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Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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SHADOW PRICES IN INDUSTRIAL PROJECT EVALUATION

Prepared by: J.A. FLEMING and M.L. FELDMAN
Oxford University,
ENGLAND

for: The Centre for Industrial Development
Department of Economic and Social Affairs
UNITED NATIONS

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CONTENTS

INTRODUCTION.

1.1 The Economic Context:

The economic context of this paper is essentially pragmatic. Although the analysis is relevant primarily to underdeveloped economies in which underemployment and disequilbrium are particularly prevalent, it is by no means restricted to them. Indeed we assume throughout the existence of a substantial private sector so that the diversion of resources to the public sector from the private one the impact on the private sector of public projects, and the allocation by the government of resources to the private sector for specific projects are all relevant problems.

Furthermore, despite the frequent occurrence of imperfect competition and the existence of taxes and subsidies affecting resource allocation, we shall assume that market prices provide a starting point and a framework for evaluating social benefits and costs on the basis of which one can develop more sophisticated shadow prices.

1.2 The Administrative Context:

In addition to an economic context the paper requires an administrative framework. Central to our analysis is the "planning agency"; this is the body which evaluates projects typically presented from outside, although it may participate in the selection of potential projects for detailed design preparation.

Individual projects once approved are assumed to be handed over for operation to managers who may be in either the public or private sector and whose

objectives cannot be assumed to be identical with those of the planners.

The function of the planners themselves can be divided between "project analysis" - the application of economic reasoning to the evaluation of various alternative projects - and the more nebulous tasks of taking decisions which have substantial value implications. We would expect the planners to concentrate on defining the areas in which such decisions were required and to seek guidance from a political level. Nevertheless we will refer to "planner's values" meaning values applied by the planning agency which may or may not have originated there.

1.3 Reasons for Shadow Prices:

In subsequent sections we discuss the uses of shadow prices and their calculations in particular situations. It is useful here to give a general classification of the circumstances in which they are likely to be necessary.

Where changes in an economy are occurring so rapidly that the market mechanism fails to adjust, the disequilibrium prices will not reflect true social costs and benefits. It may be possible to calculate equilibrium prices and use them for certain decisions before those prices would have been attained in a free market.

Another case of the inadequacy of market prices occurs with projects which are necessarily large and invisible. In this situation the project may cause market prices to change so that it may not be possible to find a single unambiguous market price with which to measure the value of inputs or outputs.

A third reason for using shadow prices instead of market prices is the existence of monopolistic elements in the market, or taxes and subsidies, which cause market prices to diverge from the proper measure of social benefits and costs.

Finally, there is the case in which only a part of the effects of a project can be associated with an exchange of money. There may be either benefits or costs which, for technical, administrative or social reasons, cannot be sold or, in the case of costs, paid for in the usual way. Nonetheless, such external effects should be evaluated at shadow prices so that they can be taken into account in project evaluation.

II

BASIC CONCEPT OF EFFICIENCY PRICES.

2.1 Shadow Prices:

A shadow price is any price other than an observed market price. For what purposes can such prices be used? Essentially there are three roles for shadow prices: (i) for doing separate accounting in a large organisation, where an entity which is being accounted, does not buy its inputs, or sell its outputs, in the open market; (ii) for investment and pricing decisions of an entity where one wishes to apply a criterion other than profit or revenue maximization, or cost minimization, at market prices: and (iii) for constructing a set of incentive payments for managers or workers, so as to induce them to operate in a way that accords with one's social criteria.

Formally, shadow prices may be identified in the mathematical problem of maximizing or minimizing subject to constraints as the increase in the optimum value of the maximand (or decrease in the optimum value of the minimand) made possible by a unit change in a constrained variable. Thus, the shadow price is the Lagrangian multiplier of the calculus or the values of the "dual" solution to the linear programming problem. (See below, section 6.1.)

2.2 Accounting Prices:

Accounting prices are shadow prices which meet a certain standard of administrative feasibility. For example, if one were to price electricity on a strictly marginal cost basis, the optimal shadow price would vary continuously with the scale of load and its geographical distribution. For administrative

reasons, it might be laid down that not more than three separate time-of-day prices could be used. Given this constraint one could then, in principle, identify the optimum set of prices and the periods for which they should operate.

Ideally, the administrative costs imposed by the structure of shadow prices should be specified and the optimal set and structure of prices calculated so that the total efficiency of the system, including the administration, is maximized. In practice this is not likely to be possible and we must accept the probability that in any context in which we wish to use shadow prices, relatively arbitrary constraints on the structure of the prices will be imposed.

It is important to notice that the best accounting price will depend on the level of output which will itself depend on the actual prices charged. Thus accounting prices should be related to the shadow prices appropriate to the market conditions that actually will prevail if the project is operated. In this paper we consider the theory of these suboptimizing shadow prices; in practice it is to these latter prices that attention should be given in formulating accounting prices.

2.3 Incentive Prices:

A manager might be required to maximize his "accounting profit". If the planner has any reason to believe that managers have any persistent bias tending to reduce their efficiency in doing this, it may be desirable to make the manager's renumeration a function of "accounting profit". The incentive effect could be strengthened if the bias of the manager were taken into account in calculating

accounting prices. Suppose, for instance, that managers of building sites are found not to utilize machinery sufficiently to maximize the "accounting profit" of the planners; it may be effective to lower the "incentive price" of machinery to the site manager below the "accounting price" used by the planner.

2.4 Assessment of Private Projects:

The use of shadow prices in project evaluation where those making the assessment will not have responsibility for recurrent decisions poses several special problems. To evaluate the project one requires to estimate the costs and benefits of the project in each year at appropriate shadow prices. The value of the project assessed in this way will always be maximized only if the subsequent operational decisions are taken on the basis of the same set of shadow prices. Yet in many cases, especially where planners are assessing the claims of a private enterprise to some scarce resources allocated by the planners, it will be known in advance that this will not occur. Thus, in general, the level of subsequent inputs and outputs will have to be predicted or calculated on the basis of the expected behaviour of the subsequent operators. This might affect the priority given to different projects. For instance, in general input flexibility is a desirable characteristic of projects. However, if the planners attach a low shadow price to labour, it may be more desirable that a private - profit maximizing - firm should adopt an inflexible process with a fairly high labour intensity than a more flexible process compatible with a wider range of labour intensities. This follows if we recognise

that the latter should be evaluated on the assumption that it will be operated at a lower labour intensity by the private firm thant it would be by operators maximizing accounting profits at the accounting prices of the planners.

2.5 External and Internal Shadow Prices:

It is useful to distinguish between "external" and "internal" shadow prices. The first type are those which might reasonably be laid down independently of the particular project being evaluated. Examples of external shadow prices would be a general directive to take labour as free, or to use a certain set of discount rates. On the other hand, internal shadow prices are derived from the characteristics of the particular project. One example is the "transfer price" between different sections of a single complex project. This might be quite important if one attempts to design each component of the project optimally rather than assessing a single design by an "accept/reject" criterion. Another case arises with the selection of construction schedules. Suppose that phase 1 of a project requires certain site plant which will also be required in phase 3 and that none of this plant would be used on phase 2 if it were costed separately on a weekly hire basis. The fact that the plant is there means that it could be used at little extra cost. It should be apparent that internal shadow prices are only relevant at the project design and work scheduling stages rather than at the stage of appraisal of a "given" project.

III

PROJECT OUTPUTS

Before looking at the problems of assigning shadow prices to project outputs, it is worthwhile considering the problems involved in identifying the set of direct and indirect benefits (outputs) associated with any project. Benefits may, of course, accrue even if there are no associated revenue receipts. In discussing the activities of private firms it is customary to refer to the benefits (and costs) which do not produce revenue (and money costs) to the firm as spillovers or external economies (and external diseconomies). In the public sector, where the primary output of a project may yield no revenues, the nature of spillovers and externalities becomes blurred. It is nevertheless important that the effects on those not directly served by the project be taken into account. For example, a hydro-electric power plant may produce irrigation and flood control. In addition to the direct and indirect benefits actually provided the project may also have the effect of assuring that certain products will be available if they are wanted in the future and of decreasing certain risks which individuals previously had to bear. Availability itself and the avoidance of risk may both be considered of value.

