the proposal.

Estimates should be made from an overall, public, or national viewpoint. Unless benefits exceed costs the project will not, in the usual case, be justified.

Benefits to be Included

Without clear justification for considering other factors, review of project reports will emphasize the following categories of primary benefits:

1. Reduction of flood damage.
2. Increases in the expected net income obtained directly from changed use of the property made possible by any form of flood control.
3. Increases in the expected net income from lands on which watershed treatment measures are to be installed.
4. Increase in expected net farm income.

5. Transportation savings resulting from:

   The differential between the expected costs of movement by non-water transport and costs of movement by water for those commodities which will be carried by land transport if the project is not built.

   Traffic which will not move without the waterway improvement, but which will move by water if the project is built.

   Whether the project improves an already navigable waterway.

6. Direct benefits of shore protection.
7. Direct benefits from harbor improvements.
8. Electrical energy to be produced. This value is to be computed by the lowest of two figures:

   The cost of equivalent energy from the cheapest alternative source of energy.

   The value of power to users considered as the highest price they would pay and applicable where the cost of alternative power would be prohibitive for particular users.

9. Value of municipal, industrial, and domestic water supply to be furnished valued by the equivalent of the cheapest alternative source.
10. Increases in the value of recreation and fish and wildlife as a result of the project. The position taken is that these are not usually subject to measurement in monetary terms.
11. Savings in the cost of water treatment or gains in the value of streams for industrial, municipal, and domestic water supply.

Evaluations must include an estimate of any secondary benefits which the program or project would provide; total primary and total secondary benefits should be shown separately however. Until standards and procedures for measuring secondary benefits are approved by the Bureau of the Budget, evaluation should be based mainly upon primary benefits.

Costs to be Included

Production evaluation shall also include a statement of economic costs expected to be induced by the program or project such as the cost of:

1. Displacement of people.
2. Decreased value of lands, minerals, etc., that are not reflected in market values.
3. Rectifying adverse effects upon sanitation, transportation, highway construction, or maintenance, etc.
4. Business losses such as disruption of trade or diversion of waterborne traffic from existing ports or channels.
5. Losses in state or local tax revenues.
6. Unprevented and uncompensated losses of or damages to fish and wildlife resources, recreation resources, etc.
7. Abandonment of economically useful structures such as box bridges.

Each evaluation shall also include an appraisal of other detriments to the general welfare whether or not they can be measured in monetary terms.

The cost of facilities or features of the program or project used only for a single purpose of water resource development shall be allocated to the respective purposes served by such facilities or features. The cost of facilities or features of a program or project used jointly shall be allocated among the purposes served in such a way that each purpose will share equitably in the savings, resulting from combining the purposes.

There are some minor rules about allocation costs to fish and wildlife benefits and handling costs of pollution control or abatement.

Section 13 requires identification of that portion of financial costs to be borne by the federal government and a statement as to whether or not they will be reimbursed.

Length of Repayment Period

The length of life is confined to 50 years or less and reimbursement must be made within this period.

Determination of Interest Rate on Federal Investment

The discount rate to be used is the average rate of interest payable by the Treasury on interest-bearing marketable securities of the United States outstanding at the end of the fiscal year preceeding such computation. The actual rate used shall be the nearest one-eighth of one percent below the computed average value.

Additional Requirements

Reclamation projects may be allowed an additional ten years beyond fifty for repayment if necessary. Where the cost allocated to irrigation is in excess of the sum of the anticipated repayment by the water users and other identifiable irrigation beneficiaries, the project report shall identify these excess costs and may propose that they be borne by the federal government as a subsidy to irrigation. (Interest subsidy to irrigation is over and above this general subsidy area.)

Recreation potential shall be given full consideration. However, the financial costs of these aspects shall be treated as a non-reimbursable federal expense.

Municipal and industrial water supply augmentation is to be considered primarily a local and state responsibility. Therefore these governmental units should reimburse the federal government for development costs.

Summary

It is clear that this is a more conservative document than the Green Book in many respects. The Circular limits the period of project life to 50 years, which at low interest rates may be of great

significance. Secondary benefits are virtually ignored in demonstrating project feasibility.

(However, it is fair to say that there was sufficient latitude in the requirements of the Circular such that none of the agencies felt that they had to take it seriously. That this situation could not last was made clear by the appearance of Senate Document 97.)

XIII

SENATE DOCUMENT 97 (28)

Motivation for Document

On May 15, 1962, President Kennedy approved for application by the Agencies of the Executive Branch (including the Bureau of the Budget) a new set of evaluation standards as unanimously recommended by the Secretaries of Defense, Agriculture, Interior, and Health, Education, and Welfare.

The new policies and standards replaced Budget Bureau Circular A-47 which had caused considerable contention both as to content and as to the propriety of its source. In order that the Senate and citizens throughout the nation might be fully informed of the accomplishment, Senator Anderson submitted a resolution to have the new set of standards printed as a Senate Document.

The document is significant in that it represents an attempt by the Executive Branch, including the Bureau of the Budget, and the Legislative Branch to get together on evaluation procedures. These must be uniformly applied by the various agencies in the formulation and review of comprehensive river basin plans and individual project plans for use in development of water and related land resources. Any deviation from the policies and standards in the documents must be delineated in the planning reports.

Objectives of Planning

Development of each region within the country is essential to the maintenance of national strength and the achievement of satisfactory levels of living. The document contains a long list of purposes and services which could be provided by project construction and which would foster regional development.

In a paragraph on preservation it is stated that resources must be

protected and rehabilitated to insure their availability for best use when needed.

The well-being of all of the people shall be the overriding determinant. Hardship and particular needs of particular groups within the general public shall be of concern, but care shall be taken to avoid resource use and development for the benefit of the few or the disadvantage of many.

Whether there is a bias toward income distribution objectives as opposed to efficiency considerations cannot be ascertained with certainty. Both seem to be stressed in different places.

Planning Policies and Procedures

National, regional, state, and local viewpoints. All viewpoints, national, regional, state, and local must be fully considered when planning resource use and development. Significant departures from a national viewpoint required to accomplish regional, state, or local objectives shall be set forth in planning reports by those charged with their preparation. (There seems to be little recognition of the tremendous problems that are involved when one looks at a project at various political levels. As an example, secondary benefits can almost be neglected if one takes national viewpoint. From the state or local level, such benefits may be very important determinants of project feasibility. From a national viewpoint there is little difference in the amount of economic rent resources can command whether used in western reclamation projects or in public or private works in the East. At the local level, all construction inputs originating outside the region are viewed as additions to the immediate economy with the potential to generate secondary benefits.)

Multiple purpose planning. This is a statement of the various benefits from resource use that must be considered in planning.

River basin planning. Authors of the document contend that river basins are usually the most appropriate geographical units for planning the use and development of water and related land resources. On this scale of planning advantages of multiple use, reconcilliation of competitive uses, coordination of mutual responsibilities of different agencies and levels of government, and the interests of others concerned with resource use can be optimally realized. (This is a very important point. The present watershed program, for example, is faulty in that it looks at only a portion of a river basin. The externalities involved tend to get neglected. Also, project development is dependent upon local initiative and financing. It is probable that at the planning level, the integrated river basin orientation is the most sensible one.)

A section is included which covers coordination within the federal agencies and with non-federal interests. Instructions are given that federal planning must be carried out on a coordinated basis and that all agencies having any interest or responsibility should be brought into the discussions. (This will be an important contribution if in fact the agencies do cooperate.)

Standards for Formulation and Evaluation of Plans

Normally, formulation and evaluation of plans shall be based on expectation of an expanding national economy. Thus, increasing amounts of goods and services are likely to be required to meet the needs of a growing population, higher levels of living, new international commitments, and continuing economic growth. (This is a more sensible statement on this issue than appears in the other documents.)

Formulation and evaluation of plans or alternative plans shall be accomplished in a manner that will permit timely application of standards appropriate to conditions of 1) less than full employment nationally, and 2) chronic and persistent unemployment or underemployment in disignated areas. Under these conditions project benefits

shall be adjusted upward by the value of labor and other resources required for project construction and expected to be used in project operation, project maintenance, and other additions to area employment during the life of the project. Adjustment should be made to the extent that such labor and other resources would, in the absence of the project, be unutilized or underutilized. Resulting additional benefits should be clearly identified as redevelopment benefits for the purposes of cost allocation, cost sharing procedures, and to indicate their significance for project justification. (This is an important breakthrough.)

A broad public viewpoint must consider all effects: beneficial and adverse, short range and long range, tangible and intangible, etc. When there are major differences among technically feasible plans which are favorably evaluated from the standpoint of intangible benefits and costs in comparison with optimum plans based on tangible benefits and costs, the alternative combinations of projects within a river basin or alternative projects giving expression to these major differences shall be planned. (In this way intangible costs and benefits are supposedly capable of being handled.)

Secondary benefits associated with the national viewpoint shall be combined with primary benefits when computing benefit-cost ratios. Secondary benefits attributable to projects from a regional, state, or local viewpoint shall also be evaluated when this procedure is expected to yield significant values. In this case, an additional benefit-cost ratio is computed to allow for secondary benefits. A description must be provided of the area in which the study takes place, its resources, markets, transportation, climate, social factors, etc.

Standards for formulation of plans. Plans should be formulated with due regard to all pertinent benefits and costs, both tangible and intangible. Benefits and costs shall be expressed in comparable quantitative economic terms to the fullest extent possible. Comprehensive plans shall be formulated initially to include all units and purposes which

satisfy the following criteria:

1. Tangible benefits should exceed project economic costs.
2. Each separable unit or purpose should provide benefits at least equal to its cost.
3. The scope of development should be such as to provide maximum net benefits.
4. There should not be a more economical means of accomplishing the objectives of the plan.

Project scale. Net benefits are maximized when the scope of development is extended to the point where the benefits added by the last increment of scale are equal to the costs.

Definitions of benefits. The discussion of tangible, intangible, primary, and secondary benefits is comparable to that of the Green Book. Primary benefits include benefits to domestic, municipal, and industrial water supply, irrigation, water quality control, land stabilization, drainage, recreation, and fish and wildlife. Criteria used to measure these benefits generally are the same. Market prices should be utilized. If price data are unavailable, the amount users should be willing to pay for the services in lieu of foregoing them is used. If this is impossible, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project. (There are many questions raised by these suggestions: Are the authors hinting at the use of consumers' surplus? What happens to prices where the supply of benefits is substantially increased? The notion of comparing alternative costs is clearly wrong; the nearest alternatives are mostly high cost options. Use of such costs opens the door to enormous inflation of benefit claims. In the case of recreation and fish and wildlife benefits, it is possible to compare the costs of private alternative sources because many such alternatives are quite analogous; that is, alternatives may be close substitutes.)

Definitions of costs. Economic costs, installation costs, operation, maintenance, replacement costs, induced costs, associated costs, and taxes are all discussed and defined. None of this differs significantly from similar discussions in the Green Book.

Period of analysis. Period of analysis should be the shorter of either the physical life or the economic life of the structure, facility, or improvement. However, because it is difficult to predict remote future conditions, 100 years will normally be considered the upper limit on the period of analysis.

