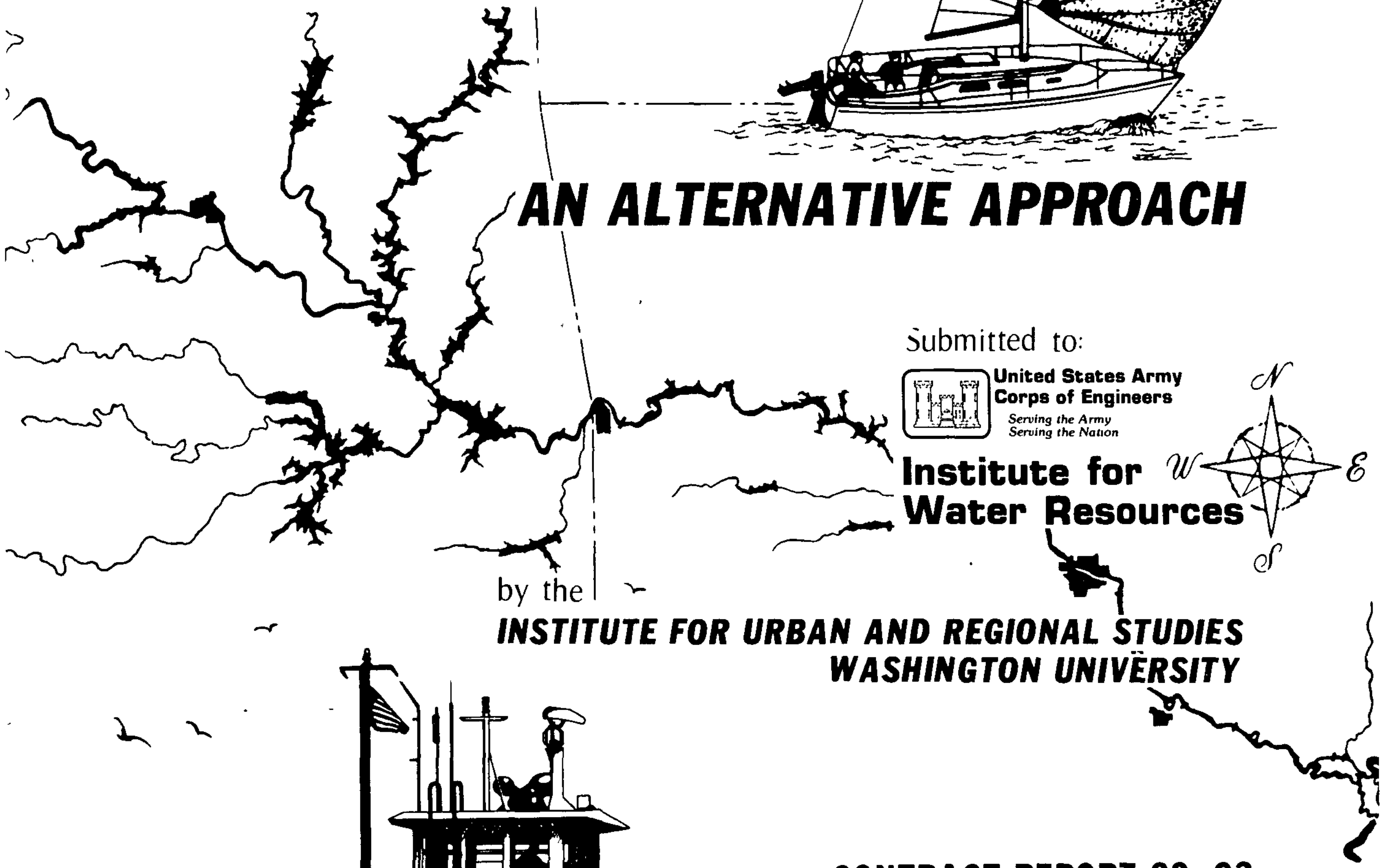
ESTIMATING ECONOMIC DEVELOPMENT IMPACTS:

AN ALTERNATIVE APPROACH



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Institute for Water Resources

by the

INSTITUTE FOR URBAN AND REGIONAL STUDIES
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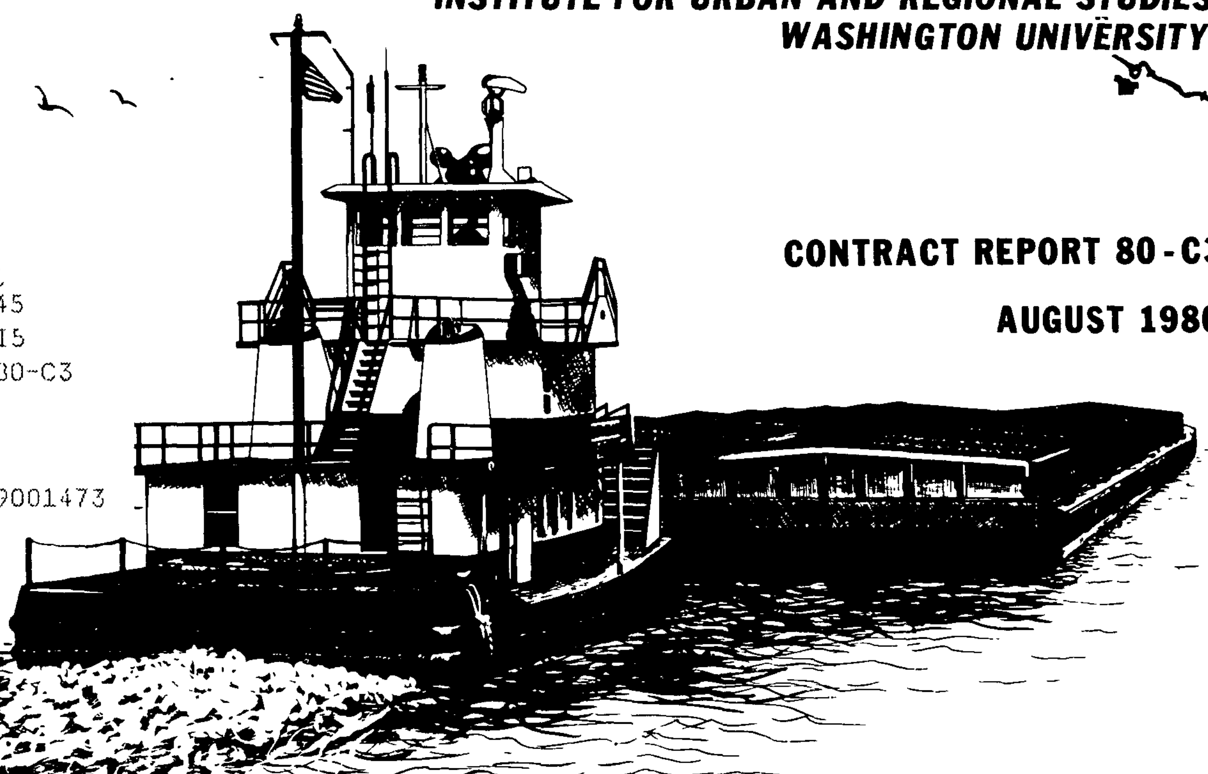

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This report is a comment on an alternative approach to estimating economic development benefits from water resources projects. This discussion is concerned only with economic impacts, which can be separated into two categories - direct or primary benefits, and secondary or equilibrium benefits. In the final section the authors comment on the methodology developed as applied to U.S. Army Corps of Engineers projects.

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ESTIMATING ECONOMIC DEVELOPMENT IMPACTS; AN ALTERNATIVE APPROACH

a report
submitted to

Institute for Water Resources
U.S. Army Corps of Engineers

by

Institute for Urban and Regional Studies
Washington University

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August 1980

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FOREWORD

This report is a comment on an alternative approach to estimating economic development benefits from water resources projects. In the final chapters the authors discuss the application of the model to the U.S. Army Corps of Engineer projects.

The report was prepared by the Institute for Urban and Regional Studies, Washington University, St. Louis, Missouri and is based on an extensive analysis effort undertaken by Edward Grennberg, Charles L. Leven, James T. Little, and Robert P. Parks of Washington University. Final editing and preparation for publishing was accomplished at the Institute for Water Resources, by Dr. L. George Antle and June Fratus.

INTRODUCTION

Federally financed investments have a variety of impacts on the immediate region in which they are located as well as on larger territories, including the whole national space. The analysis and description contained in this report pertain to only one of these kinds of impacts, and only at the level of the impacted region.

Specifically, impacts can be separated into: construction impacts, which stem from the expenditure and resource use associated with the building of the project facility; and project impacts, which stem from the existence and operation of the project facilities once completed. This report is concerned only with project or "equilibrium" impacts. To some extent, criticisms of traditional methods of estimating project impacts could be extended to construction impacts, though they are generally less important.

Current legal requirements and current practice call for estimating three kinds of project impacts: social, environmental, and economic. This discussion is concerned only with economic impacts, which can be separated into two categories. First there are direct or primary impacts, or more commonly "benefits." These refer to the economic value of the services stemming directly from the facilities that are consumed by private users; examples are recreation, water supply, or flood control. The primary benefits refer to the value of the recreation experience, the value of increment to water supply actually consumed, or the value of the reduction in flooding, typically measured by the market value of increased output on the floodplain or increased land value of the floodplain itself. In addition, there may be "secondary" or "equilibrium" effects of the existence of a project. These refer to the increased output (under assumptions of prior full-capacity utilization) and increased investment in private activity capacity associated with increased use of the project facilities. The value of swimming is a primary benefit; the value of increased output of hotel services coming from a demand by tourists coming to swim is a developmental impact. In this sense, this report is confined to a concern with developmental or "equilibrium" effects.