Although it is necessary to avoid omitting any benefits and costs, it is equally important to avoid double-counting them. Three types of benefit double-counting mistakes have been made in cost benefit studies. First, a benefit stream and an associated change in an asset value may both be counted. If land is irrigated, an increased crop may be grown on the land; this raises the value of the land. Only one of these should be

counted as a measure of the value of the irrigation. Second, a "national income accounting" mistake may be made by summing the value of intermediate products rather than looking only at the net value at each stage. Thus, irrigation may produce more wheat, which produces more flour, which produces more bread: it would certainly be inappropriate to look at the sum of the additional values at all three stages. But a third type of error is made by counting the bread instead of the wheat. The value added between the wheat stage and the bread stage is (except in an economy with substantial unemployment or under-employment) associated with an equal decrease in value elsewhere in the economy.

When the physical quantities of the benefits of the proposed project during each year of its life have been estimated, it is necessary to assign shadow prices to them. For simplicity we take as the basic unit of measure that which corresponds to the money prices of consumer goods sold in competitive markets in the economy. This allows us, under suitable conditions, to use the money prices at which project outputs are sold as appropriate shadow price measures of their social value. Consumer prices are suitable when the project output is sold in a competitive market and in a small enough quantity that the market price is not affected by the incremental output. The competitiveness of the market does not require that exactly the same product be sold by a large number of other producers but only that there are competing close substitutes and/or ease of entry into the product market. Thus a government fertiliser plant adding only slightly to national supply might generally take its selling price as an appropriate measure of the output's value.

In the remainder of this section we shall concentrate on methods of evaluating benefits when market prices are not appropriate. It will ease analysis to consider separately sales to other producers and to final consumers.

3.1 Intermediate Benefits:

Projects often produce benefits which accrue to producers rather than directly to consumers. We may call these intermediate benefits to stress their similarity to the intermediate products of microeconomic theory. Four approaches to evaluating intermediate benefits may be distinguished.

3.1.1 Market price paid for substitutes already sold under suitable market conditions: If private producers previously used coal and now substitute electricity produced by a project, the value of the substituted electricity is the decreased coal costs or, equivalently, the amount firms are willing to pay for the electricity. While in the case of electricity, which is sold to the firms, it is not necessary to use a roundabout measure in terms of decreased alternative expenditures, there may be other benefits (such as irrigation) that are not sold but that do replace private activity. The problem is more complicated if the quantity used of the new product is more than sufficient to replace the previously used input; see 3.1.3 and 3.1.4.

3.1.2 Social cost of substitutes already used: A benefit distributed to private producers which permits a decrease in some alternative input for which these firms did not previously pay an economic price (e.g., substituting road transport for subsidized rail transport) should be valued at the marginal social cost of providing the previous service, i.e., the decrease in social cost due

to smaller demands now being placed on the railways. Again this is only suitable to the extent that the new service does not provide more than a substitute for the old.

3.1.3 Minimum cost of alternative inputs not already used: We are led naturally by the previous two approaches to ask: if the project produces benefits which more than replace a firms' previous inputs or expenditures, how shall these extra benefits be valued? One possibility would be the minimum cost for which the firms could have obtained equivalent factor services before the project. If the project produces electricity and the previously cheapest source of fuel was coal, we may estimate the cost of the coal that would have been necessary to provide the additional heat and power now obtained from the electricity. It must be emphasised that this over-estimates the value of the additional electricity and should be considered only as an upper limit to its value.

3.1.4 Indirect evaluation: When the project's outputs are used by firms not merely to replace a previous input but also to increase their output, it may in some cases be possible to estimate the physical increase in output due to the additional inputs. Past experience, engineering or agricultural technology, or statistically estimated production functions, may indicate the appropriate relation. The increased output of these products can be valued at the market prices at which they are sold or, if they are final consumer goods, in the way described in section 3.2 below.

3.2 Consumer Benefits:

We now consider the methods of assigning shadow prices to those benefits which accrue directly to consumers. These include not only the actual products and services

of all enterprise but also those 'external' benefits that individuals may enjoy because of a project. For example, improved rail transport may benefit not only rail users but also those who will enjoy less congested roads. The time saved by road users and the decreased motor vehicle costs must therefore be brought into the evaluation of the rail service improvement.

Those products or services which the project sells to the public in direct competition with a large number of other sellers, and in such quantities that the market prices are not influenced by the additional output, may be valued at market prices. Although these requirements are unlikely to be met for many public projects in developed economies, many developing countries may sponsor projects that do produce consumer goods for sale on the domestic market.

When market prices are not appropriate, we must consider a method of finding shadow prices. The first three approaches discussed in relation to intermediate goods (3.1.1, 3.1.2, 3.1.3) may also be applied to final consumer goods.

3.2.1 Market price paid for substitutes already sold under suitable market conditions: This may not be substantially different from selling a product in competition with private producers of the same product, in which case the shadow price obtained would be equivalent to the product's selling price. But two cases arise in which it is necessary to look at the market price paid for substitutes. First, if the product of the project is not sold, the relevant criterion is the saving on previous substitute purchases. Second, the quantity of the product sold may be such that the selling price is substantially different from what it would have been if the project had a much smaller

output; a measure of the value of the project's output to its intramarginal consumers is given by the prices they previously paid to achieve the same satisfaction. It must be emphasized that this method assumes that all output simply replaces previously purchased goods e.g., a substitution of electric heating for coal heating, and that consumer demand for the type of good (heating) is completely price inelastic. When project output does more than replace a previous consumer good but is not sold in a competitive market, we must be able to estimate the value to consumers of this incremental output. This is discussed in 3.2.3 and 3.2.4.

3.2.2 Social cost of substitutes previously used: If the good or service previously used had a social cost higher than its market price, that social cost should be used to measure the value of the replacement. The relevant cost is the marginal or escapable social cost, i.e., the saving due to the replacement of the old good by the new. Even if the consumers valued the old good less than its social cost, the relevant value for the replacement is the reduced resource use and not the consumer satisfaction.

3.2.3 Minimum cost of alternative provision not previously used: As already explained in 3.1.3, an upper limit to the appropriate shadow price of a net increase of a good can be obtained by measuring the lowest cost alternative method of providing the same consumer good or service.

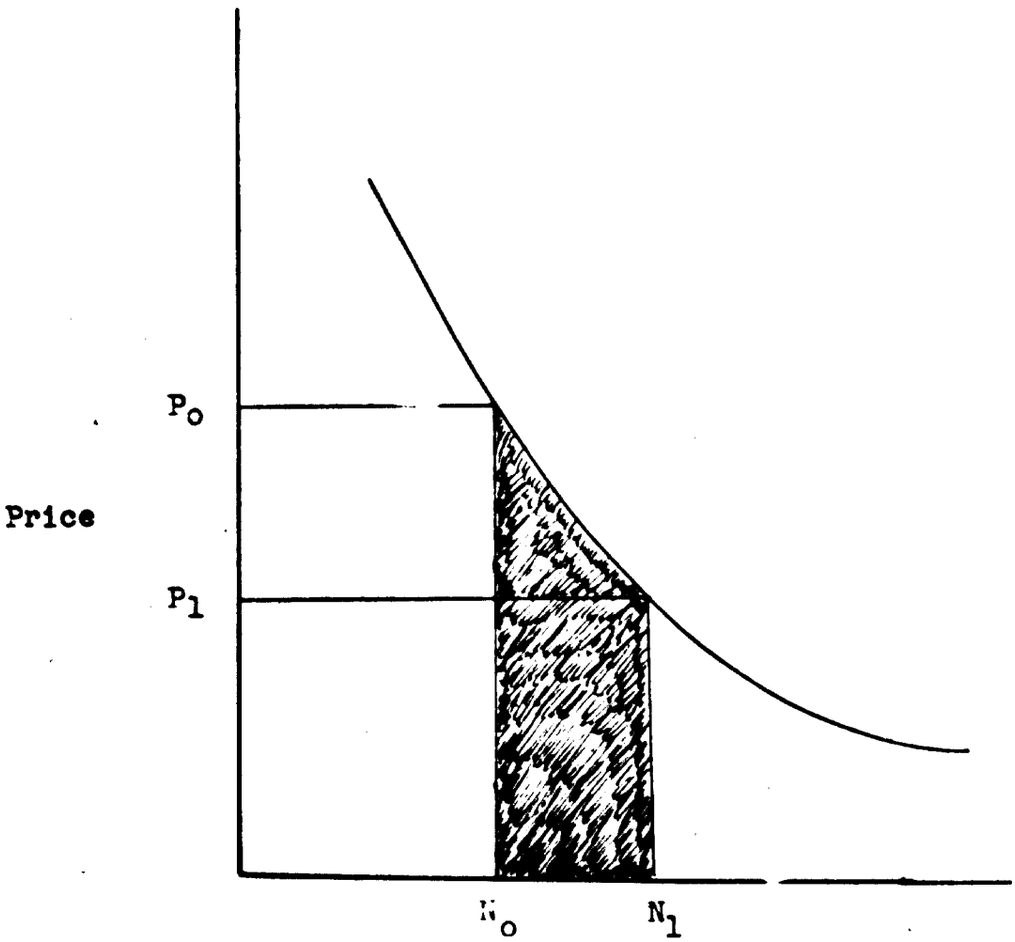
3.2.4 Willingness to pay (surplus criterion): In general, we try to shadow-price the project's output in terms of the amount consumers would be willing to pay, regardless of whether or not they are actually made to pay. This underlies each of the approaches mentioned above, except for the case where consumers had previously been paying less than the social cost of providing the good or service.