Discount rate. The rate to be used is the average rate of interest payable by the Treasury on interest-bearing marketable securities of the United States Government (outstanding at the end of the fiscal year preceeding such computation which, upon original issue, had terms to maturity of 15 years or more). The calculated value will be adjusted to the next lower multiple of one-eighth of one percent as necessary.

Price levels. Prices used for project evaluation should reflect exchange values expected to prevail at the time costs and benefits are realized. Estimates of initial project costs should be based on price relationships prevailing at the time of the analysis. Estimates of benefits and deferred costs should be made on the basis of projected normal price relationships expected with a stabilized general price level and under relatively full employment conditions for the economy. Whenever a project benefit is expected to influence prices significantly, the use of a price about midway between those expected with and without the project may be justified to reflect the public values involved. (Refer to the Castle, Kelso, and Gardner article for this argument 44.)

Relation of Senate Document 97 to Cost Allocation, Reimbursement, and Cost Sharing Policy Standards and Procedures

While cost allocation, reimbursement, and cost sharing policies are not treated explicitly, it is expected that they will be dealt with

in the same manner as previously until a future instruction can be distributed.

Supplement No. 1 to Senate Document 97--
Evaluation Standards for Primary
Outdoor Recreation Benefits

The role of recreation in the economic scheme. Evaluation of outdoor recreation must recognize that such services have values for which people are willing to pay. An accounting of relative returns from the use of resources for recreation versus other project purposes must be made in decisions affecting resource use. (This is an excellent statement and shows how recreation has moved from the intangible category into its own as an economic good.)

Categories of benefits. Direct expenditures by recreationists on project services are usually only a part of total expenditures. Therefore, allowance must be made for costs of associated services in order to determine net recreation benefits attributable to individual projects.

Overall intangible benefits associated with the protection of wild or primitive areas, areas of unique beauty, areas of scenic, historic, and scientific interest, and the preservation of rare species and their habitat are considered to be an addition to the recreation values encompassed.

The standard unit of use consists of a visit by one individual to a recreation development or area for recreation purposes during any reasonable portion or all of a 24 hour period. General activities and specialized recreation project activities are differentiated. The general category includes most warm water fishing, swimming, picnicking, hiking, sight-seeing, most small game hunting, nature studies, tent and trailer camping, marine pier, and party boat fishing, water skiing, scuba diving, motor boating, sailing, and canoeing in placid waters. In the specialized category are cold water fishing, upland bird and water fowl hunting, specialized nature photography, big game hunting, wilderness pack trips,

white water boating and canoeing, and long range cruising in areas of outstanding scenic environment.

Schedule of monetary unit values for tangible benefits. A single unit value will be assigned per recreation day regardless of whether the estimated numbers of users engage in one activity or several. For the general type of outdoor recreation day, values ranging from 50 cents to $1.50 will be credited to the project. Specialized outdoor recreation days require credit from $2 to $6.

Pending the development of improved pricing and benefit evaluation techniques, uniformity in the treatment of recreation in the planning of projects and programs and in cost allocations will be accomplished through the application of unit values that reflect the consensus judgment of qualified technicians. The unit values set forth herein are intended to approximate the amount that the users should be willing to pay for recreation resources if such payments were required to avail themselves of the recreation. (In contrast with reimbursable costs, "payments" are hypothetical.)

Unit values selected are to be considered net of all associated costs, for both the users and others, in utilizing or providing the project resources and related services. Thus they are taken to be comparable with the benefits for other project purposes.

For general recreation purposes the lower end of possible costs should be used where facilities would be capable of supporting only casual visitation. The middle and upper values of possible costs should be assigned if projects are expected to provide diversified opportunities, or if the facilities for a limited number of activities are to be unusually well developed and maintained.

In the specialized area, expensive or low density use and development should be assigned values in the higher end of the $2 - $6 scale. Big game hunting and wilderness pack trips are examples. Activities to which values of the lower end of the high range should be assigned

might include upland bird hunting and specialized nature photography. This constitutes what is called primary criteria.

Secondary criteria are set forth which relate to quality of the specific services. For example, a reservoir that is expected to carry a relatively heavy load of suspended silt or expected to be used beyond optimum capacity would be less desirable and therefore of lower unit value than one that will have clear water and be less crowded. Also, the degree to which alternative non-project opportunities are available to recreationists should also be considered in this assignment of values. Higher values should be assigned if the population to be served does not have existing water oriented recreation opportunities. (Therefore demand relative to supply in addition to quality constitutes the secondary criteria.)

Finally, when intangible recreation considerations are found to exist for a proposed project, the evaluation report will include:

1. A narrative discussion of the significance of intangible characteristics involved.
2. An estimate of the increase in project cost to provide intangible recreation benefits.
3. An estimate of the reduction in net benefits from other project purposes in order to accommodate recreation intangibles.

The Supplement calls for more research to determine recreation uses, in estimating recreation values, and in assessing some of the interrelationships of recreational uses of resources.

XIV

CONFLICTS IN COST-BENEFIT CALCULATIONS

During recent years, a number of economists have presented arguments in favor of various revisions in public works evaluation procedures. (6, 10, 12, 16, 21). However, not all the suggested revisions are harmonious and if followed could lead to widely varying levels of social benefit from given public expenditure.

Economic Implications of Certain Scale Criteria

In general, it can be stated that a project or set of projects scaled to yield a maximum benefit-cost ratio will simultaneously maximize average internal rate of return; the same project driven or enlarged to the size yielding a maximum difference between benefits and costs will equate the marginal internal rate of return with the going rate for investment funds. (13)

In Figure 28 these possibilities are displayed in a fashion that emphasizes the economic implications of the choice of one criterion rather than another. If all production and investment were confined to the private sector, and if competition extended in all directions then, in the long run, interest rate (r_1) would prevail. Under these conditions, the various scale criteria would all lead to the same result.

[Questions: In terms of the "stages of production" what does the dictum "maximize the cost-benefit ratio" suggest? Can any general conclusions about production levels and production inputs be drawn from the above results? Is there a "Paretian" result possible in Figure 28? Suppose there is perfect competition in the public sector but the government feels that a "social" rate (lower than the market rate) should be used to evaluate public works projects--would there be a divergence of the criteria from the P_a max intersection]

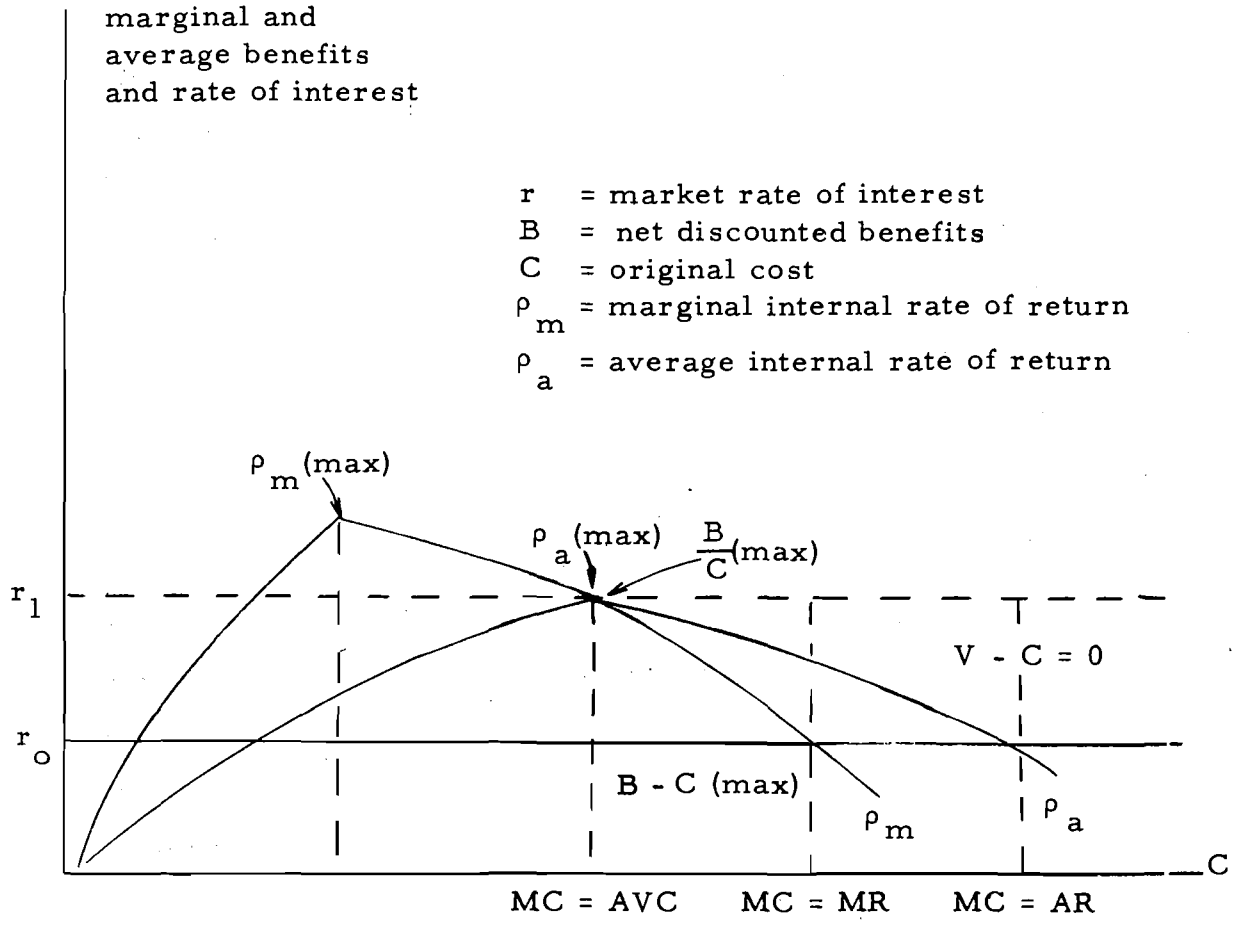

Figure 28. Four investment scale criteria. Source: See Appendix

Scale Criteria and Finances

Whether it is more rational to attempt to maximize benefits over costs or their difference hinges upon the availability of capital. Where funds are the limiting factor, maximization of the benefit-cost ratio is appropriate and vice versa. (13; p. 33n, p. 42)

The extensive literature treating the rationed situation is the result of an implicit acceptance of the notion that sizes of individual projects are fixed by engineering or technological factors. The

immediate consequence is that adjustment of project scales to accomplish the maximization of B/C is not a consideration. The sole question therefore is how to order the spending of public works budgets upon "fixed-sized" alternatives. Poised in this context, the ranking calculations are not straightforward. Numerous anomolies crop up according to the method chosen for displaying cost-benefit calculations. This in turn gives rise to disagreement over the most satisfactory display procedure.

Similar disagreement is absent in the case where funds are imagined to be unrationed. All authors who have given attention to this latter situation accept as correct the investment criterion to maximize the difference between benefits and costs. Owing to somewhat muddled presentations, however, it is not perfectly clear whether this criterion could be satisfied by the procedures advocated.