Finally, developmental impacts may be of a regional or national (extra-regional) nature. Using the example above, the stimulation of more tourist facilities in one region might arise out of a change in the regional pattern of recreation demands resulting in reductions in tourist facilities elsewhere. Under other circumstances there might be no offsetting adjustments in other regions. The concern is with the developmental impact on the region technologically affected by the project, not on extra-regional or national effects. While these important effects are not included directly in the consideration, some of the related economic welfare concerns are discussed.

Section II presents a critique of the typical approach to estimating economic developmental impacts, concluding that traditional Leontief-type calculations are valid under some circumstances. The next section presents an outline of a more general theoretic approach. It is not sufficiently general to include all possible cases that might arise, but it has considerably more application than the traditional approach which assumes fixed proportions on all inputs in all production processes. Section IV considers the practical problems of making actual impact estimates within the framework suggested in section III. The argument is that a practical estimating plan can be formulated to cover cases where factor substitution is occurring and factor proportions are not constant. On the other hand, it is pointed out that moving to estimating systems where the assumption of constant returns to scale can be dropped is exceedingly difficult. Section V discusses the problems of data availability and comments on the scope of effort required to generate a data base that would permit estimates of the type sketched out in Section IV. Section VI deals with some of the complications that might arise when distinguishing between economic impact as measured by changes in Gross Regional Product (GRP) and economic welfare of the affected region. These distinctions are relevant for policy decisions with respect to a single region; they are more relevant in a context of concern over extra-regional or national, as well as regional impacts. Finally, Section VIII comments on the methodology developed as applied to U.S. Army Corps of Engineers projects.

CRITIQUE OF TRADITIONAL METHODS

The impact that a water project has on a region is varied. There are two major types of impact: the investment impact due to the construction of the project and the "equilibrium" impact due to a change in the region's structure made by the project. The variables which are impacted include the factors of production, production techniques, aggregate demand, industrial composition, and more loosely the quality of life, or environment.

Investment Impact

The investment impact of a project is due to construction. The construction of the project causes a one time expenditure of funds and these funds will have both a direct and indirect impact on the region. In order to estimate the investment impact, a Leontief fixed coefficient production is assumed for the region. The matrix of coefficients is derived either by a survey technique or estimated from national tables which detail inter-industry flows of commodities in value terms. The direct impact is the expenditure of funds on the project and may be disaggregated into industry groupings as fine or coarse as the investigator wishes. This analysis also forms the basis for the indirect impacts, which are calculated using the coefficient matrix and the vector of demands, or expenditures, made by the project.

The indirect effects have been usually estimated by one of two methods, either a successive rounds approach or by using the Leontief inverse of the coefficient matrix. The rounds approach calculates the amounts of expenditures in each industry, and then, using the coefficient matrix, the amounts needed in each industry to produce the original amount of expenditure. If 100 dollars of steel are directly needed for the project, using the vector of input coefficient requirements in the steel industry, the amounts of iron ore, energy, etc. needed to make the 100 dollars of steel can be calculated. A second round then calculates the amounts of iron ore, energy, and so on. The number of rounds generally is no greater than 5 or 6 in this type of analysis.

The second approach, more common with the amount of computing capacity generally available, is to calculate the Leontief inverse of the coefficient matrix and then multiply by the vector of industry expenditures needed to build the project. This is equivalent to calculating an infinite number of rounds. The Leontief inverse of the coefficient matrix, usually denoted $(I-A)^{-1}$, determines the product or commodity multipliers. From it can be determined the amounts from each industry that a $1 increase in production in a given industry will require. Adding these amounts will yield the total impact, in dollars, that a one dollar increase in any industry would generate. If the vector of expenditures for the project is multiplied by the Leontief inverse, and then summed, the total impact of the investment project is yielded.

Income and employment impacts (and multipliers) are also determined in this manner, using the vector of household coefficients multiplied by the Leontiel inverse, or determing the employment coefficient vector and multiplying by the Leontief inverse. The employment coefficients may be estimated naively as the average wage, or by employment functions, where employment is related to production. Of course the basis of all this analysis is the Leontief inverse of the coefficient matrix.

There are two major assumptions implicit in these calculations. First, it is assumed that the production of the region emerges from a fixed coefficient technique, i.e., substitution of inputs, either raw or produced, cannot occur. Second, demand determines supply. The supply of all factors of production is assumed infinitely elastic. If it is determined that 100 dollars will be expended to build the project, that 100 dollars will buy the needed materials, and all the material will be supplied. The model is "Keynesian", where no attention is given to the question of where the needed factors will come from, or whether there is sufficient capacity in each industry. Whether an industry were operating at full capacity, or at half capacity, the same results will be obtained since capacity constraints are ignored in the analysis.

This latter assumption is probably more objectionable than assuming fixed coefficients of production. If the investment is a large percentage of the gross regional project (GRP), so that the impact would be great, it would seem that labor at least would need to be imported, unless there was substantial unemployment or under utilization. Of course, regional analysis has been refined to account for the fact that many products of the region that are consumed must be imported. But these trade coefficients are not related to capacity in the region or in other regions. As has been understood for some time, but is sometimes lost sight of, if there is no unemployment and all industries are operating at capacity, then the analysis of the investment impact is quantitatively false and qualitatively erroneous at best. Depending on the degree of unemployment, the errors will be less; but none the less, an appropriate model should account for capacity limits in some way.

For investment impacts the absence of capacity or employment constraints may not be so restrictive, depending, of course, on the size and timing of the investment. It may be reasonable to assume that a small project will take up the slack in the regional economy, especially if it occurs over a long period of time. But if there is no slack, then the amounts determined from the Leontief inverse will be upward biased.

Long-Run Equilibrium Impact

The second impact is equilibrium - the long run effect on the region due to the existence of the project after its construction. The equilibrium impact is measured in terms of the change in gross regional product due to the project. This measure may ignore other impacts, such as environmental or quality of life changes, that are not accurately reflected in the markets used to determine GRP. These other impacts could be incorporated in the analysis but at great expense,- so are ignored here.

Essentially, the Water Resources Council format of a separate "accounting" for regional economic impacts is followed.

Within this tradition, however, other measures than just total change in GRP might be used; for example - GRP per capita or per laborer. The trouble with per capita or per worker measures, however, is that they raise questions concerning the distribution of income among factors. In general, the distribution does change, both within the region, and even inter-regionally where there is absentee ownership of industries. Measuring on the basis of GRP per capita (or laborer) requires the additional analysis of changes in the distribution of income. Rather than complicate the analysis with such considerations the impact is measured by the percent change of GRP in this part of the report. Income distribution and welfare questions are discussed later in the report.

Unlike the investment impact, where the impact is mainly due to the expenditure of funds to construct the project, the equilibrium impact is due to a change in the infra-structure of the region. The infra-structure of a region consists of: technical relations of production (e.g., the Leontief coefficient requirements matrix), the endowments of factors of production (e.g., labor, waterways, recreational areas), the prices of the factors of production (e.g., wages for labor, prices of land, etc.), the tastes or demands of the consumers of the region's products, and the trade patterns with other regions. The trade patterns may be an indirect part of the structure derived from the demand patterns, technical relations of production in the region and trade. In other words, except for the influence of changes in technical relations in some other region, the trade patterns are affected through changes in technical relations in the region, factor costs, factor endowments, or demands for final products. Assume that the project does not affect the technical relations outside the region and the trade relations are affected indirectly by the project rather than directly.

Any effects on the final demand for products in the region can be ignored. Such effects could occur, much like the "demonstration effect" discussed in development economics. There, a new product is presented in a country, and by its existence, demand is created. This would then change demand for other products. Assume that the project cannot affect demand directly, although it might have an indirect effect through changes in factor prices and/or output prices in the region. Hence the infra-structure of concern in determing the impact of a project is the technical relations of production, the factor costs, and the factor endowments.

A project might increase the endowments of factors used in production. A project which increases the educational level of the labor force can be thought of as increasing the amount of (skilled) labor in the region. A water project can be thought of as changing the amount of waterways (or transportation facilities), the amount of usable land, or the amount of recreational facilities in the region. These factors existed in the region before the project, and the project affects the structure of the region by altering the amounts of these factors available for production of final or intermediate goods.

Less clear is how a project might affect factor costs. In the cases above - waterways, land and recreational facilities - a water project may lower (raise) the cost of those factors rather than increasing (decreasing) the amounts of them. But in that case a point to argue, in a direct way, is just exactly how the factor costs are changed. If the project provided a subsidy for the use of some factor, then there is a direct effect on the factor cost to producers, and hence the project has affected factor prices directly. But to argue that the provision of a waterway project affects factor costs is much more an equilibrium argument. Dams on the project make floodplain land usable for agriculture, and hence lower that factor cost, i.e., the cost of land. But this is not necessarily so, since the price of the factor land will be bid up to the price of land nearby which already is used in agriculture. The equilibrium resulting will probably have land at the same price as before unless so much land was made usable as to affect the price of agricultural output itself and hence the derived price of land. If the region is rather small and the goods produced are traded, factor costs are not affected in equilibrium.

Still it may be argued that the provision of a waterway lowers the cost of transportation in the region rather than increasing the regions' endowment of the factor "transportation." This may also be true of recreational facilities. These effects will be discussed in the following text. The model developed must be able to analyze the effect of a factor cost change in the region's infra-structure due to a project.