Difficulty arises in applying the 'willingness to pay' rule whenever: (i) the good is sold but the project output is large enough to cause a fall in price or (ii) the good is not sold to those who benefit from it.

Consider a project that produces shirts. Figure 1 represents the demand curve, DD, for shirts and shows the price (P_o) and output (N_o) prevailing before the shirt factory is built. Now assume that for technical reasons the project must produce a minimum number of shirts per year so that the total number would increase to N_1 and the price fall to P_1. This raises problem (i): how shall we value the (N_1-N_o) shirts? At price P_o, or P_1, or some other price? Although P_o is the price that a consumer would be willing to pay for the "first" shirt, the "last" consumer values a shirt at only P_1. Thus $P_o(N_1-N_o)$ overvalues the output while $P_1(N_1-N_o)$ undervalues it. The appropriate value would be the entire shaded area under the demand curve between N_1 and N_o. If a simple shadow price were wanted, it would not be unreasonable to use an average of P_o and P_1 (as long as the difference were not so great that non-linearity might be significant).

It must be stressed that the approach of estimating the total that consumers would be willing to pay for the incremental output - i.e., the entire consumers' surplus - is only appropriate when the incremental output is indivisible. If it were possible to produce a smaller quantity than (N_1-N_o) the use of the consumer surplus method to evaluate the entire N_1-N_o output would be inappropriate. Valuing intramarginal output in consumer surplus terms would overestimate the benefits of the project in comparison to the output of private firms.

Figure 1

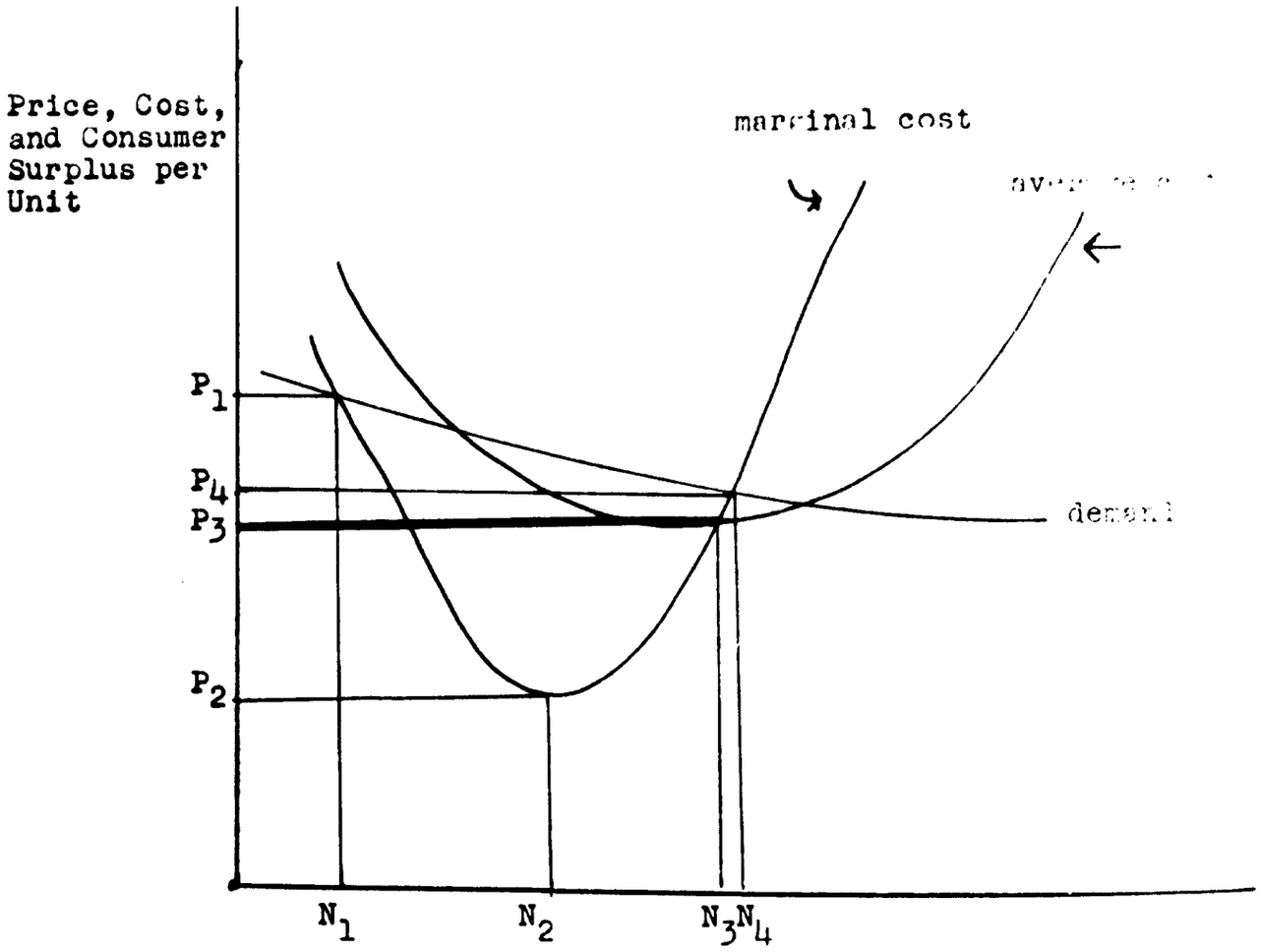


The proper shadow price is <u>generally</u> the average consumer surplus of the marginal <u>indivisible</u> block of output units. But even if output could be varied continuously, there are certain cases in which (not withstanding what has already been said) it is appropriate to value the entire output at consumer surplus shadow prices. First, if a project produces several different types of benefits in a way that does not allow the individual types of benefits to be varied separately, the smallest possible increase in one type of benefit may yield a much larger change in another type of benefit; the latter should therefore be evaluated at consumer surplus shadow prices. Second, consider a project that produces only one type of output but does so under conditions of decreasing cost. This is shown in figure 2 where marginal costs fall until N_2 and average costs until N_3. It may be that the high unit costs of a small output (less than N_1) are not justified by the benefits but as unit costs fall even more rapidly than consumer surplus per unit there is some larger scale of project at which total consumer surplus exceeds total cost. In this case the intramarginal consumer surplus is relevant. But it would still be inappropriate to extend the level of output beyond the point at which marginal consumer surplus exceeded marginal cost (N_4).

The estimation of the demand curve relevant to a consumer surplus calculation is easiest when the product is marketed. In thiscase the surplus calculation is required because the project's output causes a fall in price. As we have seen, an appropriate basic shadow price can generally be estimated as an average of the 'before' and 'after' prices.