Capital Rationing and the Ranking Problem

At least four data formulations have been suggested as appropriate for the capital rationing case: (w) ratio of present values of gross benefit and cost streams; (x) ranking by internal rate of return; (y) ranking according to present value; (z) ratio of present value of net benefit stream to initial costs. Project sets ranked by (w) and (x) always tend to differ. Extent of the difference depends upon the range of values the ratio of annual operating and maintenance costs (O) to the fixed initial investment (C_o) assumes for different projects (6, pp. 53-60; 16, 108-121). Ranking according to the ratio of gross benefit and cost streams (w) is particularly favorable to projects having low values for O/C_o, that is, where most of the cost is initial investment. The main criticism of the B/C ratio (w) is that it gives no indication of potential increases in net worth. In Table 3 examples, the greatest increase is associated with project A, whereas project B exhibits the highest cost-benefit ratio, 1.54. Since project A would also have been given priority by reliance

Table 3. Variation in ranking resulting from four methods of displaying cost-benefit data

		Project A	Project B
1.	Investment	$100,000	$100,000
2.	Each year's out of pocket expense	50,000	5,000
3.	Each year's benefit	70,000	20,000
4.	Present value of 20 year cost stream discounted at 5%	723,000	162,300
5.	Present value of 20 year benefit stream at 5%	872,200	240,200
w 6.	Ratio of discounted gross benefits to discounted costs (B/C)	1.21	1.54
7.	Increase in present worth	149,200	86,900
x 8.	Internal rates of return (approx.)	18%	15%
y 9.	Present value of net benefits	261,709	196,282
z 10.	Ratio of net benefits to initial investment (B_1/C_o)	2.62	1.96

upon the average internal rate of return method (x), it may be thought that high internal rate values are directly related to high potential increases in net worth. Generally this is true, but not always. First, the internal rate of return rule may give ambiguous (non-unique) answers; for a general net receipts or net benefit stream there may be none, one, two, or any number of solving rates of interest. Second, the internal rate of return rule may give answers that are actually wrong (inconsistent with maximization) rather than being merely ambiguous. Both these objections are associated with project ranking situations exhibiting dissimilar revenue and cost time paths or where costs tend to be bunched at the end rather than the beginning of the investment period. This situation is illustrated by projects A and B in Table 4. If they are taken to be mutually exclusive, then the average internal rate of return rule (ρ_a) would select B, when actually the

greatest increase in present worth can be obtained by choosing A, if the appropriate discount rate is 4 percent (column 5). As a practical matter the appropriateness of (x) hinges on whether costs and revenues exhibit the "usual" time paths. If they do the average internal rate of return rule will insure maximization of wealth per dollar of outlay and, in addition, there will be no need to defend a discount rate choice.

Nevertheless the average internal rate of return rule is logically defective and Hirshliefer and McKean have both argued that its use should

Table 4. Ranking by internal-rate-of-return and alternative methods: choices among interrelated projects

	1	2	3	4	5	6	7
Alternative Projects	C_o	Yr_1	Yr_2	ρ_a	Present Value Discounted at ρ_{ms} (4%)	Present Value Per-Current-Capital Unit	
						B_1/C_o*	B_1/C_o+
A	-100	0	115	7%	6.323	1.13	1.106
B	-100	110	0	9%	5.7	1.10	1.10
C	-100	104	0	4%	0	1.04	1.04
D	-100	0	108.16	4%	0	1.06	1.04

*Assuming market rate of 2%
+Assuming market rate of 4%

be shunned (even though the alternatives require establishment of a discount rate). McKean advocates use of method (y) (Table 3), ranking according to present worths (16; p. 89). He obtains the appropriate interest rate by discounting the benefit stream of the potential elements of the project set at various rates until one is found which just exhausts the budget with all acceptable elements having positive net worths (the marginal project will have a zero net worth). Call this rate ρ_{ms}, the marginal internal rate of return for the set of projects (i.e., $\rho_{ms} = \rho_a$

of the marginal project).[1]

According to Hirshliefer, McKean's rule fails in certain cases (10; pp. 170-171). If the investment budget were large enough to select two of the four projects in Table 4, then McKean's rule would choose project A, but could not discriminate between C and D. Both latter projects require inputs of \$100 at t_o, but C yields \$104 in t_1 while D yields \$106.16 in t_2. Calculation shows that each has an internal rate of return equal to 4 percent and one or the other is the marginal project. McKean's present worth rule gives no way to make a selection, for both have zero present values when discounted at 4 percent, the ρ_{ms} for the set.

Hirshliefer argues that resolution of this dilemma would require McKean to depart from the selection of an interest rate by purely "internal" rate of return procedures. It would require the assumption that only initial construction budgets are fixed, and that funds may be transferred between future periods by borrowing or lending at some market rate, r. Supposing funds can be loaned or borrowed at 2 percent and that funds are transferred between periods 1 and 2, then in symbols, project D, (-100, 0, 108.16), will be converted to (-100, 106.04, 0). This is superior to (-100, 104, 0). Turning the problem about and thinking in terms of cash throughoffs from intermediate periods, then lending at 2 percent will convert project C, (-100, 104, 0) into (-100, 0, 106.08), which is inferior to (-100, 0, 108.16). On this basis [that is, whenever r (2 percent) < ρ_{ms}] C is inferior to D. The "correct" set is therefore A and D.

To avoid these difficulties, Hirshliefer suggests ranking by use of method (z)(Table 3), the ratio of present value of net benefits stream (quasi-rents), B_1, to initial costs, C_o (10; p. 161, pp. 170-171). At first glance it does appear that revision to yet another ratio formulation of the benefit-cost data will accomplish the desired goal. But closer inspection fails to reveal a formal difference from McKean's present value rule (y).

Examination of the B_1/C_o values in column 6 (Table 4) reveals that, given a market rate of 2 percent, the B_1/C_o rule does not select the "correct" set, A and D. Similarly, inspection of row 10 in Table 3

[1] This process was used to generate the values shown in column 5 of Table 4.

reveals that the B_1/C_o criterion selects the project with the greatest potential increase in net worth. However, as long as the internal rate of return on the marginal project is not ambiguous, then the McKean and Hirshliefer systems are logically equivalent. This is easily shown through comparison of comumns 6 and 7 in Table 4. The B_1/C_o ratios of column 6 have been recomputed using a discount rate equal to ρ_{ms} (4 percent), and displayed in column 7. The rankings are now the same as they were by the McKean method (column 5). Again, there is no way to choose between projects C and D. In other words, the only time there is any difference between the two methods is when the interest rate employed in borrowing or transferring funds is <u>unequal</u> to McKean's ρ_{ms}. If McKean were to utilize the discount rate established in an "appropriate" market or by the "best" private alternative use for funds (as suggested by Hirshliefer), there would be no operational difference between the two methods.

In summary, when funds are rationed and the only question is that of ranking, display of cost-benefit data in the form of net discounted benefits and initial costs (methods y or z of Table 3) will most likely prevent ambiguity and outright error in ranking. But remember, a discount rate must be known or given from some source. Continual selection of projects with the highest benefit-cost ratios or average internal rates of return implies an acceptance of the economic consequences associated with choice of ρ_a as the investment scale criterion. It is true, however, that such project scales may never be achieved because the whole discussion of various ways of displaying cost-benefit data rests on the implicit acceptance of technologically fixed project scales.

Once it is assumed that project scales can be varied somewhat, even if public works budgets are fixed, computation of net benefit-cost ratios or present values is unnecessary. Fulfillment of an adequate investment criterion is reduced to the satisfaction of the requirement

to equate the discounted values of the marginal benefits of enough projects to exhaust the budget (6; pp. 66-67). That is to say, the relative activity level rule must be followed ($VMP_{cx} = VMP_{cy} = \ldots VMP_{cn} = P_c$). Suppose that scales are not fixed by inflexible engineering consideration, does the "ranking problem" necessarily disappear? Only if the budget is going to be spent anyway and if discontinuities in cost and return streams or functions are not unmanageable. In practice it may be quite unlikely that both conditions would be simultaneously satisfied. First, budgets are somewhat flexible, often sized according to the number of projects that can be justified, i.e., that can surpass a given minimum cost-benefit ratio. Second, project scales cannot be juggled about over nicely differentiable cost and return streams; it may be impossible to balance marginal value benefits per dollar of cost in all directions. For these reasons some ranking may always be necessary. How is it to be accomplished? Bearing in mind earlier arguments about the display of cost-benefit data, those projects exhibiting the highest average internal rates of return or the greatest increases in net worth should be chosen first.[1]

No Capital Rationing

Where there is no capital rationing the level of investment should be guided by the criterion of maximizing the difference between benefits and costs. B-C is maximized when the marginal internal rate of return is equal to the interest rate; so long as the marginal rate of return is above the interest rate, additions to the investment bring additions to the present value of profits. The marginal internal rate of return (ρ_m) is the rate which, if used to discount down to the present the marginal revenue due to an additional unit of funds invested, makes the present

[1] These choices do not imply acceptance of the same scale criterion.

value of that revenue equal to unity. Owing to somewhat muddled descriptions of their procedures, it is difficult to determine whether or not either McKean's or Hirshliefer's recommendations satisfy the above condition.

McKean argues that if a firm has investment opportunities, "including chances to loan money, which yield more than the rate at which funds can be borrowed on the money market it should invest in its projects until the next-best opportunity yields no more than the market rate." (16; p. 77) But McKean defines yield in a particular way. "Yield" means "the rate of discount which makes the present value of the project's receipt stream equal to the present value of its cost stream, or in other words, the rate of discount which makes present worth zero" (16; p. 77). This of course defines the <u>average</u> internal rate of return, ρ_a. Thus if his rule is followed, it might lead to the establishment of project scales where $B - C = 0$. Whether or not this will actually happen depends upon the interpretation given McKean's meaning of the term "incremental investment."

It appears that this term is used in two senses: (a) sometimes it means the marginal increment altering the scale of a single project; (b) at other times the incremental investment is the marginal project or the marginal element of a project <u>set</u>. In situation (a), carrying ρ_a of the marginal increment to equality with the interest rate, and treating the result as an equality of ρ_m (for the individual project) with the rate of interest, may be assumed to have a minor influence on the effective achievement of $B - C$ maximization. In situation (b) the method may fail. Here ρ_a for the marginal project (assuming it is not ambiguous) becomes ρ_{ms} for the <u>set</u> of projects. The interest rate is then used as discount rate (where $\rho_{ms} = r$) to define all the individual projects within the potential set which have positive present worth. But the sum of these positive present worths may fall rather short of maximizing $B - C$. To maximize $B - C$ for a <u>set</u> of projects, individual projects must be

scaled such that ρ_m of each equals the market rate, r. Only if sizes of the various projects are technologically given, or "fixed" because of interdependencies (which amounts to the same thing), would the strict application of McKean's rule come as close to satisfying the B - C max criterion as possible.