Input Coefficient Requirements

The third possibliity of an infra-structure change in a region due to a project is a change in the technical coefficients of production, or more appropriately the input coefficient requirements of the inter-industry table. This effect should be separated from the two cited before: changes in factor supplies or prices. Firms may change their techniques due to changes in factor endowments or factor prices. This changes the input coefficient table as it is calculated for a region, but it is an effect of changes in the endowments or prices rather than a direct change in technology due to the project.

This is explained by considering a production frontier for a region. In equilibrium, before the project's existence, the amounts produced are determined by the output prices. These output prices also determine the factor prices. If the project shifts the frontier, but does not affect factor endowments, then the project has affected directly the technology of the region. Of course, the point chosen on the new frontier may require the same input coefficients, which happens if the output prices are not affected (or if the factor costs are not affected). This impact is different in appearance at least, from the impact due to changing the factor endowments, factor prices or output prices.

The frontier will shift if the endowments are changed, just as it will shift if new technologies are implemented. The results from either shift may be the same: i.e., either laborsaving technology or more labor may be created by the project. The more productive labor is equivalent simply to more labor in efficiency units, with the same results and a much less complex format.

In other cases, a movement along the old frontier will result from changed prices. This is quite different from a shift in the frontier although end results might be the same -- at least they will be hard to distinguish *ex post*. If the factor costs are changed, then firms will try to substitute away from factors which are relatively more expensive. This will change the input coefficients at the new equilibrium, and of course the GRP will change due to this result. But here the input coefficients "changed" due to substitution in the existing technology rather than due to a new technology, as such.

Impact analysis of equilibrium effects in the past failed to carefully distinguish this difference. The impact was in part determined by estimating the new industries that would come to the region due to the project (and its effects on factor costs in the region). A new transactions table would be estimated taking into account the new industries indirectly attracted to these industries. From this transactions table new inter-industry coefficients would be determined and from this matrix, given an estimate of final demand, the total impacts could be calculated using the Leontief inverse of the inter-industry coefficient matrix. Although the input coefficients "changed," it was due to estimated effects of changed factor costs. In the model the difference between the shift of the frontier and the movement along it will be carefully distinguished.

In summary, there are three ways in which a project can affect the infrastructure of a region: *by changing factor endowments*, *by changing factor prices*, or *by changing the technology of a region*. Each will be treated in the following text in a model of a region to see the effect of a project.

A MORE GENERAL MODEL OF ECONOMIC IMPACT[1]

The gross regional product of a region is defined as the sum of prices times the final outputs of the region.[2] The equilibrium impact of a project will then be taken as the change in gross regional product due to the project. Although GRP may be increasing for other reasons, consideration is given to the static model in which the only effects are those due to the project. The effects of the project are changes in technology, factor prices, or factor endowments. The impact is measured as the percent change in GRP due to the changes in the infra-structure.

What follows is a two-factor, two-good model. The results easily generalize for cases in which the number of factors is equal to the number of goods. In case there are more goods than factors, which is the usual situation, it is unknown whether the results developed still hold. In actual application, the nature of available data determines the number of factors and goods. The unequal case is an area for further research.

The Model

In the model, labor will constitute one factor and land, waterways, or recreational sites another factor. This allows an examination of the impact of a project by considering it to affect the factor endowment or price of the second factor, or the input coefficient or production. The two goods will represent a range of goods in the real world, one good intensive in the use of labor and the other intensive in the use of the factor which the project affects. This is a rather gross simplification but as a first attempt at examining impacts by infra-structure changes it yields many tangible results.

The model is constructed as one where outputs are produced directly from the factors rather than as an inter-industry model with intermediate goods. With an inter-industry model, impacts to each industry can be assessed, of course, but concern is with the total impact; the relative rate of change in gross regional product and not in the mix of industries which creates it. Of course from an inter-industry model, one can construct the more basic model of gross output as a function only of factors, which implicitly takes into account the inter-industry coefficient requirements. For example, if the model has two goods, manufacturing and agriculture, and two inputs, labor and land, the Leontief model constructs a 2 column

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[1]The model developed is an application of the theoretical model developed in R.N. Jones, The Structure of Simple General Equilibrium Models, JPE, Vol. LCCIII, #6, Dec. 1965,pp. 557-72

[2]Prices are to be interpreted as net of payments for imported inputs.

(manufactured goods and agricultural goods) by a 4 row (manufactured goods, agricultural goods, labor and land) matrix, the amounts of labor and land needed to produce manufactured goods can be determined from the direct requirements of labor and land in manufacturing, i.e., the last two rows. Since production is of the fixed coefficient type, the input requirement coefficients cannot be determined and it is the matrix of those coefficients which determines the technology of the model. These calculations should be regarded as net of imported inputs throughout the remainder of this discussion.

As mentioned above, the Leontief model is fully determined only with the addition of information on final demand. Knowing the input coefficient matrix and its Leontief inverse, the amounts of the goods produced (gross) and the amounts of factors consumed can be determined. The model is a general equilibrium model or production. It is determined by two sets of relations. First, there are full employment relations for each factor. These can also be viewed as the factor requirement relations. For this analysis, though, assume full employment of all factors. This is due to the fact that if some or all factors are unemployed and the project increases their quantities, there is no impact except to increase unemployment of the factors. This is rather trivial, and the more interesting case is the use of fully employed factors. The two other relationships are derived from a zero profit condition in production. This could be regarded as a consequence of a linear homogeneous production, or more basically, just an assumed zero profit condition, so that all revenue is distributed to factors of production. These conditions relate the factor prices and the output prices by the input coefficients of production. The output price must be equal to the sum of the input coefficients times the factor prices for zero profit to occur.

These four relations, two full employment conditions of factors and two zero profit conditions for the goods produced, determine the equilibrium of the system. A complete specification is given by the four input coefficients, the two factor endowments, the outputs of the two goods, the two factor prices and the two output prices. The impact of a project will be the effect on the input coefficients, the factor prices, or the endowments and the resultant change in GRP.

Gross Regional Product

The percent change in GRP can be measured as a weighted sum of the relative changes in prices and outputs, the weights equal to the percent of GRP for each good. This relationship is quite simple but very important as it shows that GRP will increase relatively faster for increases in goods which account for more of the GRP. For example, increasing the production of a good which makes a small contribution to GRP will not cause a large percent increase in GRP. Also, it should be noted that the relative increase in GRP is less than the relative increase in the value of any one good. If the impact of a project is to increase the output of agriculture by 20% in value, but agricultural output is only 20% of GRP, then the relative increase in GRP will only be 4%.

The analysis of impacts begins with the assumption that the project does not affect the technology of the region. In a water project, this may be a valid assumption. It seems hard to believe that the technology of a region (or the country as a whole) is changed when a water project is built. Some technology might be developed in the building of dams or creation of new waterways, but it would apply to building of other waterways or dams and not to the technology used to produce products in the region. With a project like the space program, arguments can be made that the technology of the country will be affected by the project in a direct manner. Electronics technology was greatly enhanced by putting a man on the moon, which had effects on hand-held calculators and computer technology. But for a water project there does not seem to be any significant direct technology change with the provision of the project.

Assuming no direct project induced technological change allows a much simpler structure of the relative rates of change in the variables of interest (factor costs and output prices, endowments and output levels) to be derived. From the condition of no technological change, it can be shown that the percentage change in endowments is equal to the weighted sum of percentage break-up changes in output and that the percentage change in output prices is equal to the weighted sum of percent changes in factor prices. This is due to the fact that with unchanged technology, firms will minimize unit costs which are the sum of the factor costs weighted by the factor coefficients. The firm is assumed to treat costs and prices as constant (competitive behavior), and hence the firm will adjust input coefficients so that the sum of the percent changes in factor costs, weighted by the share of costs, is zero. This is a familiar result of profit maximization or cost minimization, i.e., that the ratio of percent changes in input coefficients will be equal to the negative of the ratio of percent shares in cost.

The percent change in output prices is equal to the weighted sum of the percent changes in factor costs, the weights equal to the shares of cost. This is quite important since it implies that factor prices will not change if output prices do not change. If the region is small, or what is the same thing, if the goods produced by the region are a small part of the national total, then it is reasonable to assume that the output prices remain fixed or do not change upon the introduction of the project. The three main assumptions used to derive this conclusion are no technological change due to the project, cost minimizing behavior on the part of industries, and regional output being small or having negligible effect on the prices of the products. This means that if a project does affect factor costs in a direct way, these factor costs will then be bid back to their pre-project levels so that output prices do not change.

Besides the two relations between output prices and factor prices (in percent change terms) there is another relationship between the outputs of goods and the factor endowments. The percent change in the endowments plus the percent saving due to factor cost changes equals the weighted sum of the percent output changes, the weights being equal to the percent of each factor used in each industry. The argument above shows that factor prices will not change unless ouput prices change, from which still another relationship emerges, namely that the percent change in the endowments is equal to the weighted percent change in the outputs. This is a dramatic conclusion.

It is true of a Leontief technology where the input coefficients cannot change due to cost minimizing behavior. But it is also true of any (unchanging) technology where output prices, and hence factor costs, do not change.

In this case the impact of a project is assessed. Suppose that the project will increase the endowment of waterways in the region; and assume that this is the direct affect of the project, and not a lowered factor cost of the waterway. The factor cost of the waterway, if there is competitive behavior, will be determined from the output prices of goods produced using the waterway, and not from the project itself. This is even more realistic when one considers that waterways are generally used without user charges. The "economic rent" firms receive by using them can be modeled as a factor cost, and this factor cost would change only if output prices changed.