The demand curve estimation problem is more difficult if the benefit is not sold. Although the principles of

Figure 2


Price, Cost, and Consumer Surplus per Unit
marginal cost
demand
P_1
P_4
P_3
P_2
N_1
N_2
N_3N_4
Number of Units Produced

when and to what extent consumer surplus shadow prices are relevant remain the same, the demand curve must now be estimated without direct reference to market prices. Market research type studies may indicate the prices that different proportions of individuals would be willing to pay for the benefits received. In some cases, however, this may not be possible. If individuals fear that they may be specially charged or taxed in relation to their own valuation of the benefits received they will not provide an honest assessment of the benefit's value. Even when they are not inhibited from providing an honest valuation of benefits received, many individuals may be unable to put a price on benefits of a type that they are not accustomed to buying, e.g., time saved in travel because of improved transport facilities. When, for these reasons, a direct estimate of the demand curve cannot be made, it may be possible to estimate the demand curve by observing, for example, what individuals do "pay" for time-saving in other situations.

It is, of course, easier to estimate surplus values when the project's output has only a small proportionate effect on total supply. When, in contrast, it is necessary to estimate not just a marginal section of the demand curve but the entire demand curve, a more detailed set of estimates is required.

3.2.5 Social values vs. private values: All of the approaches that have been described, including those for shadow pricing intermediate benefits, rest ultimately on the implicit assumption that any product's value is determined by the price that consumers would be willing to pay for it. There are a number of cases in which 'society' rejects the individual's assessment of a product and alters the price to the consumer in a way

that encourages consumption (free libraries, schools, health care, etc.) or discourages consumption (high taxes on alcohol and tobacco). When society acts in this way it is generally because the consumer lacks the knowledge or foresight to make the appropriate decisions. More paternalistically, the government may replace private valuations by social ones in the belief that individuals' tastes are inadequately developed to make 'right' decisions and that altering the prices that individuals pay is more efficient than using resources in advertising to educate consumers. In these cases, the appropriate shadow prices are the government's valuations of the products.

Even in the case of a project producing a single such output it may be useful to force government officials to state a shadow price (or schedule of prices) for the good. Many projects undertaken because government officials believe that the benefits are "very important" may be rejected as extravagant if a unit shadow price is explicitly stated. In more complex cases, where a project produces a variety of benefits, it is even more important that each be valued.

3.3 Special Problems:

A number of special problems have been omitted from the discussions of shadow-pricing outputs in order to keep the above discussion short and direct. We consider these problems now, more in order to indicate their existence than to provide any detailed guide to the assigning of shadow prices.

3.3.1 Availability: An individual may be willing to pay to assure that at some future time he will have the option to buy some good or service, such as admission to hospital or rail transportation between two places.

Therefore to the benefits accruing to those who will actually use a project's output must be added the total amount that everyone would be willing to pay to assure the availability of the output. Of course, availability need not be absolute. If the existence of a project of a certain size does not assure everyone of the availability of its output but rather gives them a probability of (say) one-half of obtaining the output when they want it, the appropriate value of the "availability benefit" is the amount that everyone would pay for a probability of one-half of obtaining the output. This need not equal one-half the amount they would pay for the "availability benefit" associated with a probability of one.

3.3.2 Risk Reduction: Related to the availability benefits is the notion that the reduction of risk confers a benefit. A project which (either as its primary function or as a by-product of hydroelectric power generation) provides flood control not only decreases the expected amount of flood damage but also decreases the uncertainty of those whose property is protected. Two types of benefits are therefore ignored if the flood control is valued only in terms of the decrease in expected flood damage. The nature of these benefits may be seen by considering the motives of an individual who pays an insurance premium greater than the expected value of his loss. First, because of the diminishing marginal utility of money to an individual the expected disutility of a large loss may be greater than the disutility of a small premium although the money value of the premium is greater than the expected money loss. Second, the individual prefers to reduce the uncertainty about his future 'losses' and therefore to

substitute a known stream of premium payments for an unknown stream of losses. This type of risk aversion can also be seen in the individuals' portfolio selection behaviour where assets of a given yield and risk may be preferred to others of higher yield and greater risk. Although in the case of flood control the same risk-reduction benefits could be conferred by an insurance scheme without undertaking the physical project, in other cases the project may reduce the uncertainty of specific physical benefits or losses as well as of financial losses. The provision of local hospital services provides a risk reduction that could not be provided simply by insurance against financial loss.

3.3.3 Location and Income Distribution: The government may wish, as a matter of national policy, to discriminate in favour of or against certain locations. In these cases it may be desirable to weight benefits and costs on a basis of the location of the project or of the recipients. The arbitrariness of this method, which places a tax or subsidy on public but not private projects in an area, must be recognized.

Similarly the government may wish to assign different weights to benefits received by individuals in different income classes. An implicit valuation of relative marginal utilities of income as suggested by the progressiveness of the tax structure. Policies to favour other specific groups may also be adopted.

3.3.4 'Public Goods': Economic analysis defines "public goods" as those goods the enjoyment of which by one individual does not decrease the ability of others to enjoy them. The elimination of a disease vector from an area (e.g., destruction of malaria-carrying mosquitoes) simultaneously confers benefits on everyone in that area. The

appropriate demand curve for use in assessing the benefit of "public goods" is the sum over price of the individual demand curves - i.e., the schedule telling the total amount that everyone together would be willing to pay for each additional unit provided. This demand curve is appropriate both for marginal decisions (small increments to supply) and for surplus calculations (when there are substantial indivisibilities).

3.3.5 Incommensurables and Intangibles: Although shadow prices should be assigned to benefits and costs whenever possible and an approximate value is generally more useful than none at all, there are situations in which benefits and costs should be accepted by the project analyst as incommensurable or intangible. It is important to distinguish between these two situations. An intangible benefit or cost, such as the improvement of a landscape by a park or its spoliation by a power line, is characterized by the inability to measure it on any scale. In contrast, incommensurable benefits may be measured in physical units but cannot be readily converted to money or any other common unit of measure. These include such things as decreases in death or sickness. Although the project analyst could assign arbitrary values to such benefits, it would be better to admit their incommensurable nature and describe the benefits and costs of a project in terms not only of money but also of specific physical effects. A final cost-benefit report would thus contain information about the net social value of those benefits and costs to which shadow prices can be assigned together with an itemization of the incommensurable physical benefits and costs associated with the project and a description of the expected intangible effects.

The presence of incommensurable effects makes the

final selection of projects more difficult. When the number of incommensurables is not large, choice may be facilitated by examining the sensitivity of the decision to differences in shadow prices. It may well be that for all "reasonable" shadow prices of the incommensurables the project is acceptable and superior to available alternatives. Even where this is not the case one can specify the precise value of the shadow price which will make the project acceptable or make one alternative preferable to another.

IV

PROJECT INPUTS

The set of "inputs" associated with a project should include both direct inputs (the resources used by the project) and indirect social costs (the 'negative spillovers' or 'external diseconomics') that cause inconvenience, expense, or other forms of disutility to individuals and firms other than those operating the project).

4.1 Direct Inputs:

Resources used directly by a project should be valued at their social opportunity cost, i.e., their value in the best alternative use to which they would have been put.