Hirshliefer argues that "if benefits and costs are calculated correctly, it is obvious that every project with a B/C ratio greater than one should be adopted since, if B/C is greater than unity, then B - C must be positive (there is a net surplus of benefit over costs)(10; p. 138). While this conclusion is correct, it must be noted that the mere existence of a net surplus indicates nothing about a maximum surplus. None of this is surprising since it has already been shown that Hirshliefer's "logically prior" criterion is fundamentally the same as the McKean procedure. The rule only maximizes B - C for a set of projects where the scale of each element is taken as technologically given. To the degree that individual project scales are variable, maximization of B - C requires that all potential projects be driven to the size where the marginal internal rate of return from individual projects is equal to the interest rate.

With respect to single projects, McKean's system, if applied to the increments of an individual project, will lead to a scale such that B - C is approximately maximized. But in the case of application to a single project the Hirshliefer, Dehaven, and Milliman method is not a scale criterion at all. The mere computation of the present value of a project can only indicate whether or not "costs" will be "covered."

In summary: Even if budgets are not limited, the B - Cmax criterion cannot be achieved unless individual project scales can be varied. However, in contrast with the rationed funds case, a definite investment scale criterion is accepted as appropriate by all. Again, as in the cost-benefit display procedures most advocated for the rationed situation, an "appropriate" interest rate must be chosen for this rate

establishes the lower limit of acceptable marginal internal rates of return from successive increments of investment.

There is another way of viewing the investment situation when funds are unrationed that is not considered in any of the works of the authors cited. If one imagines public investment to be an on-going activity without time limit, then in a sense, public funds are always limited. For even if it were financially possible to undertake all "optimum" scale projects planned at any one time, it is technically impossible to build everything simultaneously. Thus it may be that the public should maximize the return per dollar as society goes forward through time. This would mean that the B - Cmax criterion would not be appropriate but rather that project scales should be established by the requirement to maximize ρ_a or B/C. [Students should also evaluate the argument in connection with the choice of $\rho_a = r$ (Figure 28) as a scale criterion.]

"Durability" and "Technique" in Cost-Benefit Literature

Careful reading of benefit-cost literature reveals a lack of explanation as to why only project size or scale is treated as an optimization problem. Ordinarily optimization of durability (time life of the benefit stream) and optimization of technique (ratio of variable inputs to fixed capital) must also be considered.

Durability. It appears that optimization of durability is ignored because planning decisions often are treated as choices between projects where the life of each has already been pre-determined by engineering design.[1] Certainly engineering technology may dictate "minimum"

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[1] "The choice between a very durable asset and a flimsier one, when either would be appropriate to the immediate job to be done, is rarely publicly discussed.... The local Works Department...must only convince the government that the durability of the project which it undertakes is appropriate to the task. The result can be seen in the massive bridges and dams scattered throughout the land."(24; p. 89)

construction or quality standards, but beyond this there is no necessary connection between the length of life "ordinarily" engineered into a project and "optimum" durability.

On first view it seems appropriate to ignore this optimization dimension only in cases where the minimum engineering life would produce benefits for very long periods. If these periods last beyond 60 to 70 years, funds horizons may be treated as independent of project lives, for present values of benefits are then fairly insensitive to data changes (using typical values for the discount rate). The number of public works projects likely to exhibit such long lives is obviously a question of fact, but there does appear to be an increasing tendency to plan long-lived projects as "programmed" developments. Such programs require segments of a given project to be constructed successively over time. In these cases lives of some segments may be fairly short and acceptance of durability as purely an engineering variable becomes even less satisfactory.

Unfortunately there are serious difficulties standing in the way of any improvement in evaluation methods. The problem of durability optimization can be considered from two aspects:

1. As a determination of the lifetime of a <u>given</u> durable good.
2. As a determination of the <u>technical</u> lifetime that should be built in during construction. (13; p. 101)

In the past " authors like John Rae, Böhm-Bawerk, Akerman, and Wicksell tried to determine the technical lifetime" because their attention was addressed mainly to durable goods of the "constant efficiency type" (e.g., electric light bulbs) (13; p. 101). But determination of such lifetimes is not a very important economic problem. In contrast, determination of the lifetime of durable goods of the "diminishing efficiency type (e.g., machinery and buildings) is a difficult problem because repairs and service expenditures can prolong life almost indefinitely (13; p. 102). "There is, then, even under static assumptions, a problem

of how long it pays to go on extending the lifetime of a given durable good of this type, a problem that must be solved before the entrepreneur can choose the optimum durability of a durable good..." (13; p. 102)

The need to fix optimum life spans creates little difficulty when dealing with constant efficiency type of goods, but in the case of diminishing efficiency types, the replacement lifetime cannot be established unless the quality (i.e., the need for future maintenance) is given. At the same time the quality cannot be established until the optimum lifetime is known. "It is here impossible to establish a functional relationship between cost of investment and the durability of the equipment as could be done with the constant efficiency type." (13; p. 124) Two possibilities seem to be open:

1. Reduce the problem to choice between capital inputs exhibiting various degrees of "engineered" durability, or
2. Assume "quality" as given and attempt to establish optimum lifetimes.

Recent work by Vernon Smith suggests that this latter approach would lead to fruitful results (26; Chaps. IV and VI, exp. pp. 164-169).

Technique. It is not surprising that the effects of interest or wage rate changes on production techniques are ignored by the critics of the American water resources program. First, as a practical matter, there are enough constraints upon choice of technique to inhibit response unless changes in the data are very large (13; pp. 127-128). Second, in the case of public enterprise, it is possible that the managers have no direct control over choice of technique for they do not control current inputs, e.g., there is no way to control current individual farm inputs that will be combined with the fixed inputs of a given irrigation project; in the case of the production of highway services, there is no way to control completely the individual use of roads.

This must all be conceded, but during the investment planning and evaluation period, before funds have been committed, failure to

consider potential patterns of production techniques is less excusable. In cases where it is impossible to control current inputs, it may still be possible to predict their variation over time. These expected future alterations in the ratio of current inputs to capital inputs will affect the initial choice of investment scale and possibly the initial choice of durability.

XV
INTEREST RATE THEORIES

Modern "theories of interest" are hypotheses about economic interrelationships that give rise to particular interest rate levels or to alterations in rates. Interest rate theories that emphasize the physical or material relationships that underly all money transactions are known as "real theories": "monetary theories," on the other hand, stress the economic forces in operation in money or capital markets.

Real Theories

Marginal productivity theory. As the amount of capital equipment within an economy grows, the annual return from individual increments falls. This must be the case, for given the state of the arts, the best paying opportunities are exploited first and less satisfactory returns must be accepted as poorer and poorer alternatives are taken up. In the aggregate, the average return on capital falls over time, but the marginal return falls even faster. Since at any given moment, the stock of capital goods is fixed, the marginal return associated with that stock is the "going rate" of interest. In addition, since capital goods may be treated as inputs much as any other factors of production, the marginal physical product of capital goods must be identical with the interest rate at any moment in time. Figure 29 makes clear the analogy between increases in capital and the law of diminishing returns as applied to marginal productivity theory.

Allowance for technological advance is made by shifting the MPP curve to the right. (Defined in money terms, technological advance means that a given amount of capital goods produces more now than it could before; the MPP of capital must be greater at all levels.) The tendency for interest rates to fall as capital goods are accumulated is offset to a greater or lesser degree by technological advances.

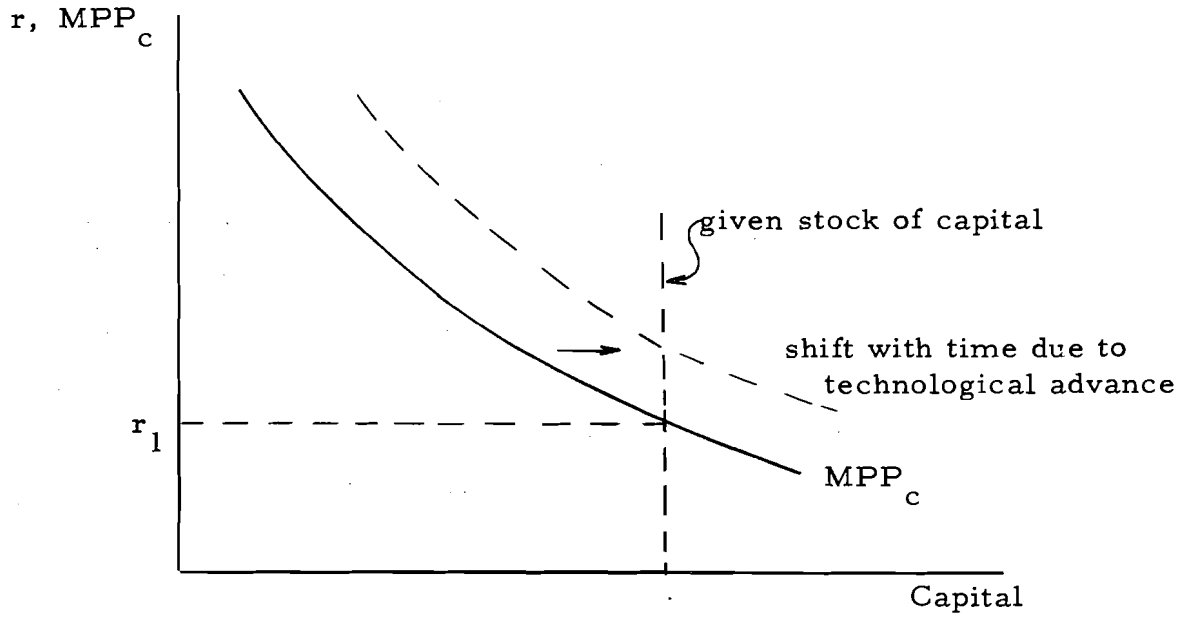

Figure 29. Marginal productivity of capital

Loanable funds theory. This theory concentrates upon the acquisition costs of a particular increment of capital goods. Prior to making any physical addition to an economy's productive capital, an array of investment choices from relatively high to relatively low returns may be thought to exist. In Figure 30 such an array, termed an investment demand schedule, is presented. The money capital for the investment increment actually selected most came from suppliers of funds. These suppliers are more interested in making loans at high rather than low rates of interest. If savings funds would actually be forthcoming as diagrammed in Figure 30, the market rate of interest would be established at an equilibrium of savings and investment devices. This "price" in turn would dictate the final choice of an investment increment.

It is argued that the loanable funds theory emphasizes short-run or existing real forces, whereas the marginal productivity theory depends upon the workings of secular or long-run changes.