The effect of increasing the endowment of waterways will shift the production frontier. But the input coefficients will not change, or what is the same thing, firms will adjust to the old coefficients. The quantity of the good which is relatively intensive in the use of waterways will increase in percent terms a greater amount than the percent increase in waterways. This is known as the magnification effect in the theory of international trade . If the project does not affect the other factor of production, then the percent change in its endowment is zero. This leads to a decline in the production in the output using the unaffected factor relatively intensively. At unchanged commodity prices, an expansion of one factor and one factor alone leads to an absolute decline in the production of the good intensive in the factor which does not change.

The impact of such a project can be positive (increasing GRP) or negative (decreasing GRP). Whether there is an increase or decrease depends upon the factor intensities in production and the share of output of the two goods. Following is a hypothetical example to show the conclusion.

Let 50% of the existing waterway be used in the production of each of the two goods - steel and food. Also, let 20% of the labor force be employed in the steel industry and 80% in the food industry. The matrix of these factor usage percents in then:

$$\begin{pmatrix} .5 & .5 \\ .2 & .8 \end{pmatrix}\begin{pmatrix} S^* \\ F^* \end{pmatrix}=\begin{pmatrix} T^* \\ L^* \end{pmatrix} \quad \text{or} \quad \begin{pmatrix} 8/3 & -5/3 \\ -2/3 & 5/3 \end{pmatrix}\begin{pmatrix} T^* \\ L^* \end{pmatrix}=\begin{pmatrix} S^* \\ F^* \end{pmatrix}$$

Where S^* and F^* are the percent changes in steel and food, and T^* and L^* are the percent changes in waterways and labor. If the provision of the project increases the amount of waterways by 100% and does nothing to the amount of labor, then for this example, steel would increase by 267% and food would decline by 67%. If steel accounted for less than 20% of gross regional product, then GRP of the region would fall (note the sum of .2 times 2.67 minus .8 times .67 is zero). The determinants of the relation are easy to estimate, being the percents of factors used in each industry, the percent increase in the endowment of the affected factor, and the shares of GRP for each industry.

The model can be complicated somewhat by allowing demand for the goods to be a function of their prices. In general the ratio of the output prices will determine the ratio of the amounts demanded. With this relation added to the model, adding to the factor endowments can change the output prices and the factor prices. The end result is that the expression for the percent changes becomes modified to be, in the example presented:

$$\begin{pmatrix} S \\ F \end{pmatrix} = \begin{pmatrix} 8/3 & -5/3 \\ -2/3 & 5/3 \end{pmatrix} \begin{pmatrix} T \\ L \end{pmatrix} + \begin{pmatrix} e_S \cdot (P_S^* + P_F^*) \\ e_F \cdot (P_F^* - P_S^*) \end{pmatrix}$$

Where e_S is the percent change in output of the steel industry associated with a 1 percent rise in steel's relative price along the given production frontier times the difference of the relative (percent) price changes (steel minus food), and e_F is defined similarly for output elasticity of food.

To summarize the discussion to this point, a project might affect a region's infrastructure through: 1) an increase in endowments; 2) changes in factor costs; and, 3) changes in technical coefficients.

There seems to be no convincing reason to believe that the typical Corps activity would lead to a change in the underlying technology. Of course, a change in input usage resulting from a change in relative factor prices is not considered to be a change in technology. The latter term is reserved for changes in the production function, and such changes are likely to result from research and development devoted to new products or production processes. Thus, we do not further consider this type of change.

The possibility that a project may affect factor costs has been noted. If the region is small relative to the size of the market in which it buys and sells, it may be assumed that changes in the region's outputs will not affect output prices. Therefore, factor prices will not change, which in turn implies that input coefficients are not changed. There is a difficulty with this formulation which requires further research: although it may be reasonable to assume that changes in a region's output which result from a Corps project will not influence the market prices of those outputs, some Corps projects may affect transportation prices which, in turn, may affect the delivered prices of intermediate and final goods.

Substitution Between Local and Imported Inputs

In general, changes in the prices of intermediate goods will induce substitution between locally available inputs and imported inputs. Thus, the availability of cheap transportation may induce firms to import intermediate inputs formerly produced with local labor and other local resources. Short of complete substitution, of course, firms may find it possible to produce at lower costs by substitution at the margin between local and imported inputs. If this possibility is considered to be significant for particular projects, methods must be developed to estimate the changes in the resulting coefficients. In practice, it is hard to say how important this effect will be and it will no doubt vary greatly from region to region. Thus, it is not likely, given the economics of scale in its production, that a region was producing its own steel before cheaper transportation became available and switches to imported steel because water transportation becomes available. Moreover, imported intermediate goods may take the form of raw materials which are not found in the region.

One special case of the effect of a change in transportation costs is worth examining. If the production technology is such that imported goods must be used in fixed proportion to output and if they are not available locally, the analysis is simplified. This case may not be unusual. It would arise, for example, if a raw material or fuel necessary to the production of some goods is not available locally and must be imported. Conceivably, the import is used in fixed proportions to output. In this case, a reduction in transportation costs may be viewed as a subsidy to producers, where the amount of the subsidy per unit of output depends upon the import-to-output ratio and the relative change in transportation costs. If the amount of the "subsidy" can be determined, the model can be used to predict the resulting change in GRP. However, additional parameters must be estimated compared to the case in which the only effect of a project is a change in resource endowments.

Complications introduced by changes in final goods prices are considered later with the welfare effects of changes in GRP. Conceptually, it can be argued that changes in the imported final goods do not change GRP, which depends only on local production. However, such changes will affect the economic welfare of the region's inhabitants.

The following is a detailed discussion of the estimation of the percentage change in GRP brought about by a change in resource endowments. Figure 1 may aid in understanding the model. In this Figure, the axes represent inputs, and $\bar{L}$ and $\bar{T}$ are the beginning endowments. The line through the origin labeled S (F) indicates increasing outputs of good S (F) as more inputs are used. Thus, point S_2, being twice as far out on S as point S_1, represents twice as much output, obtained from twice as much of each input. This happens because of the constant returns assumption. The slopes of the lines S and F indicate factor input proportions. If fixed proportions are assumed, these are the only possibilities; if variable proportions are assumed, other slopes are possible for S and F, depending on factor prices.

The point A, which occurs at ($\bar{L}$, $\bar{T}$) is of special interest. It occurs at full employment of both factors, hence it is the point which will be observed according to our general equilibrium assumptions. Given the production possibilities (S and F) and the full employment of factors (point A), the model determines the quantity of each product to be produced and the quantity of each input used to produce each output. These points are found by starting from A and drawing a line parallel to S (F) until F (S) is reached. GRP is then computed by multiplying each output by its price, assumed to be determined in the larger market.

Assume that the major effect of a Corps project is to change one or more of a region's endowments of primary factors. For example, additional recreational areas are opened, or more water transportation becomes available. As a first approximation, a perfectly elastic demand is assumed at the market price for the region's outputs. Thus, changes in real outputs are weighted by current market prices.

Imagine that a Corps project shifts the endowment of only input T, so that the horizontal line $\bar{T}$ is shifted upward to $\bar{\bar{T}}$. (See Figure 2) Assuming no change in technology or $\bar{L}$, it is easy to see that a new full employment point A', will result, and that this will necessitate a change in the composition of production. In fact, in this simple case the result will be an increase in the production of F and a decrease in the production of S. (Note that output F is, relatively speaking, a more intensive user of T than is output S.) Thus, the effect on GRP of the new project is determined in this model by finding the new composition of output and valuing it at market prices, compared to the original value of GRP.

Model Limitations

Before turning to the data required for implementation, two qualifications should be noted. First, the model does not predict how long it will take for a new equilibrium to be reached. Second, the model is cast in terms of percentage rates of change, not absolute amounts, relative to the starting point. That is, the model predicts the initial direction and rate of change in GRP from its starting point. The qualifications arise partly because results from the model are based on derivatives which are defined in terms of "small" (infinitesimal) changes in endowments, although actual changes are not; and partly because parameters other than endowments are likely to change over time, so that results are presented as instantaneous rates of change before other parameters change.

Regarding data requirements, the appendix shows that the following equations illustrate the rates of change for the example described:

$$\begin{pmatrix} S^* \\ F^* \end{pmatrix} = \begin{pmatrix} \lambda_{LS} & \lambda_{LF} \\ \lambda_{TS} & \lambda_{TF} \end{pmatrix}^{-1} \begin{pmatrix} L^* \\ T^* \end{pmatrix}$$

$$= \frac{1}{\lambda_{LS} - \lambda_{TS}} \begin{pmatrix} \lambda_{TF} & -\lambda_{LF} \\ -\lambda_{TS} & \lambda_{LS} \end{pmatrix} \begin{pmatrix} L^* \\ T^* \end{pmatrix}$$

or

$$S^* = \frac{1}{\lambda_{LS} - \lambda_{TS}} \left(\lambda_{TF} L^* - \lambda_{LF} T^* \right)$$

$$F^* = \frac{1}{\lambda_{LS} - \lambda_{TS}} \left(- \lambda_{TS} L^* + \lambda_{LS} T^* \right)$$

where

S^* = rate of change of output S (steel)

F^* = rate of change of output F (food)

L^* = rate of change of input L

T^* = rate of change of input T

λ_{LS} = fraction of input L used in producing output S

λ_{LF} = fraction of input L used in producing output F
($\lambda_{TS} + \lambda_{TF} = 1$)

λ_{TS} = fraction of input T used in producing output S

λ_{TF} = fraction of input T used in producing output F
($\lambda_{TS} + \lambda_{TF} = 1$).

Thus, to obtain estimates of S^* and F^*, it is necessary to estimate the percentage changes in the endowments (T^* and L^*) and the shares of these endowments used (before the change) in producing each output. Data availability is discussed below. S^* and F^* would then be weighted by their respective shares of GRP to obtain an estimate of the rate of change of GRP.