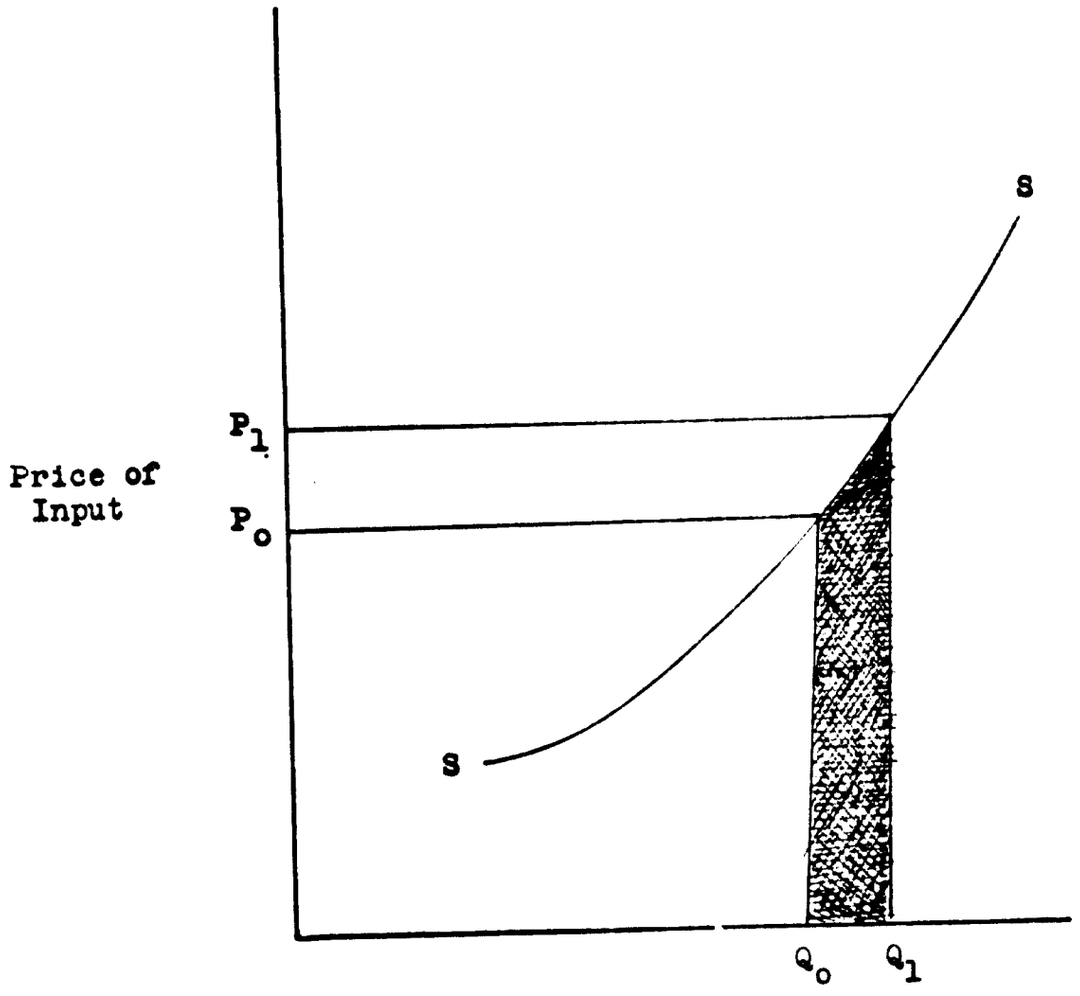
When a public enterprise buys its inputs in a competitive market, and does not buy a large enough quantity to influence the market price, the price paid can be taken as a measure of the social opportunity cost of the resources. When either or both of these two conditions - competitive market and relatively small purchases - are not fulfilled, a shadow price must be found for the inputs.

4.1.1 Government purchase altering market price: if the government purchases goods or services in a competitive market but in such quantity that the price is increased, the appropriate shadow price for each unit is the price that the government as a discriminating monopsonist would have had to pay. This type of situation may commonly arise in the hiring of local labour for a large project. In figure 3, line SS is the input supply curve. Without the input purchases required for the project the total quantity sold of the input was Q_o and

the price was P_o. The project requires an input of Q_1-Q_o, raising the market price to P_1. If P_1 were used as a shadow price for the entire quantity, the social opportunity cost of the resources would be overestimated; the converse would be true if price P_o were used. The appropriate value on the resources is the entire shaded area under the supply curve - in effect the appropriate shadow price is weighted average of the prices between P_o and P_1. For simplicity, if the price change is not great we might assume a linear supply curve and take the average of P_o and P_1 as an approximate shadow price.

If the project causes an expansion of the production of the input good in a way which yields economies of scale and consequently lowers price, the shadow price of the input good should reflect the extent to which lower cost of production reduces prices to previous users as well as to the project. In this way the case of falling price is not parallel to the case of rising price. Figure 4 shows a supply curve, SS, which slopes downward to reflect economies of scale; P_o and Q_o are the original price and quantity. The project buys (Q_1-Q_o), allowing unit costs and therefore price to fall to P_1. The direct social opportunity cost of inputs (Q_1-Q_o) is therefore $P_1(Q_1-Q_o)$, the shaded area. But this increased output has lowered the cost to previous users from P_o to P_1. The saving in resources is therefore $(P_o-P_i)Q_o$. The net social opportunity cost of the added output is therefore $P_1(Q_1-Q_o) - (P_o-P_1)Q_o = P_1Q_1-P_oQ_o$ The appropriate shadow price is therefore $(P_1Q_1-P_oQ_o)/(Q_1-Q_o)$. What if the new lower price induces additional private users to purchase the good, causing output to rise to

Figure 3

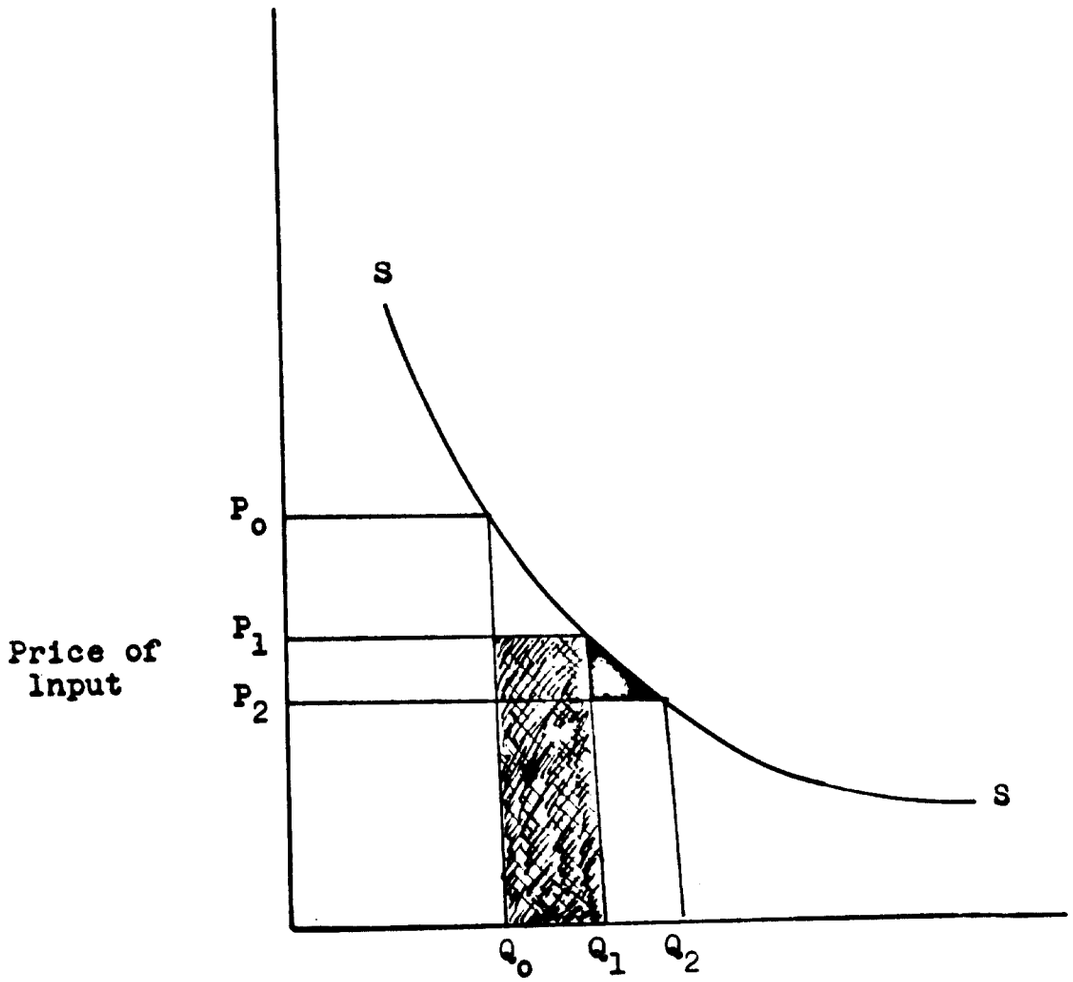


Q_2 and price to fall to P_2? In that case the direct social opportunity cost is $P_2(Q_1-Q_o)$ and the saving of resources consumed by the original purchasers is $Q_o(P_o-P_2)$. The total paid for the new private purchases, $P_2(Q_2-Q_1)$ underestimates their value to the purchasers. The extent of underestimation is at least equal to the black triangle between the supply curve and P_2 line above the (Q_2-Q_1) segment: it may be more if some of these private purchasers would have been willing to pay a price above P_1. In this case, therefore, the maximum net social cost that should be associated with the project's purchase of (Q_1-Q_o) is $P_2(Q_1-Q_o) - Q_o(P_o-P_2) - \frac{1}{2}(P_1+P_2)\ (Q_2-Q_1) = P_2Q_1-P_oQ_o-\frac{1}{2}(P_1+P_2)(Q_2-Q_1)$.