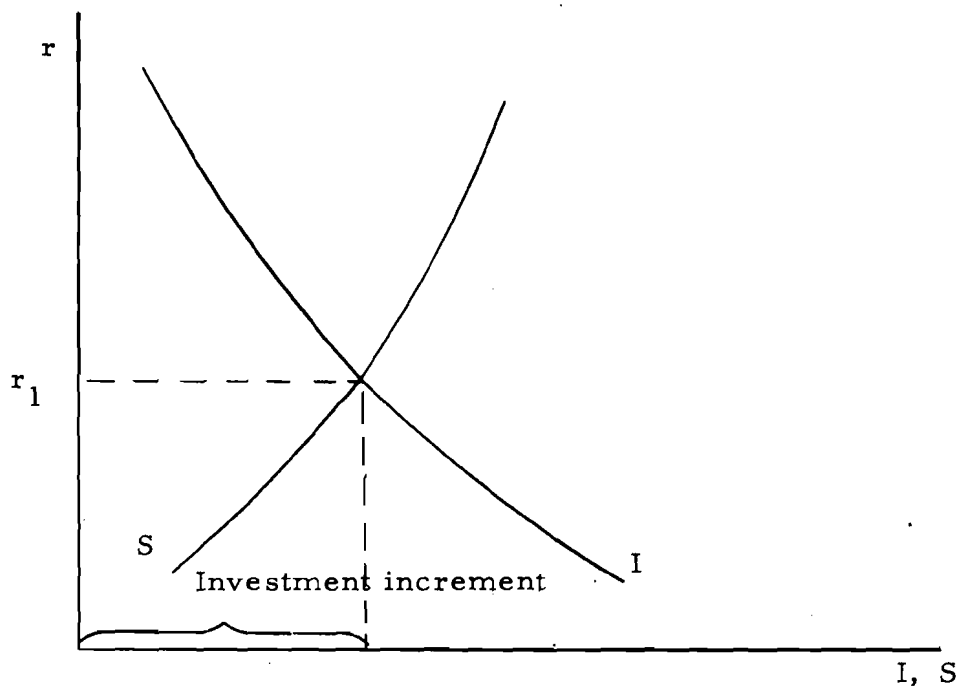

Figure 30. Loanable funds and interest rates

Monetary Theories

Liquidity preference theory. According to this theory, the key to particular rate levels is the form in which cash balances (not needed for current consumption) are held. Where there is a resale market for bonds and other securities, cash can readily be traded for "paper assets" that not only bear interest but (more importantly) which may or may not appreciate in value. It is the expectations of potential for capital gain or loss that determines how cash balances are held. In general, the lower paper asset prices fall, the greater the expectations for a rise rather than further fall--individuals would prefer to be "fully invested" in this case. When asset prices are high, the danger of capital depreciation is also relatively high--individuals would prefer to stay out of the market or move to more liquid assets (cash) in order to protect their funds. If it is recalled that high prices for paper assets are associated with low interest rates and vice versa, a schedule can be drawn up of how

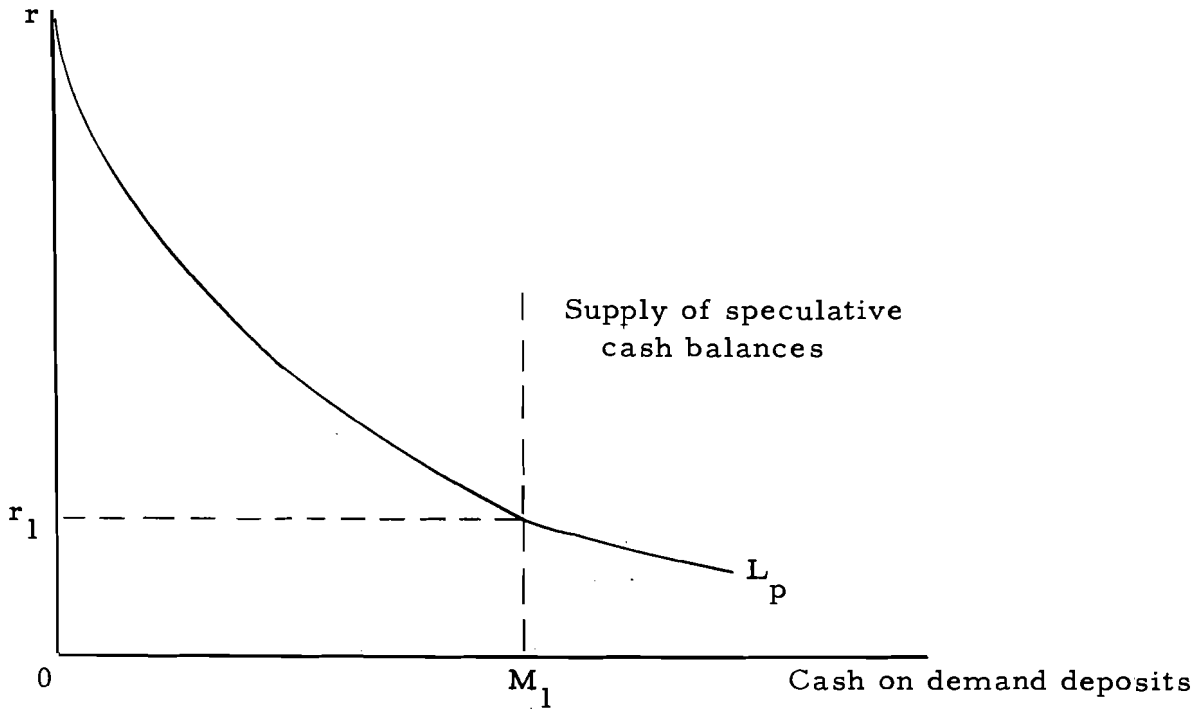

Figure 31. Liquidity preference determination of interest rates

individuals would prefer to hold cash balances at various rates of interest.

In Figure 31 a liquidity preference curve (L_p) is drawn to show that the lower the interest rate (higher asset prices) the greater the desire to hold cash. Despite preferences, at any moment in time only so much cash, other than that needed for consumption transactions, is available. Since this is a known, fixed amount, the interest rate is given.

Suppose at a relatively low interest rate, security purchasers are unsatisfied. This means new bank loans, an expanded money supply, and even higher asset prices. If buyers disappear, this means that some people are covering bank loans, security prices will be driven down, interest rates will go up, and the money supply will tighten. Exactly opposite movements are possible starting at a position of relatively high

interest rates. The tendency for monetary expansion may be said to be greater in this latter case, whereas on balance the tendency would be for contraction at low interest rates.

When expectations are really bad or really good the tendencies have been known to be reversed, i.e., during the 1930's and 1920's. Since the Federal Reserve Bank can also buy and sell securities, it can affect the money supply in the same fashion as individuals. If the "Fed" buys securities when private individuals are very pessimistic it can offset the tendency of interest rates to rise to deflationary extremes. If its purchases are heavy enough the Fed can lower interest rates (by expanding the money supply) and hopefully stimulate any potential investors that may be sensitive to opportunities to borrow at lower rates. Whether such stimulation would actually bear fruits depends upon two factors, the actual shape of the L function and the interest rate elasticity of investment demand.

If the L_p curve becomes essentially horizontal at some interest rate, no amount of monetary expansion, beyond a point, will induce further rate reductions. More important, a lot of evidence has been accumulated to show that so much expansion of large companies is financed through cash flows generated internally by their operations, that aggregate investment demand may be "interest inelastic."

Time preference theory. The significant attribute of this theory which distinguishes it from the others is the importance of time. As is the case with the other theories of interest, however, the time preference theory can be broken down into demand and supply determinants.

On the demand side, resources are used to produce either consumption goods or capital goods. Capital goods are those goods which are used to produce other goods that might be eventually consumed. Thus the production of capital goods means that society foregoes the production of consumption goods. This "roundabout" production of capital goods yields a rate of productivity in terms of the eventual increase

in consumer goods. This provides the inducement for the producers of capital goods to demand resources for this purpose, and generally it is theorized that the greater the length of the period of "roundaboutness" the greater the yield of the resources.

On the supply side, people must be induced to provide the resources from which the capital goods can be produced. There must be a sacrifice of current consumption which is the same thing as saying that saving occurs. The cost of saving reflects itself in the unpleasantness of postponing consumption; i.e., in time preference. There are a number of reasons advanced as to why people prefer present rather than future consumption. They may not be alive later to enjoy the fruits of abstinence. Prices may rise so that the real value of consumption may fall. In addition, people just seem to be constituted in such a way that they prefer present enjoyment over prospective enjoyment. In any case, this theory postulates that the rate of interest on saving is the inducement to entice people to postpone consumption. The greater the rate of interest the greater the inducement to save.

The equilibrium interest rate is set by the interaction of demand and supply determinants.

XVI

SOCIAL DISCOUNT RATES

Assuming that cost and benefit streams must be discounted with some interest rate, the following discussion will be devoted to what various people have indicated would be appropriate for public investment purposes.

McKean

In Efficiency in Government Through Systems Analysis (16), Roland McKean advises discounting at the "market" rate if there is no budget restraint (16; pp. 76-81). Just what "market" rate is appropriate in the non-ration case is never made clear because his attention is directed largely to rationed situations. A fixed budget is taken to require the computation of an "internal" discount rate, the marginal internal rate of return for the project set (ρ_{ms}). The value of ρ_{ms} is actually equal to the average internal rate of return generated by the last project or portion of the project which could be built so that the entire appropriated budget will just be used up. The trouble with this concept is that it does not relate in any way to the social time preference or to the opportunity cost of capital. If either of these concepts has relevance as a discount factor, then McKean's procedure cannot be valid.

Eckstein

In Water-Resource Development (6), Otto Eckstein also presents his analysis in the context of a budget restraint, but his approach to the "proper" discount rate involves the use of a discount rate determined "outside" the project set. This does not mean that he accepts the Hirshliefer argument that project should necessarily earn the rate of return equal to private companies whose investment decisions are comparable to those made by public agencies (6; p. 146). He first

discusses the question of the borrowing rate for government bonds. If the government sought to raise investment funds for water resource development in the capital market it would find lenders were willing to supply the money at the going Federal rate. This might be taken as evidence that the social cost of a loan is measured by this rate. Eckstein argues that this line of reasoning overlooks two fundamental factors which make the argument invalid. The first factor is the social cost of risk bearing, since if a project should fail to produce the expected benefits, the loss is socialized or pooled so that bond holders do not run any risk of forfeiture. Any loss is suffered by general tax payers. The Federal bond rate does not measure the social cost of capital since it makes no allowance for risks of individual projects. Secondly, most of the money that is acquired through bond sales is not acquired by voluntary sales to the public. An increase in the federal water resource program will require an increase in taxation and there is no voluntary choice about the payment of these taxes. Besides, there is even a question about whether the sales of government bonds reflect open market voluntary exchanges or whether the rate is pegged at some low level by sales to the Federal Reserve System from commercial banks.

Eckstein also rejects private market rates as being inappropriate. An increase in public expenditures for water resource development comes at the expense of tax increases, and these increases cut into consumption as well as into investment; thus the rate of return on the private investments also holds little normative significance for public projects. (But at the margin the returns to consumption and saving or investment are exactly the same as in the private sector.)

Eckstein then asks what rate would be an appropriate measure of the social costs of federal capital. He argues that this rate can only be estimated by tracing the capital to its source and discovering its value in the use to which it would be put in the absence of a public budget. Since the money is actually raised by taxation, the incidence of the

marginal tax is a consequence of the project and must be assigned to various businesses and households. An elaborate analysis of this type is contained in Krutilla and Eckstein's Multiple Purpose River Development (12). Assuming 1955 market conditions (full employment and consumers' sovereignty with regard to inter-temperal choices) the social costs of federal financing are set at 5 to 6 percent (12; p. 120).