As long as the number of outputs equals the number of inputs, the above results are easily generalized with straightforward matrix algebra. As above, the rates of change in each output are linear functions of the rates of change of the endowments, and the rate of change in GRP is found by weighting the rates of output change by shares of GRP.

Impacts on Market Prices

Still confining attention to the effects of changes in factor endowments, examine the case in which demands are not perfectly elastic. That is, it may happen that a change in endowments changes output sufficiently that a change in market prices results. This might occur if the region is a very large supplier to the national market of some outputs or if some output is used only locally (nontraded good), and a significant change in quantity occurs. In this case, at the cost of greater data requirements, the resulting rates of change in output may be estimated. For example, if all residents have the same preferences, and these preferences are homothetic (proportions of income spent on various commodities are independent of the level of income), the rate of change in an output, S, can be expressed as:

$$S^* = \frac{1}{\lambda} \left[\left(\lambda_{TF} - \frac{e_S}{o_S + o_D}\right) L^* - \left(\lambda_{LF} - \frac{e_S}{o_S + o_D}\right) T^* \right]$$

where the new symbols are defined as:

e_S = the percentage change in the quantity of S associated with a 1 percent rise in S's relative price along a given production frontier.

(e_F is defined analogously).

o_S = the elasticity of substitution between commodities along the production frontier.

o_D = the elasticity of substitution between the two commodities in demand.

$\lambda = \lambda_{LS} - \lambda_{TS}$ (assumed to be positive)

It can be shown that e_S and e_F may be expressed as functions of the λ_{ij}'s already defined, each factor's share of the output in each industry, and the elasticities of substitution between inputs for each output. In particular, if there are fixed coefficients, $e_S = e_F = 0$, and the equation for S^* reduces to the previous expression.

It is believed that significant changes in factor proportions will occur, it may be possible to use existing estimates of substitution elasticities to compute the e_i's. These have been estimated for many factor and output combinations.

The above formulation takes into account changes in input and output prices which arise from the interaction of endowment changes and demand functions. It does not take into account any induced change in the labor supply, L. This could occur via migration or changes in labor force participation in response to a changed rate of return to labor. In principle it could be handled by the model in the same way as a change in any factor endowment, but the change in L would have to be specified outside the model from estimates in the migration or labor force participation literature. Making induced labor supply change endogenous to the model is formally possible, but only at the cost of greatly increasing the difficulty of obtaining impact estimates.

Major Economic Issues

Before turning to data availability and the problem of inferring changes in economic welfare, the following review of the major econometric issues in implementation of the model is necessary.

1) For the case in which (i) one or more of a region's endowments changes because of a Corps project, (ii) relative input proportions do not change, and (iii) output prices do not change, the problem is straightforward for the case in which the number of inputs equals the number of outputs. It is necessary to know the distribution of inputs among the various outputs and the rate of change in endowments. To the extent there are possible measurement errors in any of the variables, it would be simple to compute the change for combinations of values which would provide a range of estimates. Derivation of the small sample statistical properties of the estimate would not be trivial, however, as the estimator depends on the inverse of a random matrix.

2) For the case in which transportation costs are lowered as a result of a Corps project, the analysis is manageable if it can be assumed that the intermediate goods, whose delivered price is lowered, are used in fixed proportions and were not previously available locally. In this case, the reduction in transportation costs is equivalent to a subsidy to producers, and the analysis goes through fairly easily. However, estimates of substitution elasticities are required.

More work needs to be done on the case in which lowered delivered prices of intermediate goods will lead to substitution against local inputs.

3) The most complex case which arises in this framework is that in which output prices and input proportions can be expected to change because of endowment changes. This occurs if demands are not perfectly elastic. This problem requires additional parameters, some of which have been estimated in previous research. The more it is necessary to rely on such estimates, which are subject to estimation error, the more uncertain the forecasts become. As before, derivation of statistical properties will be difficult.

In addition to its role in forecasting the effects of a project, results of previous projects which changed endowments might be examined to see whether predictions of the model can be verified, and whether output changed in the expected direction might be tested, depending on data availability. Also, of special interest to the Corps, would be the effect on GRP of an increase in recreational facilities. For this particular output it may be desirable to examine effects on demand rather than assume all impacts can be captured through changes in endowments, since provision of such facilities may result in a significant lowering of the cost of recreation to a large number of users. Since recreation uses are frequently a large component of Corps' projects, this problem merits special treatment.

DATA REQUIREMENTS

The data needed to estimate relationships as those described in the preceeding section pose a data collection effort that would not be more difficult or extensive than the kinds of data efforts presently undertaken for impact analysis; in fact they would seem to call for less rather than more data to be collected. Also, for the most part the data needed would be neither more complex nor ultimately more difficult to collect than that frequently collected by division and district offices of the Corps. It is, however, a different approach which requires working with non-typical sources and constructs not normally considered. These differences probably can be seen most easily by going through the categories of data that would be required. In doing this, we will first consider data on regional variables. These would consist of: a) Gross Regional Output, b) Gross Regional Product, c) factor and basic endowment inputs to GRP, d) unit prices of outputs, factors and endowments, and e) regional stocks of factors and endowments. Next, we consider data for estimating parameters, mainly price elasticity of demand for regional products and elasticity of substitution between factors and endowments in regional production functions. Finally, we consider related to questions about observations across sectors, regions and time periods, and the implications of aggregation strategy for the scope of the data collection effort.

Gross Regional Output

The most fundamental data requirement is to obtain estimates of gross regional output independent of estimates of regional employment. Unfortunately, employment data are much more available at a regional level than are output data, and where there is an analytical need for dimensioning variables in output terms, approximate figures for output are often derived as multiples of employment figures. However, since allowance for possibilities of factor substitution is part of the impact, this kind of simple inflating of employment data by sectoral or national employment-output ratios cannot be done. This makes this part of the data requirements seem very difficult. Difficulties will be involved, but not as extensive as might be first supposed. The major simplification is that with little loss of reability, estimates are made of gross output as a multiple of employment for any sector where factor substitution would not occur as a consequence of the project. While there might be some more distant general equilibrium effects, for most projects independent estimates of output would not be required for any categories of trade, service, finance, insurance, and real estate. Moreover, directly observable data on output in agriculture, mining, and public utilities normally exist, even at a regional level, from existing federal data sources. This means that the difficult problem is reduced to getting some estimate of output in construction and manufacturing independent of employment. For construction this could be patched together from various kinds of building permit data, though this would require dealing with various and non-standard data sources. For manufacturing, the best source is the re-tabulations of Annual Survey of Manufacturers' Data. However, this source does not contain output data for individual counties, both for disclosure and sampling reasons.

In general, the impact model described here is almost never estimated at an individual county level or anything near that small. On the other hand, it could be applied to fairly large multi-county areas not following state boundaries. Thus, it seems possible to develop a retabulating capability in the Bureau of the Census that could recombine the Annual Survey on an as-needed basis, without violating disclosure rules. For census of manufacturers' years, of course, a pretty close fit could be obtained from normally published tabulations.

Gross Regional Product

The basic determination of economic development impact would be in terms of GRP. This is in contrast to a more traditional setting where impact is most often in terms of jobs, payrolls, or sometimes output, but with the latter usually a transformation of labor input. This also poses a difficulty, but not a serious one. Since the interest is only in percentage changes in GRP, a fairly rough estimate of GRP based on gross output is acceptable so long as the ratio is consistent over time. The direct way of estimating this is to subtract imported intermediate good inputs to the region. From the standpoint of data availability this is not remotely practical.

Alternatively, GRP will be estimated as simply the sum of returns of factors of production and endowments. Labor's contribution can come from quarterly covered payrolls and employment data, as in County Business Patterns, with some adjustment for non-complete coverage. Payments to capital and land will be made as county apportionments of Department of Commerce estimates at the state level. Returns to other endowments (government), in general, are simply indirect tax and nontax payments (also derivable for multi-county areas from state level estimates), but returns to the specific endowments represented by the project in question should be included much more explicitly. For example, where transportation services are part of a project, the total sales of such services to business users in the region should be accounted for. Similarly, where electric power is a project output, its sales should also be accounted for. But these later kinds of specialized input accounting should not pose real problems. They are not, in general, estimable from standard data sources, but should be available in some form as part of the project's operating reports itself.

Within this context regional imports of intermediate goods are simply the difference between gross output and GRP.

Factor and Endowment Inputs

In essence these levels are determined implicitly in the value-added calculations needed to get to estimates of GRP. They differ from the value-added components, however, in that they are in physical rather than value units. For labor services this poses no problem in that the physical unit (for annual reporting units) is simply man-years of labor employed. In most cases this could be satisfactorily, if roughly, approximated simply by employment, averaged over the year or for a representative date. Inputs of project-related endowments, such as ton-miles of transport, kw of electric power, ft^3 of drinking water, acre-feet of irrigation water, etc. are to be determined ad hoc, but again, should be knowable from project management records. Data on physical level of capital services as opposed to value added attributable to capital simply cannot be collected as a practical matter. As indicated in the following paragraph, unit price will be assumed to be equal to the national unit price (rate of return). Thus, its physical quantity could be derived from that price and the regional aggregate value added by capital.

Unit Prices

The unit prices of labor are made implicit in the calculations above, and the unit price of capital services is assumed equal to the national average rate of return. Unit prices of project related endowments are directly obtainable from project records, though some problems of aggregation will be encountered. For example, there is not a single ton-mile price for shipping goods by barge on a river system; rather there is a very complicated tariff structure. Nevertheless, some reasonably defensible weighted aggregation of these tariffs is possible. The same would be the case for unit prices for outputs of very aggregated sectors of production. Dr. Larkin Warner of the Kerr Foundation made some estimates of this type for commodities moving on the McClellan-Kerr navigation project. His methodology can be extended to get unit price estimates for any of the output aggregates for which estimates are required.