(The reader may note that the asymetry between rising and falling costs rests on the assumption that where costs are rising price equals marginal cost but when costs fall with output price equals average cost.)

4.1.2 Taxes and Subsidies: When a project input is bought in a competitive market and in small enough quantities to leave price unchanged, the appropriate shadow price is the market price, including any indirect taxes or subsidies that are included in the price, that private firms would have to pay. For example, the shadow price for fuel or labour should include any indirect fuel tax or payroll tax. This assures that resources will not be used in a project unless they are as productive as they would be to private users. If, however, the inputs to the project are not taken away from private users but rather constitute a net increase to national supply, taxes and subsidies should be ignored. If fuel imports are increased to provide

Figure 4



an input for the project, the shadow price of the fuel should not include any import duty. If there is a separate policy to discriminate against imported inputs by using a special shadow price for foreign exchange, this general foreign exchange shadow price but not the specific tariff on fuel should be taken into account. Although this does mean that the marginal productivity of fuel will not be equal in the public and private sectors, that is a necessary consequence of suboptimizing under the constraint that private producers pay a special tax on fuel imports. The relevant shadow price is always the social cost of the inputs or if it is higher, their productivity in the alternative use to which they would be put under prevailing market conditions and tax structure.

4.1.3 Non-competitive Markets: This brings us directly to the question of what shadow price should be put on inputs purchased from firms that are price makers. If government use causes a decrease in private use, the market including monopoly profit should be the shadow price because it measures the productivity of the resources in their former use. But if the government's demand causes the monopolist supplier to increase output, the situation is more complicated. When the quantity produced is changed, average cost of production will change and, for small increases in output, will decrease. If the monopolist leaves the price to the previous purchasers unchanged, the social cost of the increased production for use as the project input should be calculated as the net addition to the monopolist's costs. Thus if average cost falls from C_o to C_1 when output increases from previous sales (Q_o) to the new total

sales (Q_1), the social cost of the additional output is approximately $\frac{1}{2}(C_1+C_o)(Q_1-Q_o) - Q_o(C_o-C_1)$. The demand for the project's inputs can be viewed as a shift in the product's demand curve. If the monopolist does not irrationally keep his price unchanged, the result of this will be to change the quantity purchased by non-project users. The exact result will depend on the nature of the project's demand curve and the previous demand curve as well as on the specific cost curves. But in the situation that may be most likely, the price will fall and non-project use expand. In this case the net social cost is the manufacturer's cost of the project inputs minus the fall in cost of producing the original non-project quantity minus the excess of the value of the additional non-product use over its social cost.

In these cases it is clear that a single shadow-price on the inputs is not appropriate. Rather the project analyst should be seeking a shadow cost for the total purchase of inputs.

4.1.4 Unemployed Resources: If otherwise unemployed resources - usually labour or land - are to be used in a project, their social opportunity cost is zero and a shadow price of zero should be assigned to them. This may be especially important in an underdeveloped country or in a period of long-term unemployment. A not uncommon mistake is to measure the cost of otherwise unemployed labour as the difference between the wage rate and unemployment compensation benefits paid by the social security system. Although this does indicate the additional money payments required in order to hire labour, it does not reflect the social opportunity cost of the labour. More generally, if labour (or land)

is being paid a wage (or rent) exceeding its marginal productivity, it is the marginal productivity and not the wage that should be taken as the social cost of taking labour from its previous employment.

This rule should be qualified in three ways: First, if it is possible to employ the "unemployed" resources in some use other than the project - e.g., to stimulate employment by private producers - the productivity of labour in this alternative use and not zero is the most appropriate social opportunity cost. But even if it would be possible to find productive employment for currently unemployed labour, the required action may be outside the jurisdiction of the project administration. The relevant suboptimizing decisions then requires taking the opportunity cost at zero.

Second, if employing labour requires additional expenditure on food, clothing, and shelter - particularly likely if unemployed labour is moved from rural to urban areas of an underdeveloped country - it may be appropriate to treat these expenses as part of the real social cost of the labour. But although this is undoubtedly an increased consumption of real resources, there are two reasons why it may be appropriate to disregard these. First, it may be possible to produce these goods with other unemployed labour; this is the traditional Keynesian case. Second, it may be argued that the food, clothing, and shelter are not merely necessary supplies to the worker (like tools) but do add to his level of well-being.

Third, an unquestioning application of the zero shadow price rule for direct labour inputs would bias evaluation in favour of labour intensive and vertically

integrated projects. If unemployed labour can be used in producing intermediate goods for the project those goods should be valued at a shadow price less than market price, with the difference equal to the wage component of the otherwise unemployed labour. All labour inputs, direct and indirect, should be valued at the same shadow price.

4.1.5 Other Direct Input Problems: Project inputs that are already owned by the government should be shadow priced at their value in the best alternative use. Replacement cost is not necessarily the appropriate value: it will be so only if the input good is sold in the market under conditions which make market price equal the input's marginal revenue product.

Inputs purchased from abroad or which otherwise might be exported have a foreign exchange value that may deserve a premium over the value indicated by official exchange rates. See section 6.2.

4.2 Indirect Social Costs:

A project may cause others to incur inconvenience, discomfort, or expenditure. The shadow price appropriate to these indirect social costs ("external diseconomies") is the price that those who suffer them would be willing to accept as compensation and feel neither worse off nor better off.

Measurement is easiest when those affected do make expenditures that make them as well off as they were before. In general the evaluation is similar to measuring the consumer surplus accruing to benefit recipients. A simplified example will illustrate the principle. It is proposed that an airport should be built. If this is done, those who live in the area must suffer the discomfort of airport noise. How should

this discomfort be evaluated? One approach would be to consider the expected fall in residential land values in the area. The extent of this fall might be predicted on the basis of experience with previous airports. A second approach, which would provide an upper limit to the appropriate shadow price for that part of the noise thus eliminated, would be to use the cost of sound-proofing the homes so that the noise could not be heard in the house. This might, of course, be impossible, in any case it would only relate to noise within houses and not out of doors. The consumer surplus method requires drawing up a schedule of the amounts that the home-owner would be willing to pay to prevent building the airport, or, equivalently, would be willing to accept as "full compensation" if it were built.

V

SHADOW PRICES FOR INTERTEMPORAL CHOICE

Until now we have disregarded the problems of time, tacitly assuming that all benefits and costs occur in the present. In practice the problems associated with the timing of benefits and costs are extremely important. Significant public investment choices, arising in both the design and final decision stages, require intertemporal evaluations. Should we use a technique of production that requires large capital investment but has low operating costs (e.g. nuclear generation of electric power) or would the opposite 'time profile' of expenditure (conventional power generation) be preferable? Should we select a project with a constant stream of net benefits or one which produces few benefits in early years but greater benefits later? Should we postpone all or part of a particular investment, such as building a narrow road now and widening later?

Time affects our project evaluation in three ways: (i) changes in the market prices of benefits and costs; (ii) the relatively greater desirability of consumption in the near future than consumption in the more distant future; (iii) the possibility of alternative productive investment of the funds used in a public project and of the benefits received from the project. Each of these aspects of the 'time problem' has been the subject of extensive discussion among economists. Although the literature that has evolved is too complex for summary here, some of the basic issues can be reviewed.

Changes in the absolute level of prices (i.e. a uniform change in all prices), for example a general inflationary trend, can be ignored and all calculations made as if the current level of prices remained unchanged.