Eckstein modified the above argument in an important respect in his own book. He argues that a discount rate of 5 or 6 percent would preclude the justification of most projects, especially most long-lived projects. He argues that there may be a bias against redistribution of income toward future generations and therefore too few long-lived projects. His proposal therefore is that the following compromise should be made to preserve the long-time perspective of the federal program. At the same time the compromise would insure that only projects are undertaken for which capital would yield as great a value as it would in its alternative employments. He suggests letting the government use a relatively low interest rate for the design and evaluation of projects. But let the projects be considered justified only if the benefit-cost ratio is well in excess of unity. He then provides illustrations of how various low interest rates and high benefit-cost ratios interact to produce the equivalent of a discount rate of 6 percent.

[It is easy to see that the Krutilla and Eckstein analysis continues to be influenced by the assumption that competitive private uses for capital are entitled to the same consideration, from the point of view of the public interest, as government sponsored projects. This assumption is unlikely to be acceptable to everyone. A very rough guide to the degree of its acceptability (when planning specific projects) might be given by the degree to which it appears possible to apply the "benefit principle" of taxation to the projects in question. The assumptions may not be acceptable for evaluation of the worth of national defense measures or the worth of those kinds of public works made available to the public completely without charge.]

Scott

In Natural Resources: The Economics of Conservation (24), Anthony Scott addresses the question of whether a special (lower) social rate exists (in the sense that it has some support in political theory). That such support clearly exists is doubtful (24; chap. 8). He quotes Professor Robbins to the effect that there is no way to show "it is usually a good thing to force upon the different members of the community, through the apparatus of politics, a rate of accumulation fundamentally out of relation to their time preferences formulated individually." (22; pp. 25-27)

The only elements of a rudimentary theory justifying political intervention are held by Scott to be:

1. "A socialist argument that in a planned economy accumulation would be, or should be, quicker than in a private economy." (24; p. 91)
2. A belief in a partnership theory of social continuity, and that "society should be governed as though this contract existed, and in such a way as to achieve its assumed ends." (24; p. 93)

"The resultant doctrine seems, however, far removed from western attitudes to the role of the state or the meaning of social obligations." (24; p. 97) Scott argues that there is no evidence that the time horizons of private decisions are less than state decisions, and that in our society market interest rates do reflect the relative preferences of individuals, and the opportunity cost of capital. He therefore would use, for most circumstances, a private market rate of interest.

Hirschliefer, Milliman, and DeHaven (10)

These authors reach the same conclusion as does Anthony Scott. They argue that in the case of most large, long-lived projects, risk is extremely important and that a large adjustment for risk should be made in the interest rate. They would go to the private markets for comparable kinds of services under comparable risk situations and use the prevailing

rate. They even argue that 6 percent might be too low and that a rate approaching 10 to 12 percent would be more realistic.

Marglin

Will private market interest rates do for discounting? If not, a social rate should be used, not only for government projects, but for all investment decisions. (This is an important point.) Should there be a difference between the way we view savings vs. consumption decisions collectively and the way we view them individually?

In "The Social Discount Rate and the Optimal Rate of Investment" (39), Stephen Marglin rejects Professor Pigou's authoritarian solution that government is the protector of all rights of future generations. He argues that this conflicts with the notion that a democratic government reflects only the preferences of individuals who are presently members of the body politic. Whether individuals regard the welfare of future generations is a moot question.

In addition, Marglin rejects the "schizophrenic" solution that economic man and the citizen are two different individuals. He says this solution is artificial since we cannot say which is the true preference map.

An acceptable solution is as follows. Utility from consumption is dependent upon the level of consumption of others. An individual may wish to have more than he does, but in the political field where these kinds of decisions are made for some products he cannot get more unless he can find enough others who feel the same way. To get this kind of support at the national level involves tremendous costs which curtail savings below the optimum level. (Marglin's reasoning may be correct a priori, but the importance of this factor remains open to question. Before its weight can be assessed there must be some estimates as to how high the market rate is actually pushed by this factor. There are no known attempts to quantify this influence.)

Steiner

In "Choosing Among Alternative Public Investments in the Water Resource Field" (41), Peter Steiner argues that the social productivity of investment depends on where the funds come from and upon the particular investment opportunities displaced by the planned project expenditures. Steiner seems to argue for the supra-marginality of projects in the private sector which are displaced by public expenditures. If these private projects really are the ones replaced, then the social rate of interest must be even higher than private market rates. If, of course, the reverse is true, that is, that the supra-marginality exists in public projects, then the social rate of interest may be lower than private market rates. Again, much empirical study is needed to determine the importance of this argument.

Feldstein

In "The Social Time Preference Discount Rate in Cost-Benefit Analysis" (32), M. S. Feldstein has argued that in traditional capital theory a single interest rate equates the marginal time preference, (MTP of savers with the marginal productivity of investment). But he denies that this single rate can be used in a mixed, complex economy (such as ours) for discounting purposes. And in fact, it is impossible to determine any single rate of interest due to the multitude of earning assets with different productivities.

Feldstein identifies two types of discount rates: 1) the social time preference (STP) and 2) the social opportunity cost (SOC). STP assigns current values to future consumption and need not be constant over time. SOC measures social value of the best alternative use of funds. SOC depends upon the source of funds, and therefore applies or reflects STP. Thus Feldstein argues that the STP rate or function is the most appropriate one.

STP cannot be derived from market rates but must be administratively determined. Even in a perfect capital market, STP would not equal market rates of interest. In his work, Feldstein demonstrates that Fisher's indifference curve analysis may be utilized to show the properties of the STP function and its relation with the STP rate. It is then possible to say that a useful X ante estimate of the STP rate can be made. The STP rate may vary through time and response to changes in the consumption level and growth rate, the rate of population growth and the pure time preference rate. It is not unreasonable to expect the STP rate to rise as a function of time. Public investment decisions must also reflect the social opportunity cost of the funds. This can best be done by using a shadow price that reflects social time preference and the productivity of funds in private investment.

In summary, it is clear that this area is still far from being settled. Many of the best economists in the country, mainly of the Harvard influence, argue strongly that the social rate of discount should be lower than market rates of interest. Equally eminent economists headquartered in Chicago argue that private rates of interest should be used. (One wonders how much the ideological position of these economists is reflected in their feelings about appropriate discount rates.)

XVII

THEORY OF COMMON PROPERTY RESOURCES

The benefits or services of certain desirable resources are not subject to private ownership. Air for breathing or combustion processes, use of the oceans for transport, wilderness recreation, or certain fishing activities are examples of resources, the uses of which are received or taken in common. The distinguishing feature of the utilization of such resources is that individual appropriation of benefits often takes place in an atmosphere of: "If I don't get it, someone else will." That is to say, individual appropriations of benefits are marked (to a greater or lesser degree) by the treatment of scarce resources as though they are free. In certain cases, such as the appropriation of air, the good may indeed be free. Passage over a bridge or along a roadway, however, is a different matter. The way bridges, streets, and wilderness are used often leads to congestion and high social cost. More precisely, in such cases utilization patterns create technological diseconomies or a divergence between private and social costs. A reduction or elimination of such divergences is a requirement if an "efficient" allocation of resources is to be attained.

External Effects: A Descriptive Note

In the past there has been a good deal of confusion over what actually constitutes an external economy (diseconomy) in the sense that social costs are unequal to private costs. Many of the examples originally put forward by Professor Pigou in the earliest editions of The Economics of Welfare have been shown to be incorrect (19, 20). Pigou argued that whereas competitive industry output is determined by the intersection of the industry demand curve and the industry marginal cost curve, "correct" output would be determined by the intersection of the demand curve and a "marginal" cost curve indicating " 'the difference

made to aggregate (industry) expenses' by the production of one more unit." (32) The examples used by Pigou to support this contention all featured either diminishing returns or external diseconomies represented merely by rising transfer costs. Allyn Young and others have pointed out that these features do not create a divergence between social and competitive industry cost.

If expansion of an industry increases factor cost at the margin because of diminishing returns or rising transfer costs, the marginal social (opportunity) cost for resources yielding n units continues to be given by the marginal cost of resources required for production of the nth unit. The intramarginal factors already being supplied earn rents that are not social costs in terms of resources (38; p. 167). From a monetary standpoint, rising transfer costs and diminishing returns represent diseconomies to the firms within an industry and are therefore labeled "pecuniary external economies of scale."[1]

For other arguments, of course, Pigou did use examples of social diseconomies that are ignored by producers, e.g., wasteful forms of tenancy where "...a farmer in his natural and undisguised endeavor to get back as much of his capital as possible takes so much out of his land that, for some years, the yield is markedly diminished." (19; p. 175) And Sidgwick speaks of cases of social waste when the "economic" exploitation of natural resources cannot be achieved without state action, e.g., hunting and fishing during the closed season (25; p. 410). As distinct from pecuniary diseconomies/economies, these examples arise from the technical or institutional circumstances as a consequence of which scarce goods are treated as though they are free.[2] The

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[1]This appears to have been the accepted terminology ever since the publication of Viner's "Cost Curves and Supply Curves." (42)

[2]Viner, op. cit., p. 221; external technological diseconomies are "increases in technical coefficients of production as output of the industry as a whole is increased."

characteristic feature of these situations is a divorce between scarcity and effective ownership.[1]

This is easily seen in the case of highway transport. There it often is true that a road user's share of total transportation cost does not match his contribution to the total cost incurred by traffic in the system. Whenever there is congestion each additional vehicle causes some delay and risk to others already on the roads for which the owner does not bear the cost. These additional costs are not extracted for the use of road resources because it is difficult to prevent their use by anyone who desires to employ them.

A similar example is provided by sea fisheries. Baumol gives as a description of an external diseconomy the case of the fishing industry where fish are scarce (2; p. 33). If one fishing firm increases its scale of operation it increases the scarcity of fish to the remaining firms and hence raises their costs. The analogy between a fishing boat and a motor vehicle is clear. In either situation the direct result of increased group activity is that individual "firms" (boats or vehicles) require additional real inputs to maintain a given output. Pigou and Baumol both argue that the essence of such external diseconomies is that they arise from "defects" in the pricing system as a result of which the individual firm is not

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[1] Natural resource examples are connected with only one of two sub-classes under the general heading: "cases where the entrepreneur appropriates not less but more than the whole net gain to the community of his enterprise." The other sub-class includes cases of social waste due to the interlocking of immobile factors like land sites leading on to the problems of industrial location and town planning, e.g., Professor Pigou's case of smoky chimneys (Sidgwick, op. cit., pp. 408-409). Sidgwick also identifies another general set of cases where socially desired goods and services are not produced because, due to technical peculiarities, the private producer cannot collect his reward. He cites the cases of the lighthouse, afforestation, promotion of scientific research, etc. (Ibid., pp. 406-407)

compensated (or compensating) for what it does to other firms in the industry (2; p. 33; 19, p. 183).