Estimates of Stocks of Inputs and Endowments

These are probably the easiest of all the data requirements to implement. For labor it is simply the size of the region's labor force. Changes due to migration or different labor force participation, while analyzable, must be specified outside the model. For capital, the size of the stock really is not known, but it does seem fairly safe to assume that its supply to the region at the national rate of return is close to infinitely elastic. Stock of project-related endowments must be estimated as well as the various service capacities of the project.

In principle, parametric estimates of the equations in the model are made by generating a sufficiently large set of observations on the variables, as described above, after a long tradition of the kind described here is established. In general, however, this is not feasible in the foreeeable future. Accordingly, the equations reported above in Section IV should be regarded much more as computational formulae than as estimating equations, at least until a much richer supply of regional output, product and input data are developed. Of course, where constant returns to scale are assumed the computations are not difficult. In that case marginal factor productivities and the expected change in GRP can be calculated from single observations on the model's variables as described above. Where it seemed desirable or necessary to assume variable returns to scale, a vastly more complicated situation is present that, in general would require a vastly more price elasticity of demand for the region's outputs and the elasticity of substitution between factors and endowments in the region's production functions. Here only ad hoc estimates of these parameters from existing studies seem at all practical. Many such estimates are made for situations like those found in a given context such as the Arkansas basin. In other cases, the most reasonable proxy available must be used. Admittedly, for the non-constant return-to-scale case the empirics are crude. But they should be unbiased, and, this case cannot be handled at all under traditional approaches to economic impact estimation.

In principle, more formal parametric estimation is obtained by generating sufficient observations across sectors, regions, or time periods. In time, such possibilities no doubt will emerge, but not in the foreseeable future. Thus, carrying out the analysis with more, rather than less, sectoral and geographic detail seems to produce no increase in statistical reliability. True, in some cases project evaluation calls for estimates of economic impact on a particular sector or small area. Since project regions normally follow topography rather than state boundaries, the basic data base must be carried at the county level to permit reasonably conforming multi-county aggregations. Also, since the role of particular inputs may be a radically different technological relationship in different sectors, the analysis probably should be carried at a 2-digit level in agriculture, mining, manufacturing, and transportation, communication and transportation, communication and public utilities, and at a one-digit level elsewhere. Since all practical data are reported for annual periods, finer time disaggregation is probably neither supportable nor necessary.

WELFARE IMPLICATIONS OF ECONOMIC IMPACT ESTIMATION

The foregoing disucssion assumes that any change in GRP is observed unambiguously -- which is so, at least in principle -- and that the change in GRP necessarily is a change in real GRP -- the latter may not necessarily be so. To a considerable extent the potential ambiguity of GRP as an index of economic welfare is related to the distinctions between primary and secondary benefits. It is standard practice to distinguish between these two types of benefits of public involvement projects. The first category -- primary benefits -- are taken to be the "value" of the goods or services directly produced as a result of the increase in the capital endowment embodied in the project. Secondary or developmental benefits are the "value" of goods or services resulting from additional capital accumulation (public or private) induced by the project. The net "value" of the project is then the sum of primary and secondary benefits less the cost (either in terms of foregone consumption or foregone investment) of the increments to the capital stock.

This part of the report shall first attempt to clarify some of the conceptual issues which this definition does not resolve. Ways in which the measurement of benefits can be operationalized in the context of general equilibrium approach outlined in the first part of this report are discussed in this section.

There are three important conceptual questions to be resolved. The first of these questions is one which is common to all economic evaluations: what do we mean by "value"? The prevailing practice is to measure benefits by increases in gross regional product. To understand the implications of this, consider the problem within the context of maximization of a social welfare function.

Broadly defined, a social welfare function is a metric by which the consumptions of individual households are compared. In its most general form, it is written:

$$W = W(x_1, \ldots x_n)$$

where x_1 through x_n are the consumption vectors of individual households. Thus, the change in social welfare resulting from an investment project would be measured as W calibrated $x_i^{\prime}$ (after project) and x_i (before project) consumption.

This specification of the social welfare function is extremely general and in practice projects are not evaluated on the basis of the after project consumptions. Rather, it is implicitly assumed that the change in social welfare is a function (usually a linear, additive function) of changes in consumers' surplus. The argument for consumer surplus as a measure of changes in individual well-being is that under certain conditions consumer surplus is the compensating variation; that is, the income value to the households themselves of the change in consumption. A literal operationalization of this is to require an estimate of the changes in consumption for each household and an estimation of the change in consumer surplus which each change entails - but simplifications are possible

If public goods and externalities are ignored for the moment, it is possible to respecify the welfare function as a function of the prices of final goods and of individuals' incomes. This follows from the fact that under fairly general conditions, there is a one-to-one relationship between consumers' budgets and their final demands. It is appropriate in this framework to employ compensating variation directly as a benefit measure. Compensating variation is that change in base period income which makes a household indifferent between its consumption at base period prices and income and at new prices and income. Thus, it is argued that the first step in the measurement of project benefits is the measurement of this compensating variation.

Implicitly, it is this approach which is taken in the regional development literature. Under the usual assumptions of the Leontief system, output prices are held constant. Holding prices fixed, the compensating variation is simply the change in income. However, within the general equilibrium framework, prices may change. Therefore, the implementation of this framework requires a method for computing (or estimating) the compensating variation associated with the project. A method for estimating this compensating variation based on the "true" cost of living index is discussed later.

Impact Regions

The second conceptual problem is the appropriate geographic scope of the social welfare function. This problem is discussed in some detail in the regional development literature (see, for example, Charles L. Leven (ed.), Development Benefits of Water Resource Investment), but is not resolved. Part of the problem is that the decision criteria of the Congress are unclear and vary from project to project. In some cases, Congress appears to evaluate projects purely in terms of the region in which the investment is made; in other cases, a broader viewpoint is taken.

Thus, it seems appropriate in providing benefit estimates to provide reasonably complete information; that is, to provide decision makers with estimates of project benefits both within and outside the particular region. How difficult it is to estimate extraregional benefits depends on the extent to which the project results in changes in prices of final goods outside the region. In a situation in which the region receiving the investment is small and the investment is small, it is likely that the investment has little effect on prices outside the region. Hence, compensating variation is simply equal to the change in income resulting from the project.

Change in Prices Outside Impact Region

If, on the other hand, the project does produce extraregional price changes, an estimate of compensating variation taking these changes into account is required. In essence, this problem of the interregional distribution of benefits is a subproblem of the third general conceptual difficulty with the evaluation framework. This problem is concerned with the role of income redistribution in evaluating benefits. It is possible that projects having the same total compensating variation (that is, summed across all individuals) could have quite different patterns in terms of their effect on various income groups. One project, for example, might increase land rents significantly, thereby raising the income of renters, while at the same time having little impact on wages. An alternative investment might raise wage income while at the same time reducing rents. It is difficult to infer a general weighting scheme from Congressional decisions, but at the same time it is clear that questions of income distribution are important components of their evaluation. Consequently, it is appropriate that the delineation of project benefits include information not only on the interregional distribution of income, but also on the effects of the project in terms of benefit by income class.

Benefit Measurement

To provide a context for this, consider the following problem: an investment project will change output prices from p^b to p while at the same time changing the income of the only two households in the region from M_1^b to M_1 and M_2^b to M_2 respectively. The first problem is to determine whether the consumers are better off as a consequence of the investment, and the second problem is to develop a quantitative index of the changes in their well-being. Furthermore, these measures should be individualistic in the sense that they are derived from individual's preferences.

Although it is standard practice to take consumers' preferences as ranging over commodity bundles, an equivalent specification takes consumers as having preferences over pairs of the form (p,M) where p is the price vector and M income. The numerical representation of these preferences is the indirect utility function. A particular form of the indirect utility -- the so-called minimum income function is singled out for analysis.

Letting $\Phi(p,M)$ be an arbitrary indirect utility, and (p^b, M^b) be an arbitrarily selected base reference budget, the minimum function $\lambda(p,M)$ is defined as follows:

$$\Phi(p^b, \quad \lambda(p,M) \quad M^b) = \Phi(p,M)$$

Thus, $\lambda(p,M)$ is the proportional adjustment to base period income required to make the consumer indifferent between (p,M) and the reference budget. Under fairly general circumstances $\lambda(p,M)$ is itself an indirect utility and has the desirable property that $\lambda(p,M) \quad M^b$ is equal to the compensating variation relative to the reference budget. In addition, it has the property that $\lambda(p,M) < 1$ implies the consumer is better off at the new prices and income than at the reference point; conversely, $\lambda(p,M) > 1$ implies the consumer is worse off.

A related concept is that of the "true" cost of living index. One definition of a true cost of living index T(p,M) is that $T(p,M) > 1$ implies the consumer is worse off ("true" inflation), $T(p,M) < 1$ implies the consumer is better off ("true" deflation) and that $\Phi(p^b, \frac{1}{T(p,M)} \cdot M^b) = \Phi(p,M)$. It is immediate then that the inverse of $\lambda(p,M)$ is a true cost of living index. Thus, the compensating variation and true cost of living are equivalent concepts. Using this fact, the techniques employed were developed by Little and Rader to approximate the true cost of living from demand data and thereby approximate the compensating variation.