Not so for changes in relative prices. If some prices are likely to change relative to others this should be reflected in the cost-benefit calculations. For example, it would be reasonable to expect that wages will continue to rise relative to the prices of manufactured goods, raw materials, etc. In calculating the future costs of a public project, this relative price change should be taken into account. Other goods may change in price because of changes in the demand for them (due, for example, to the introduction of other new products or to a change in tastes brought on by higher standards of living) or in their supply (due for example to changes in technology, import regulations, etc.).

5.1 Social Time Preference :

The first and most basic aspect of intertemporal comparison is the measurement of the relative desirability of consumption in different years. In general, as individuals we prefer consumption in the near future to consuming something of the same market value in the more distant future. This preference may reflect an irrational bias in favour of the near future but it also corresponds to the more rational calculation (i) that our incomes are rising and thus decreasing the significance of any given quantum of consumption and (ii) that death may intervene before the more distant date. Although it may be inappropriate for the government's intertemporal calculations to reflect the purely irrational short-sightedness of individuals and their personal expectations of death, it is reasonable for society as a whole to recognize that the standard of living is rising and that benefits and costs in the more distant future should be given less weight. Establishing a specific quantitative

relationship between the significance of a one dollar benefit (or cost) today and a one dollar benefit (cost) in a future year is an important prerequisite of cost-benefit analysis. The social time preference rate for discounting consumption is a basic 'external' shadow price. Economic analysis can help to elucidate the relation among factors that should influence the selection of such a social time preference rate - the rates of growth of consumption and population, the 'pure' time preference (discounting future utility merely because of its futurity), and the assumed elasticity of the utility function - but the specific choice rests on the adoption of parameters that must reflect public policy.

5.2 Social Opportunity Cost of Capital:

If the government is able to influence the rate of private investment, it should pursue a policy which makes the marginal social rate of return on private investment equal to the social time preference rate. This may, however, not be politically possible or may be an aim toward which government policy has been directed but which will not be achieved for a number of years. If so, the social productivity of private investment may exceed the social time preference rate.

In this case, intertemporal choice requires considering not only the relative desirability of consumption at different times but also the use to which those funds would have been put in the private sector. In particular, funds withdrawn from private investment should be valued at a shadow price equal to the present value of the consumption stream that would have resulted, both directly and indirectly, from the foregone investment. This shadow price for the social opportunity cost of private investment will therefore reflect the social rate of

return on private investment and the social time preference used for discounting the resulting consumption streams.

When changes in private investment are measured in terms of this shadow price, the benefit and cost stream of a project can be unambiguously evaluated by using the social time preference rate.

5.3 Budget Constraints:

If the agency does not have to operate under any budget constraint but is able to obtain sufficient funds for all projects that it demonstrates are "worth doing", the proper basis for project appraisal is the net present value of the generated social benefits minus social costs. A project is "worth doing" if this net social benefit is positive: as between two mutually incompatible projects that one should be selected which has the greater net social benefit.

If, however, the agency's budget is limited so that there are insufficient funds to do all projects that have positive net social benefits (and are not inferior to other incompatible projects), different criteria of project choice must be used. In effect, a shadow price of the constrained agency funds must be selected.

The appropriate shadow price of a constrained agency's funds is the ratio of net social benefit to constrained funds expected to prevail on the marginal project. In practice this could be estimated on the basis of past experience. It is a measure of the amount of net social benefit that could be obtained by the agency if it had an extra dollar of funds. This shadow price should be recognized as an "internal" shadow price - internal not to the project but to the agency. A similar problem arises when any input is

"rationed" to agencies. Internal shadow prices for each of these factors should be calculated by each agency as the basis for their own choices. The use of these "agency's own shadow prices" in improving the original allocations is discussed in Section 6.3.

VI

SOME TECHNICAL NOTES

6.1 Shadow Prices and the Linear Programming Dual:

Consider the problem of a firm (project) that produces one or more outputs and uses several inputs. At least one of the inputs is available in only limited quantity and the firm has no opportunity to buy any additional quantity or sell any excess not used; we shall refer these inputs as "non-purchasables". The values (prices) of a single unit of each output are given. The production process can be described in terms of a fixed amount of each input required per unit of each output. The problem of the firm enterprise is to maximize the total net value of the output (the value of the output minus the cost of the resources which are non purchasable bought) subject to the constraint inputs. The solution of this maximizing problem implies, in general, that while there is slack (excess unused quantities) of some of the inputs, other inputs are effective constraints on output. We may then ask of each input: what price could be paid by the enterprise for an additional unit of the input so that the increased output made possible would have a value equal to that input price? For those inputs for which slack exists, the price would be zero (i.e. there would be no value to additional quantities of input) but for those inputs which were binding constraints on output a positive price could be paid. This is the shadow price of the linear programming dual associated with the maximizing problem. A second interpretation of the shadow prices would be: what prices could be paid for the non-slack inputs so that the total shadow cost of

non purchasables in the production just equalled its net output value; the shadow price of the slack inputs is again implicitly zero.

6.2 On the Use of Import- Export Prices:

If the domestic markets in intermediate and final goods do not provide a suitable basis for constructing shadow prices, their part in the analysis can sometimes be taken by world market prices - import or export prices depending on whether the good is imported or exported. Indigenous non-tradeable resources - labour and land - should be shadow-priced at either their marginal productivity in the production of exports (or import substitutes) or at zero if they are unemployed. The calculation of marginal productivities may not be practicable on an economy-wide basis. But in those countries in which domestic market prices are unsuitable as a basis for shadow price calculation (primarily the underdeveloped countries), it may not be unreasonable to assume that the appropriate shadow price for labour is zero.

If it can be assumed that the aggregate levels of both consumption and investment have previously been determined, so that all marginal capital comes from abroad, it may be rational to evaluate inputs, both capital and returned, at their foreign exchange cost, and outputs at their export selling price. This simple form is only appropriate where both import and export prices are insensitive to quantities bought and sold; otherwise the procedure would be to use the marginal cost and marginal revenue respectively.

A problem arises in the case where the inputs to a particular project as initially defined include non-tradeable items, such as electricity, transport or

residential services, which have an import component. In these cases it can be assumed that a certain amount of extra capacity, say, in generation, roads, railways, or houses, will be needed and this will have a specifiable tradable import content which should be added into the project as originally narrowly defined. In each case it is important only to charge the appropriate extra cost to the project. It may be that the project requires an amount of electricity which it would be costly to generate for that purpose alone but if the plant can be located near other users of electricity it may be the difference between the cost of 195 and 100 megawatt stations that is relevant not the cost of a 5 megawatt station.

Similarly if population and housing standards are given there will only be any relevant "township" costs if the import content of the township varies from site to site.

It should be re-emphasised here that it is inconsistent to use foreign prices for making investment decisions and domestic prices for employment and output decisions. It is even worse to use foreign prices for investment decisions on the false assumption that they will also be used for recurrent decisions. For instance it might well be that agencies were allowed to retain their foreign exchange earnings. In such a case they would have a very strong incentive to export if they were maximizing their foreign exchange "profit". If the planners were to assume this to be the agency's objective, they might frame an optimistic estimate of future foreign exchange earnings for the economy as a whole which would be completely invalidated, if concerns in fact maximize "profits" at domestic prices.

6.3 Iterative Multistage Factor Shadow-Pricing:

In this paper we have generally assumed that market prices provide not only a starting point for the determination of shadow prices but also the basic allocative mechanism in the economy as a whole. In any particular economy this may not be true for one or more inputs such as labour, capital, foreign exchange, or specific raw materials in short supply. In such cases an alternative to market allocation is the administrative allocation by the central planning agency to sub-agencies responsible for projects in particular fields. To perform this function efficiently, the central agency would have to know the value of each type of resource if employed in the next most productive use in each sub-agency's field. The central planning agency is unlikely to have sufficient technical information to ascertain these values by itself. One administrative solution is to make arbitrary allocations of the inputs to the sub-agencies. Each sub-agency could then calculate its own "internal shadow prices" of the rationed factors in the way described for capital in section 4.3. These internal shadow prices would be the result of project evaluations in which project outputs were valued at "external shadow prices" laid down by the central agency.