External Effects and Group Average Costs

In the original edition of the Economics of Welfare (20; p. 194) Pigou contended that, in the case of two roads connecting the same two points, if the superior (lower operating cost) road were subject to congestion and therefore diminishing returns, it would be over-exploited in competition unless taxed differentially. As an example of the situation between various firms in competitive industries, the road illustration was shown to be fallacious by Professor Knight who demonstrated that in a society in which property is privately owned the owner of the good road would set a toll that would raise the costs of travel on the good road until they were level with those on the poor road (37). This toll would exactly equal the "ideal output tax" suggested by Pigou and therefore over-exploitation would be prevented by the normal market mechanism.[1]

Pigou's road illustration did not serve his intended purpose as regards competitive industries, but as regards roads it is an exact description of what may happen on a system of alternate routes between two areas. If "vehicle operators as a group" is substituted for "competitive industries" then it becomes correct to say that competitive output of highway services by a class of vehicles on a given road is determined by the curve of average group costs.[2]

Knight utilized exactly the same curve in his 1924 article. The situation is the same as given by Pigou, i.e., a system of two roads,

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[1] Competitive industry supply price is established at the level of marginal factor cost for the entire industry. (This is analogous to the level of cost established by the marginal or broad road in Pigou's example.) But as was shown by Allyn Young, Knight, and others, competitive supply price may be looked upon as average industry cost plus average Ricardian rent (i.e., the "toll"). (32, p. 249; 36, pp. 165-166)

[2] And it is recognized that in real life roads are not privately owned.

one, superior in terms of lower transport costs, subject to diminishing returns because of width, the other a high cost road that is broad and not subject to diminishing returns. Knight's geometry assumes that the average vehicle of a single class would have constant costs for passing over the superior road unless the road becomes congested. He also supplies a group marginal cost curve for all the travellers using the road (this is analogous to the usual concept of a competitive industry supply curve) [37, charts A, B, C, and D; cf. 33, pp. 246-249 (descriptions of functions ϵ and β in Figures 2 and 3); 40, p. 210, n 4].

The group marginal cost curve or its analog, the group marginal revenue product curve, is a measure of the net gain to society through group use of the road. Knight shows that individuals of the group do not adjust their personal use of the superior road on the basis of group marginal cost. Rather, their adjustment is on the basis of group average cost or, in terms of productivities, individual adjustment is on the basis of group average productivity. Individual users transfer to the broad road (where average and marginal productivities are equal) only when average productivity on the superior road is equal to average productivity on the broad road. The result is that, in total, the individuals of the group "appropriate (in Sidgwick's terms) not less but more than the whole net gain to the community (road group of vehicle owners) of their enterprise."

Exactly similar conclusions are reached by Gordon regarding production from sea fisheries (34). Since the natural resources of the sea are not private property, the rents superior fishing grounds might yield are not capable of being appropriated by anyone. "The result is a pattern of competition among fishermen which culminates in the dissipation of the rent of the intra-marginal grounds." (34, p. 131) This comes about because individual fishermen, in deciding which area to fish, do not take into account the marginal productivities of the various areas, they consider only average productivities. Then given the free and competitive nature of fishing, "average productivity of all grounds (will) be brought to equality." (34, Ibid; cf. 3, p. 58, p. 63)

Because it is not always immediately apparent why individuals should make private (marginal) decisions on the basis of average productivity (cost) of fishing grounds or roads, some amplification of the Knight/Gordon analysis is warranted. The key to the situation is that on a given road or fishing ground each individual fisherman or vehicle operator appropriates to himself some portion of total production (fish/highway services). Given that individuals are all "alike," each appropriates an equal share or an average percentage of the total. And given, in addition, diminishing returns, marginal physical product is less than average physical product and consequently group marginal productivities (costs) are ignored. The amount an individual is willing to expend to appropriate some average percentage of the total will be termed "private unit cost." But this unit cost is not a constant. The value changes with each expansion and contraction of group activity (say on successive days). Thus as some function of the group's activity, the locus of all possible unit cost values traces out a curve exactly equal to the group average cost curve. As viewed by a single individual the function might loosely be termed "a private marginal cost curve."[1]

This argument may be summarized as follows:[2]

Individual's cost function	$C_i = f_i(s_i)$
Congestion function	$S = g(V),\ V > V^*$
Individual restraint on speed	$s_i = S$ for all i $\quad V > V^*$

[1]Cf. 3, p. 87. But the term does not have all the usual meaning. Unit cost is "marginal" only in the sense that it will be saved if the vehicle or fishing trip is cancelled. The first derivative of total cost of fishing effort on a fishing ground or of transport inputs on a highway is the marginal cost of total group activity. But this is usually thought of in terms of the costs of a single day's fishing or a single hour of highway travel, etc. It is extremely difficult to conceive a total cost function for some quantity of transport service over a period of time (for an individual) which could be differentiated in any meaningful way either with respect to the individual's "output" or with respect to vehicles per hour.

[2]This proof provided by Dr. L. Hartman, Department of Agricultural Economics, Colorado State University.

C_i = cost per mile for the ith vehicle

S = group average speed after onset of congestion

s_i = ith individual speed

V = vehicles per hour, V^* beginning of congestion

An individual's decision to use a particular road is based on private cost depending on observed flow of traffic, i.e., (with congestion)

$$C_i + f_i(S) \quad \text{and} \quad S = g(V)$$

$$\bar{C} = \frac{1}{n} \sum_i^n f_i(S) = \text{group average cost and if } f_1 = f_2 \ldots = f_n,$$

then

$$C_i = \bar{C}, \quad V > V^*$$

Thus, for the marginal vehicle to enter the road after the onset of congestion, private cost is $\bar{C}$ while group marginal cost is $\sum_i dC_i$, where $dC_i = f_i'(S)\, dS$, $dS = g'(V)dV$ and $dC_i = f_i'(S)\, g'(V)\, dV$.

Let C_i^* = ith individual's reservation cost whereby he will defer the trip or choose another road, then the criterion for the trip is $C_i < C_i^*$.

Efficiency: Reduction of Technological Diseconomies

Having shown that vehicle operators' decisions based on private costs lead inevitably to the creation of technological diseconomies, and assuming that an economic interpretation can be given the interaction of many drivers achieving a state of traffic flow equilibrium, some judgment of the performance of the system is required. For this purpose the notion of "best" utilization or "efficiency" shall be employed. This may be described in general as minimization of aggregate transport cost (demand given) for all road users (3; p. 81).

Cost minimization is readily illustrated for the single corridor case involving only two routes. In Figure 32 the total hourly vehicle flow (demand fixed) is given by the length of the line 0-X. Following

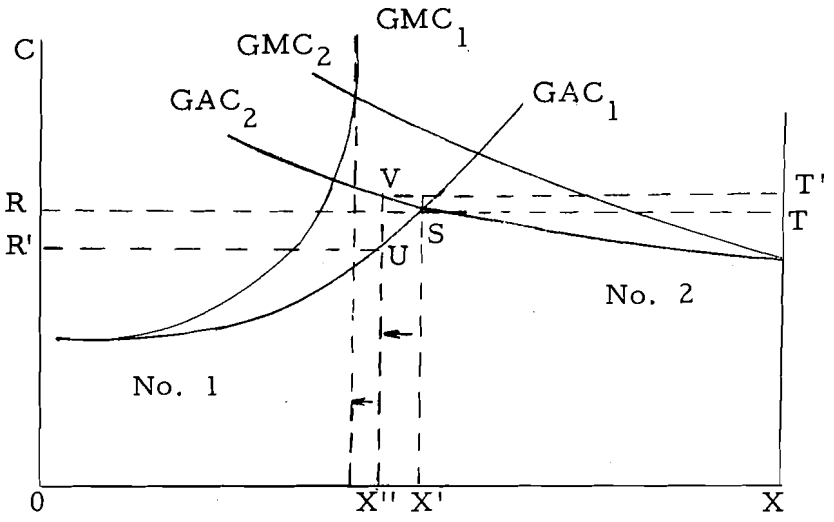

Figure 32. Transport cost minimization on two roads

the earlier argument, the equilibrium use of both roads will be such that the average cost of travel will be the same on each. Thus 0-X' number of vehicles will utilize road No. 1 and the remainder of the total, X' - X, road No. 2. The total hourly cost of travel for some trip length will equal the sum of the rectangles 0X'SR and X'XTS. The problem is to minimize this sum for the given flow. If one vehicle is transferred from road No. 1 to road No. 2, (shown as X'→ X'') total transport costs on No. 1 will fall (area 0X''UR') and the rectangle of costs on No. 2 increases to X''XT'V. It is clear that the reduction in cost on road No. 1 more than offsets the increase in cost on road No. 2. On balance total transport cost has fallen. This shifting of "marginal" vehicle units is continued until the incremental cost reduction on road No. 1 is exactly equalled by the incremental cost increase on road No. 2. The division of traffic between the two routes will then be "efficient" in the sense that hourly costs of travel will be at the lowest level consistent with the fixed demand. The incremental cost adjustments for the group of operators on either road brought about by the shifting of one operator

is summed up in the respective group marginal cost curves. Thus where the group marginal cost on road No. 1 is equal to that on No. 2, total combined hourly costs of transport through the corridor are at a minimum. The difference between this total minimum cost and the total cost at the equilibrium division of flow is a measure of the technological diseconomies brought about by individual vehicle operators' private choices.

When roads are subject to congestion, the presence of an extra vehicle in the traffic stream causes delay and increased risk to all vehicle operators already on the road, but the sum of such costs is not borne by the operator of the extra vehicle. He incurs only the average cost of travel per hour. If he were to incur the average cost plus a toll equal to the sum of the additional costs his vehicle's presence imposes on other vehicles, his private cost would equal the group marginal cost. Efficient division of flow between the two roads would be established when the marginal group costs for the last vehicle on each road are equal. The tolls would just hold the system in equilibrium, for the average cost plus the toll on road No. 1 would just equal the average cost plus the toll on road No. 2. The same condition must hold for any number of roads contained within a corridor (during peak travel periods). This can be shown best in terms of an adaptation of Knight's graphic formulation. Figure 33 is designed to show just what toll rates would be necessary at given traffic volumes in a corridor composed of two roads. Suppose

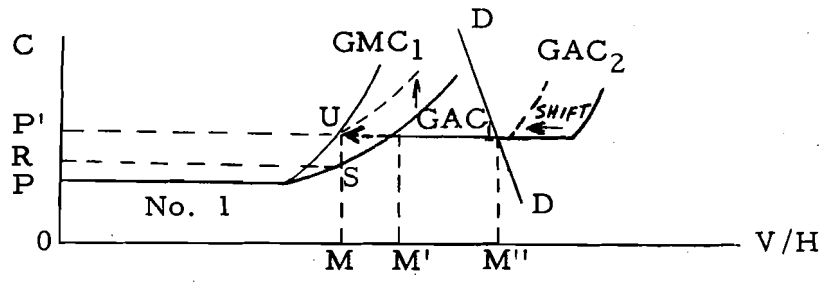

Figure 33. Surrogate pricing and rent maximizing tolls

road No. 1 is privately owned, but road No. 2 remains "free." The traffic demand level for corridor travel at some particular time of day is shown by D-D. In the absence of a toll, vehicle operators will stay on road No. 1 until the average cost of transport rises above the average cost of the next best alternative, road No. 2. The average cost of travel on either road is equal to 0-P'. If the owner of road No. 1 wishes to maximize producers' surplus (or site-rents) from the best facility, a toll should be set equal to R-P'.[1] No consumers' surplus is extracted in this process; any such attempt would cause traffic to shift to the second road. In short, the owner of the "best" road sees the demand for use of his road as a perfectly elastic curve at the level 0-P' (thus AR = MR).