Suppose individual demands in a series of price-income situations are observed. Denoting demand as $d(p,M)$ and one price-income pair as (p^b,M^b) the usual Laspeyres and Paasche indices of prices are defined respectively by:

$$L(p,M) = \frac{d(p^b, M^b)\cdot p}{d(p^b, M^b)\cdot p^b}$$

and

$$H(p,M) = \frac{d(p, M)\cdot p}{d(p, M)\cdot p^b}$$

these indices have the property that:

$$\frac{1}{H(p,M)} \geq \lambda(p,M) \geq \frac{1}{L(p,M)}$$

It is well known that neither of these indices is in general a true cost of living index. However, the ability to produce a better index and obtain a finer approximation of $\lambda(p,M)$ depends on the nature of the demand data. If the data consist only of the two points $d(p^b, M^b)$ and $d(p,M)$, computing the simple Laspeyres and Paasche is the best method. However, since the implementation of the general equilibrium framework for complex cases requires an estimate of demand functions, it is presumed that fairly extensive demand information would be available.

Using these data, chains of demand observations and corresponding chained Laspeyres and Paasche indices can be constructed. A chain c from (p, M^b) to (p,M) is a sequence of demands, $d(p^1,M^1), d(p^2, M^2),\ldots,d(p^n, M^n)$ where $p^1=p^b$, $M^1=M^b$, $p^n=p$ and $M^n=M$. The chained Laspeyres and Paasche indices on c are then defined as:

$$\hat{L}(c) = \prod_{i=1}^{n-1} \frac{d(p^i,M^i)p^{i+1}}{d(p^i,M^i)p^i}$$

and

$$\hat{H}(c) = \prod_{i-1}^{n-1} \frac{d(p^{i+1},M^{i+1})p^{i+1}}{d(p^{i+1},M^{i+1})p^i}$$

These indices are simply the product of simple Laspeyres and Paasche indices with a moving base.

There are in general many such chains between (p^b, M^b) and (p,M). The best approximations (given the demand data) to $\lambda(p, M)$ are given by $L^*(p, M)$ and $H^*(p, M)$ defined respectively as the smallest $\hat{L}(c)$ and the largest $\hat{H}(c)$ Provided income elasticities of demand are unitary then:

(1) $$\frac{1}{H^*(p, M)} \geq \lambda(p, M) \geq \frac{1}{L^*(p, M)}$$

(2) The demand data alone (without additional assumptions as to the nature of the preferences generating demand) can produce no better estimate of the compensating income or of change in consumer surplus (using the compensating variation definition) than condition 1.

(3) (i) $L^*(p, M) > 1$ implies $\lambda(p, M) \leq 1$ or that the consumer is <u>at best</u> as well off under (p, M) as under (p^b, M^b).

(ii) $H^*(p, M) < 1$ implies $\lambda(p, M) \geq 1$ or that the consumer is <u>at worst</u> as well off under (p, M) as under (p^b, M^b).

Hence, for the individual consumer, $L^*(p, M)$ and $H^*(p, M)$ provide closest bounds to the compensating income that can be inferred from the demand data, and further, they provide a measure of the direction of change in the individual welfare.

To return to the example with which we began this discussion, the above analysis would produce the following conclusions: if both $H_1^*(p, M_1)$ and $H_2^*(p, M_2)$ exceed unity, both consumers 1 and 2 have benefitted as a result of the project. The value to consumer 1 (in terms of base income) is between $\frac{1}{H_1^*(p, M_1)} \cdot M_1^b$ and $\frac{1}{L^*(p, M_1)} \cdot M_1^b$ with similar bounds for the second consumer.

If it is deemed appropriate to use the sum of compensating income as a welfare measure (and this is a question that ultimately must be decided by the Congress) then the best available approximation to project benefits is $(\frac{1}{H_1^*} M_1^b + \frac{1}{H_2^*} M_2^b)$ as an upper limit and $(\frac{1}{L_1^*} M_1^b + \frac{1}{L_2^*} M_2^b)$ as a lower limit.

It must be stressed that this analysis applies to single consumption units and to implement it as it stands would require that observation of individual demands be feasible both in terms of data availability and cost. Quite clearly, such is not the case; any practical application must necessarily involve aggregation of both demands and commodities. Thus, the properties of measures of compensating income based on aggregated data must be considered. As noted, it is standard practice to use change in GRP as a measure of the benefits of an investment project. However, little attention is paid to the relationship between GRP change and changes in the welfare of the residents of the region. The problems with GRP as a welfare measure are numerous, not the least of which is the fact that it includes only valuations of commodities traded on the market, taking no account of externalities or non-market transactions. However, even if all commodities are marketed and population is unchanged, there is a fundamental problem: an increase in GRP is not sufficient to imply a welfare increase.

The arguments which demonstrate this claim will not be presented. The most important conclusions in measuring developmental benefits are the following:

(i) If output prices are unchanged and the distribution of income is unchanged, then an increase in GRP unambiguously implies an increased level of welfare for all consuming units. The assumption of constant output prices implies furthermore that the change in GRP is the sum of compensating incomes, and the assumption of unchanged income distribution implies that for all consumption units the compensation is equal to before-project income times the rate of change in GRP.

(ii) If preferences of all consumption units are identical and have the additional property that income elasticities of demand for all commodities are unity, then an increase in GRP can be redistributed so that all consumption units are better off (i.e., there exists a feasible pareto-superior output).

(iii) If neither (i) nor (ii) holds, it does not follow that all increases in GRP necessarily imply that the post project equilibrium is pareto-superior to the initial equilibrium nor that there exists a redistribution of income which would make it so.

One of the conditions for case (i), unchanged prices, is assumed in almost all studies of economic benefits. Yet it is important to note that even in the case of fixed output prices, the income distribution must remain fixed if GRP is to serve as an unambiguous measure even of aggregate welfare. While this point is hardly profound, it is nonetheless important. Unless income distribution is fixed, using (iii) there may exist no redistribution scheme producing a pareto-superior allocation to that prevailing before the investment. The best the project analyst can accomplish is to specify the changes in distribution in sufficient detail that the political process can perform its evaluatory function.

The same argument appears in the case in which output prices as well as income distribution are altered as the result of the project. The main difference in this case is that measurement of compensating income now involves estimation of the true cost of living indices. But this in turn leads us back to the problem indicated earlier, namely, what is the appropriate level of aggregation? There appears to be no way to solve this problem on an *a priori* basis. As a practical matter, distributions over only a limited number of consumer classes can be considered.

The analysis above of the welfare properties of GRP applies equally to the welfare properties of changes in income of any sub-group. While it may be somewhat more plausible for such homogeneous sub-groups to have identical preferences, the requirement of unitary income elasticities of demand remains suspect.

One way out of this dilemma is offered by a striking empirical regularity: demand studies show that as commodities are increasingly aggregated , income elasticities of demand for groups of commodities do tend to unity. That is, although disaggregated commodities violate unit income elasticity, for less refined commodity definitions, the condition is satisfied. Thus, if the "approximation" of commodity aggregation is accepted, changes for sub-group become acceptable indices of changes in potential welfare, and compensating income for the group becomes a measure of sub-group welfare that is comparable across groups. Fortunately this is defensible, since as noted above, large numbers of classifications are not feasible anyway.

This solution, however, is still somewhat unsatisfactory in the sense that it depends on a statistical quirk. Yet, quite another argument leads us to the same point. It is clear that the decisions of the public sector are not based on detailed appraisal of the effect on all individuals. Rather, they are based on the evaluation of the impact of the decision on the "average" individual within a series of subgroups. For example, the BLS constructs price indices reflecting buying patterns of urban workers of low, moderate, and high income, and similar indices for rural residents. Congressional debate on budgetary matters frequently centers on the effect of particular policy on "representative" members of particular groups. Thus, it is plausible to argue that the objective function of the public sector is not a function of consumptions of individual units, but rather a function of consumptions of average members of sub-groups. If one further argues that the weights attached to each "representative group" consumption are the number of consumers in the sub-group, then the appropriate measure of benefit is the vector of real income changes (compensating incomes) for the relevant sub-group.

Taking this as the appropriate measure of benefit, the following empirical questions emerge:

(1) What are the sub-groups over which benefits are defined?

(2) Do demand data exist which would allow a reasonably fine specification of the true cost of living index?

(3) Do data exist which would generate accurate predictions of price and income changes resulting from investment projects?

APPLICATIONS

This report presented a description of an alternative approach to estimating economic impacts of developmental investment projects. Included was a theoretical description as well as a discussion of the problems of appropriate specifications for empirical estimations and problems of data generation. In addition, the thorny problem of possible lack of correspondence between GRP and economic welfare was addressed.

The approach described here should be implemented in actual economic impact analysis. As will be pointed out below, the analysis of the economic impacts of the McClellan-Kerr Arkansas River Navigation Project offers an unusually convenient and appropriate opportunity for such application.

Despite these favorable conclusions, however, it must be stressed that they should be regarded as provisional; in no sense can the authors claim to have developed an alternative methodology that is in finished and proven form ready for general application. Limitations of the method still remain, and aspects of its application must still be regarded as experimental.

At a theoretical level some annoying limitations persist at this stage. Having to deal with a format where the number of factors and the number of goods are necessarily equal (a square economy) is cumbersome. In most cases it can be overcome by somewhat synthetic means. More serious is the clumsy way in which the infrastructure-enhancing characteristics of the project are inserted into the theoretical framework. Essentially this must be done by translating them into changes in the stock of some endowment used in identifiable production processes. For most development project features this is not too serious, but it is awkward for analyzing changes in transport availability, especially the building of a new transport mode or route. Further theoretical development is required to permit such cases to be handled in a straightforward way in the theory. This is a good reason for a project that would make experimental impact estimates for the Arkansas River Navigation Project (ARNP); a new transport mode is an important feature of that project, and trying to make impact estimates for it offers possibilities for experimentation with transport mode availability analysis in a situation where trial empirical estimates could be used to assess theoretical formulations.