The sub-agencies would notify the central planners of their internal shadow price for each factor. The central agency could then redistribute the rationed factors from those sub-agencies having a lower internal shadow price to agencies with a higher shadow price. After the redistribution, the sub-agencies again could calculate their internal shadow prices and simultaneously determine the set of projects that they would undertake if this were the final allocation. In the light of the second set

of internal shadow prices, the central planners might want to make a third allocation and the process could in principle be repeated until, for each factor, the internal shadow price was the same in all agencies.

This process might also be repeated at lower levels; each agency's internal shadow price being the result of an iterative allocation of its resources to particular plants.

The effective implementation of this procedure would probably be very costly administratively but would ensure an optimal allocation of the resources in question and the selection of an optimal set of projects.

BIBLIOGRAPHY

Burknead, J. — Government Budgeting, New York: John John Wiley & Sons, 1956.

Chakravarty, S. — The Logic of Investment Planning. Amsterdam: North Holland Publishing Company, 1959.

_____"_____ — "The Use of Shadow Prices in Programme Evaluation," in P.N. Rosenstein-Rodan (ed.), Capital Formation and Economic Development. London: George Allen & Unwin, 1964.

Dorfman, Robert. — "Basic Economic and Technologic Concepts," in Arthur Maass, et. al., Design of Water Resource Systems. Cambridge (Mass): Harvard University Press, 1962.

Eckstein, Otto — "A Survey of the Theory of Public Expenditure Criteria," in James M. Buchanan (ed.), Public Finances: Needs, Sources and Utilisation. Princeton: Princeton University Press, 1961.

_____"_____ — Water Resource Development. Cambridge (Mass): Harvard University Press, 1961.

Feldstein, M.S. — "Net Social Benefit Calculation and the Public Investment Decisions," Oxford Economic Papers, March 1964.

_____"_____ — "The Derivation of Social Time Preference Rates," Kyklos Vol. XVIII, 1965.

_____"_____ — "The Social Time Preference Discount Rate in Cost-Benefit Analysis," Economic Journal, June 1964.

Feldstein, M.S. & Flemming, J.S. — "The Problem of Time Stream Evaluation: Present Value versus Internal Rate of Return Rules," Bulletin of Oxford University Institute of Economics and Statistics, February 1964.

Hufschmidt, Maynard M., Krutilla, John, Margolis, Julius, and Marglin, Stephen, A. — Report of the Panel of Consultants to the Bureau of the Budget on Standards and Criteria for Formulating and Evaluating Federal Water Resource Developments. Washington: June 1961 (unpublished).

McKean, R.N. Efficiency in Government through Systems Analysis. New York: John Wiley and Sons, 1958.

Marglin, Stephen A. Approaches to Dynamic Investment Planning. Amsterdam: North Holland Publishing Company, 1963.

———"——— "The Opportunity Costs of Public Investment." Quarterly Journal of Economics May 1963, No. 2.

———"——— "The Social Rate of Discount and the Optimal Rate of Investment," Quarterly Journal of Economics, February 1963, No. 1.

Massé, Pierre Optimal Investment Decisions: Rules for Action and Criteria for Choice. Englewood Cliffs, N.J.: Prentice Hall, Inc. 1962.

Nelson, J.R. (ed.) Marginal Cost Pricing in Practice Englewood Cliffs, N.J.: Prentice Hall, Inc., 1964.

Papanek, Gustav F., and Qurechi Moeen A., "The Use of Accounting Prices in Planning," in Organisation, Planning, and Programming for Economic Development. Vol. VIII of United States Papers prepared for the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas. Washington, D.C.: U.S. Government Printing Office.

Peacock, A.T. (ed.) Public Expenditure: Appraisal and Control. Edinburgh: Oliver & Boyd, 1963.

Qayum, A. Theory and Policy of Accounting Prices. Amsterdam: North Holland Publishing Company 1960.

Rosenstein-Rodan, P.N. (ed.) Pricing and Fiscal Policies. London: George Allen & Unwin, 1964.

Samuelson, P.A. "The Pure Theory of Public Expenditure," Review of Economics and Statistics, 36, November 1954.

Weisbrod, Burton A. "Collective-Consumption Services of Individual-Consumption Goods," Quarterly Journal of Economics, August 1964, No. 3.

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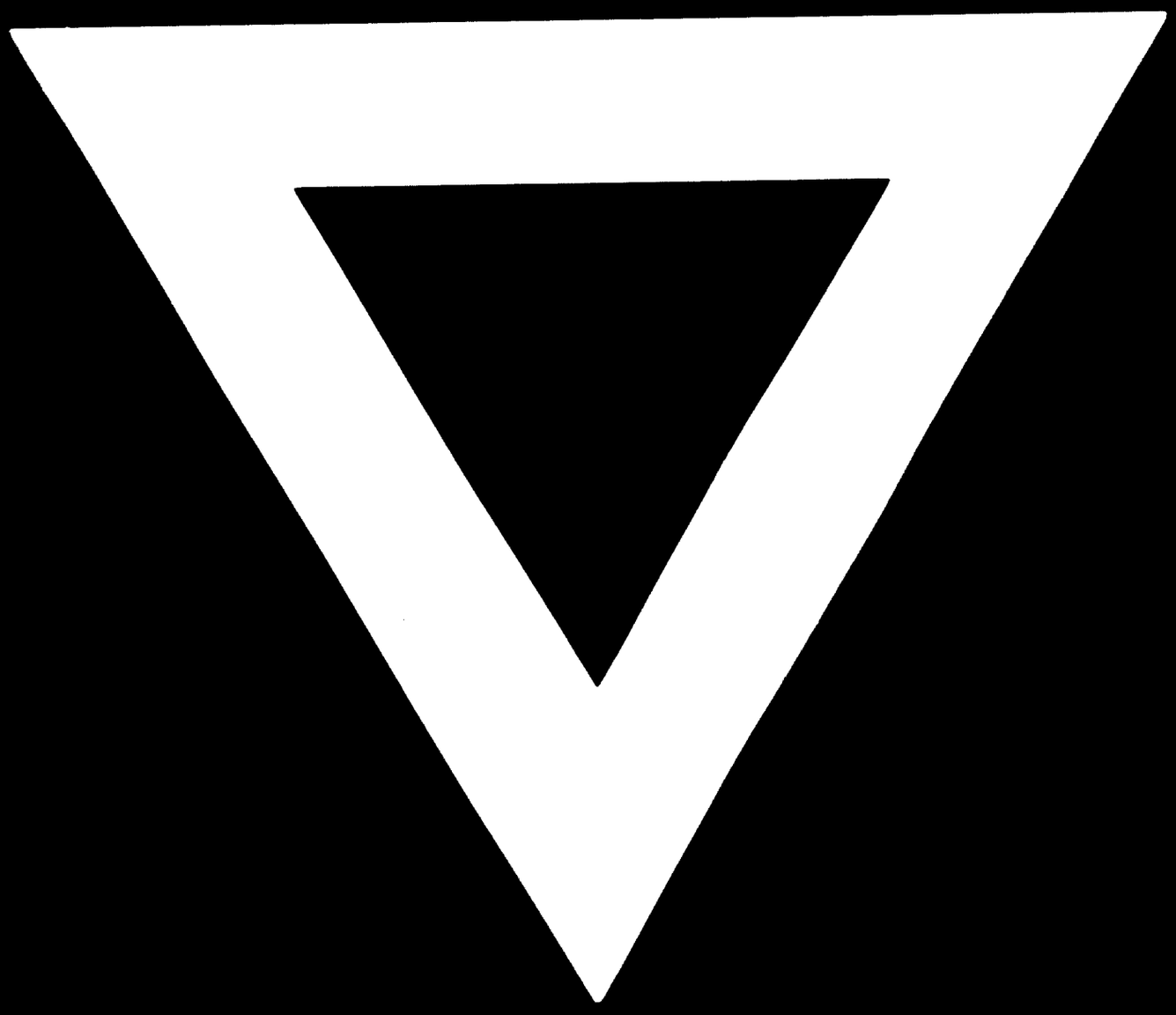

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