As a consequence of the imposition of tolls traffic flow on road No. 1 will be reduced to the 0-M level and the flow on road No. 2 will increase from M'-M'' to M-M''.[2] In this over-simplified situation there is no diminution of corridor traffic flow. There is a definite reduction of congestion on road No. 1, that is, a reduction in external effects. The system is in equilibrium because the private unit cost 0-T plus toll, R-P' on road No. 1 is equal to the private unit cost 0-P' on road No. 2.

The road case lends itself especially well to the notion of surrogate pricing. But the simulation of a private market for other common property resources can be accomplished in an analogous manner. Numerous ingenious pricing systems have yet to be devised in cases involving recreation, etc. What must be noted in all common property uses is

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[1] The toll would equal $(0R)(1 + \frac{1}{\epsilon})$; ϵ = elasticity of GAC_1.

[2] It would not be correct to imagine that in the absence of a toll road users receive a gift of the producer's surplus. The pattern of individual drivers' activities dissipates the surplus through the higher costs caused by external effects.

the "lack of a market," the tendency towards technological diseconomies and attendant mis-allocation of resources, and that many public investments establish or make more accessible resources that exhibit common property features.

XVIII
LOGIC IN CONSERVATION

No discussion of the economies of water allocation and development would be complete without brief reference to the subject area known as "conservation." A whole philosophy of resource use has developed centering on this term, which has caught the fancy of the public and has dominated action decisions by government agencies. But despite the widespread appeal and impact of conservation, it is clear that the word means different things to various advocates who use it. Perhaps this is one reason why so many have found it possible to embrace the cause of conservation: they make it fit their own ends. The result has been a great deal of confusion and fuzzy thinking and a wide variety of policies and programs.

Words and Goals

Probably the most widespread use of the term conservation is in reference to the avoidance of resource waste. In this context conservation unquestionably is regarded as something "good" and in the public interest. For example, it is good to prevent soil erosion, it is good to maximize the yield from an oil well, it is good to grow two blades of grass where one grew before, it is good to use water before it is wasted into the sea.

An extreme version of the above notion as applied to stock resources, such as petroleum and minerals, is that conservation actually means "non-use." Resources are thus conserved in the present, permitting their use sometime in the future.

In the case of so-called flow resources, such as products of the soil or water in streams (where benefits of the resources will be lost if the resources are not utilized), conservation often implies a sustained-yield level of production. This means that the resource productivity base will

not be allowed to deteriorate, thus maintaining some pre-determined level of production. One often encounters this concept in the fields of plant ecology and range management. Confusion can arise if it isn't clear what the real products of the resources are, or if there is disagreement as to the relative value of various products. Thus, if the targeted level of sustained-yield forage production, for example, is the maximum biological yield, it is conceivable that this can be achieved only in the complete absence of livestock grazing. Accordingly, advocates of watershed improvement might get what they want at the expense of commercial ranchers.

The practical problem with the foregoing concepts of conservation is that they fail to account for economic considerations underlying resource management. Prevention of resource waste is hardly ever costless. American soil conservation programs, for example, are often very expensive, yet agricultural land is plentiful at the present time. Thus, conservation programs are not necessarily good for society per se. It depends on the costs and returns of particular policies and programs.

It is important that conservation issues be removed from the ideological and emotional planes in order to subject policies and programs to the rigors of feasibility analysis wherever possible.

In an attempt to facilitate analytical advance, economists have defined conservation as a redistribution of resource use in the direction of the future. In this context conservation would be the opposite of depletion or exploitation which imply present use at the expense of future use. Defined in this way, conservation is independent of ethical standards; i.e., it is not something good or bad. This definition does, however, tend to draw attention to the possibility that balancing of present and future claims is the goal that must be optimized. The truth is that it is possible to use resources up too quickly under some circumstances and too slowly under others. The optimal level of conservation

depends among other things on the magnitude of particular resource endowments, the interest rate, resource productivity, and the costs and returns of resource regeneration.

Critical Questions

A. Does exploitation of natural resources imply an impoverishment of posterity? The doctrinaire conservationist would say, yes, of course. There are just so many tons of minerals in the earth, a fixed quantity of oil, and exploitation now means fewer resources available in the future. This position is much oversimplified.

The economic welfare of future generations is determined by the total endowment of economic wealth and capital accumulation which is passed on to them. Natural resource reserves are only a small part of this endowment. The vital thing to keep in mind is that natural resources are generally an essential ingredient (but only one ingredient) in the production of all capital goods which constitute the total endowment. Without the exploitation of natural resources the production of capital goods might be much diminished. Therefore, if one is to look to the welfare of posterity, natural resources should be used in such a way as to assure a high level total wealth endowment. This will necessitate the exploitation of resources over time, not their absolute conservation.

Of course, natural resources conceivably could be used up "too rapidly" by the present generation, thus imposing heavy costs on some future generations. Since it is easy to guard against over-use of any resource for which future demand is clearly predictable (e.g., it was obvious late in the 19th century that forest depletion had to be curtailed if 20th century demands were to be satisfied), over-use could only have two meanings:

1. Future generations discover a completely new technological process that is rendered difficult or impossible to exploit due to improvidence of their forebears.

2. Over-use means simply that the current generation makes "incorrect investments," i.e., it passes on a stock of capital goods of lesser value than would have been attained utilizing hindsight.

Whatever may be said in the way of assessing these possibilities pretty well boils down to the difficulty of predicting the future. Tastes, needs, incomes, and technology all change over time and shift the demand for natural resources. All this simply means that conservation may or may not induce increased wealth for future generations of people.

B. What effect does technological development have on conservation decisions? An intuitive guess is that progress in the "state of the arts" creates a systematic bias toward using resources too slowly. Large research expenditures are directed to finding substitutes for scarce or costly commodities or discovering more efficient ways of producing them, thus utilizing resources more effectively. Often these technological breakthroughs are not foreseen at all, and if so, very imperfectly. This means that technological advance almost always comes to society's rescue just when we seem to see serious resource shortages developing. Thus, fears of national impoverishment due to resource depletion seldom materialize; many programs to conserve resources, which are responses to such fears, might well be ill advised.

As an example, in the early part of this century many people were worried about the ability of the American farmer to feed an ever-growing population. A feverish campaign to conserve soil and water resources developed along many fronts (including irrigation projects to bring high productivity lands into production). Then in the 1940's and 1950's the so-called "technological revolution" in agriculture became a reality. It was apparent that the agricultural sector of the economy had made more rapid progress in increasing output per unit of input than any other. Agricultural economists now generally believe that Americans

have a superabundance of agricultural land to meet their current needs and those of the foreseeable future. Indeed, technological progress has made it necessary to take a critical look at the economic feasibility of the costly conservation programs. The agricultural example is not unique. The same result may be in the offing for other natural resource areas, such as energy fuels (since commercial atomic energy is on the horizon).

On the other hand, one must proceed with some caution and remember that technological advance is not always certain. Society must make resource-use decisions in the present, and it may be a little foolish to argue that because hindsight has shown that we have made past mistakes by being too pessimistic about the future, that we can abandon concern about saving resources for future generations. This is particularly true with respect to the really "critical" resources on which our civilization depends, lack of which would impose severe costs. In these cases the best rule might be "better-safe-than-sorry," even though time may prove that over-conservation was the consequence.

Excepting the better-safe-than-sorry situations, it is possible to say in conclusion that the rule should be to maximize resource contributions to growth of national economic wealth (as the first approximation to setting gross exploitation rates). This can only be accomplished if society rids itself of as much emotional bias as possible in this area and subjects conservation policies to the rigors of rational economic analysis wherever possible.

APPENDIX

Mathematics of Figure 28

The results shown in Figure 28 are based on a very simple functional relationship between revenue and cost, but they give insight into more complex relationships. The conditions which hold for the maximization of the various criteria have been demonstrated by the Lutzes (13; pp. 18-20) and may be paraphrased as follows:

Revenue (R) = f(C) where C is the units of investment at t_o and R accrues at a single moment at the end of the technically determined investment period. The present value of R is $V = f(C)e^{-rt}$, where t is the fixed period and r is given.

(a) $$V - C = f(C)e^{-rt} - C \qquad (1)$$

and the maximizing condition is $\frac{d(V - C)}{d(C)} = 0$, which gives

$$f'(C)e^{-rt} = 0 \qquad (2)$$

In the equation

$$C = f(C)e^{-\rho_a t} \qquad (3)$$

ρ_a represents the average internal rate of return, the rate if used to discount down to the present all the revenues from the investment, makes their present value equal to the total cost of the investment. In the equation

$$1 = f'(C)e^{-\rho_m t} \qquad (4)$$

ρ_m represents the marginal internal rate of return, the rate which, if used to discount down to the present the marginal revenue due to an additional unit of funds invested, makes the present value of that revenue

equal to unity. Solving for ρ_a and ρ_m

$$\rho_a = \frac{1}{t} \log \left(\frac{f(C)}{C}\right) \tag{5}$$

$$\rho_m = \frac{1}{t} \log f'(C) \tag{6}$$

It follows from (2) and (4) that V - C is maximized when the marginal internal rate of return is equal to the rate of interest. The expression for the relationship between the marginal internal rate of return and the average internal rate satisfies the usual condition for equality between average and marginal values, i.e.,

$$\rho_m(C) = \rho_a(C) \quad \text{where } \rho_a'(C) = 0 \tag{7}$$

or that $\rho_m = \rho_a$ when the latter is at its maximum.

(b) $$V/C = \frac{f(C)e^{-rt}}{C} \tag{8}$$

and the maximizing condition is $f(C)e^{-rt} - C\left[f'(C)e^{-rt}\right] = 0$, therefore,

$$\frac{f(C)}{C} = f'(C) \tag{9}$$

Taking the logarithms of both sides of (9) and multiplying by 1/t gives

$$\frac{1}{t} \log \left(\frac{f(C)}{C}\right) = \frac{1}{t} \log f'(C) \tag{10}$$

i.e., V/C is maximized where there is an equality between the average and marginal internal rates of return.

(c) ρ_a maximization requires $\rho_a = \rho_m$ as shown in (7) and thus ρ_a maximization is identical with V/C maximization.

(d) The conditions for the maximization of k* are of no concern in the public investment case unless it can be imagined that the investment "agency" "holds" capital outside the Exchequer budget. However, the Lutzes have shown that in nearly all cases the investment that would maximize V - C would maximize k as well (op. cit.; p. 42).

(e) A possibility not considered by the Lutzes might be thought to have some application in the public investment situation. This would require investment such that V - C = 0, i.e., that "costs are just covered." Then from (1) and (3)

$$f(C)e^{-rt} - f(C)^{-\rho_a t} = 0 \qquad (11)$$

Dividing by f(C) gives

$$e^{rt} = e^{-\rho_a t} \qquad (12)$$

and taking the logarithm of both sides gives

$$-rt = -\rho_a t \qquad (13)$$

and therefore V - C = 0 requires that the average internal rate of return ρ_a be set equal to the interest rate, r.

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*k = owner's share of capital.

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