Other limits in the theory are that it does not include possibilities for a project's directly influencing basic technology or product prices. This is probably not serious as these kinds of impacts probably occur infrequently, at least for the kind of projects developed by the U.S. Army Corps of Engineers. The exogeneity of the labor force in the present theoretical formulation is much more serious. It is not really limiting in an ultimate or practical sense, since estimates for ancillary models of migration or labor force participation borrowed from existing literature can be employed. At the same time it makes the model less general than might ultimately be possible, though a good deal more general than the Leontief systems typically employed.

Note that these systems are not necessarily inappropriate in all cases;

in sections II and III there was discussion of situations in which traditional methods would give quite defensible estimates.

While it would complicate the theoretical exposition, there are few problems in considering cases with non-constant returns to scale. As an econometric problem, however, the problems are serious. And even ad hoc estimation of individual cases would rely on independent estimates of price elasticity of demand of effected products and elasticities of substitution in their production. Many such estimates do exist in the literature, but a good deal of judgement is required in selecting representative cases and relevant estimates from other situations. Handling non-constant returns in a normal econometric estimating context in a single closed estimating system is difficult and poses requirements for generation of data observations that probably are unrealistic, at least for the foreseeable future. In short, handling non-constant returns (to say nothing of true external economics) in the framework as now developed, while possible, is difficult. But within a traditional Leontief approach it is not possible at all!

In sum, the scheme outlined in this report offers a good basis for an experimental effort at estimating economic impacts of a project in an alternative way that is both more defensible theoretically and calls for less data, though of a somewhat less conventional sort. Ultimately it would permit estimates of economic impacts of projects that were both cheaper and easier as well as more reliable. Reaching that goal will depend on experimental application of the approach to situations that are rich in empirical content, have substantial magnitude, and are reasonably complex. In this way initial theoretical application will permit theoretical revision that will lead to new estimation experiments. The ARNP offers an appropriate and convenient case for experimental application.

The technology is described by the matrix A, where

$$A = \begin{pmatrix} a_{TS} & a_{TF} \\ a_{LS} & a_{LF} \end{pmatrix}$$

and a_{Ij} is the quantity of factor i used to produce a unit of commodity j, the outputs are S and F, and the inputs are T and L. Factor demands are then

$$A\begin{pmatrix} S \\ F \end{pmatrix} = \begin{pmatrix} T \\ L \end{pmatrix} \qquad (1)$$

Also, with 0 profits, the unit costs of production are given by the columns of A multiplied by the factor prices, or

$$(r \;\; w)\; A = (P_S \;\; P_F) \qquad (2)$$

where r is the cost of a unit of T and w is the cost of a unit of L.

Let T^* and L^* denote the rate of change of T and L; i.e., $dT/T = T^*$ and $dL/L = L^*$ (similarly with the other variables). Also let x_{ij} be the fraction of factor i used in the production of output j and e_{ij} be the ith factor share of output j. With

$$P = \begin{pmatrix} P_S & 0 \\ 0 & P_F \end{pmatrix} \qquad W = \begin{pmatrix} r & 0 \\ 0 & W \end{pmatrix}$$

$$E = \begin{pmatrix} T & 0 \\ 0 & L \end{pmatrix} \text{ and } X = \begin{pmatrix} S & 0 \\ 0 & F \end{pmatrix}$$

the matrices and λ and θ (which are the percents and shares of the factors used in each industry, respectively) are given by

$$\lambda = E^{-1}AX, \text{ and}$$

$$\theta = P^{-1}A^TW,$$

where A^T is the transpose of A. i.e.,

$$\lambda = \begin{pmatrix} \lambda TS & \lambda TF \\ \lambda LS & \lambda LF \end{pmatrix} = \begin{pmatrix} a_{TS}\cdot S/T & a_{TF}\cdot F/T \\ a_{LS}\cdot S/L & a_{LF}\cdot F/L \end{pmatrix}$$

and

$$\theta = \begin{pmatrix} e_{TS} & e_{TF} \\ e_{LS} & e_{LF} \end{pmatrix} = \begin{pmatrix} a_{TS}\cdot r/P_S & a_{LS}\cdot w/P_S \\ a_{TF}\cdot r/P_f & a_{LF}\cdot w/P_F \end{pmatrix}$$

Now write the equations of change in terms of rates of change as

$$\lambda \begin{pmatrix} S^* \\ F^* \end{pmatrix} = \begin{pmatrix} T^* \\ L^* \end{pmatrix} - \text{diag}\ \lambda\ (A^*)^T \qquad (1.1)$$

and

$$\theta^T \begin{pmatrix} r^* \\ w^* \end{pmatrix} = \begin{pmatrix} P_S^* \\ P_F^* \end{pmatrix} - \text{diag}\ (\theta^T\ A^*) \qquad (2.1)$$

where A^* is the rate of change of the A matrix, i.e., $a^*_{ij} = da_{ij}/a_{ij}$, and diag $\lambda(A^*)^T$ is the vector containing the diagonal elements of $\lambda(A^*)^T$.

If the coefficients of production are fixed, so that $da_{ij} = 0$, then the equations reduce to

$$\lambda \begin{pmatrix} S^* \\ F^* \end{pmatrix} = \begin{pmatrix} T^* \\ L^* \end{pmatrix} \qquad (1.2)$$

and

$$\theta^T \begin{pmatrix} r^* \\ w^* \end{pmatrix} = \begin{pmatrix} P^*_S \\ P^*_F \end{pmatrix} \qquad (2.2)$$

If the coefficients of production are not fixed, 1.4 still holds, if production is cost minimizing. This can be seen by considering unit costs in the S industry, $a_{TS}r + a_{LS}w$. The first differential of these unit costs, for fixed factor prices (production is competitive in factor markets), is

$$da_{TS}r + da_{LS}w$$

and is set equal to 0 to find the minimum of costs. Dividing by P_S we have

$$\frac{da_{TS}\cdot r}{P_S} + \frac{da_{LS}\cdot w}{P_S} = 0$$

or using the definitions of θ_{TS} and θ_{LS}, we have

$$\theta_{TS}\ a^*_{TS} + \theta_{LS}\ a^*_{LS} = 0 \qquad (3).$$

Hence, assuming cost minimizing behavior and no monopsony,

$$\text{diag}\ (\theta^T A^*) = 0. \tag{4}$$

Hence, the system is described by the four equations,

$$\lambda \begin{pmatrix} S^* \\ T^* \end{pmatrix} = \begin{pmatrix} T^* \\ L^* \end{pmatrix} - \text{diag} \quad \lambda (A^*)^T \tag{5}$$

and

$$\theta^T \begin{pmatrix} r^* \\ w^* \end{pmatrix} = \begin{pmatrix} P_S^* \\ P_F^* \end{pmatrix} \tag{6}$$

Now, if output prices do not change, so that $P_S^* = P_F^* = 0$, then factor prices do not change, so that $r^* = w^* = 0$. But if factor prices do not change, then, under cost minimization, $a_{ij}^* = 0$ for constant returns to scale. This can be seen more formally by noting that the elasticity of substitution for factor is given by

$$o_j = \frac{a_{Tj}^* \quad -a_{Lj}^*}{w^* \quad -r^*} \qquad j = S, F, \tag{7}$$

or $(w^* - r^*) o_j = a_{tj}^* - a_{Lj}^*$. If $w^* - r^* = 0$, then $a_{Tj}^* = a_{Lj}^*$. But diag $(\theta^T A^*) = 0$, so that we obtain $a_{ij}^* = 0$ all i.j. Specifically, from (3) and $a_{TS}^* = a_{LS}^*$, we have

$$(\theta_{TS} + \theta_{LS})\ a_{LS}^* = (\theta_{TS} + \theta_{LS})\ a_{TS}^* = 0$$

and since $\theta_{TS} + \theta_{LS} \neq 0$ (in fact $\theta_{TS} + \theta_{LS} = 1$), we must have $a_{LS}^* = a_{TS} = 0$. Hence for constant returns to scale (or production where unchanged factor prices implies unchanged coefficients of production), diag $\lambda (A^*)^T = 0$ and the system is much simplified to

$$\lambda \begin{pmatrix} S^* \\ F^* \end{pmatrix} = \begin{pmatrix} T^* \\ L^* \end{pmatrix}$$

or

$$\begin{pmatrix} S^* \\ F^* \end{pmatrix} = \quad {}^{-1} \begin{pmatrix} T^* \\ L^* \end{pmatrix}$$

Gross product is the sum of prices times outputs, i.e.

$$G = P_S \cdot S + P_F \cdot F$$

so that

$$G^* = Y_S\ (P_S^* + S^*) + Y_F\ (P_F^* + F^*)$$

where Y_j is the percent of gross product from output j. i.e.,

$$Y_S = P_S \cdot S/G, \text{ and } Y_F = P_F F/G.$$

With no price changes, G^* can be measured as

$$G^* = y^T \cdot \lambda^{-1} \begin{pmatrix} T^* \\ L^* \end{pmatrix}$$

Where

$$Y = \begin{pmatrix} Y_S \\ Y_F \end{pmatrix}$$

In case the project affects output prices by subsidization, we can take P_S^* and P_F^* to be the relative change due to subsidization in (6) and solve for w^* and r^*. Using (4) and (7) one can then solve for diag $\lambda(A^*)^T$ and use 1.1 to estimate the effects. This procedure can also be used if w^* and r^* are affected directly.

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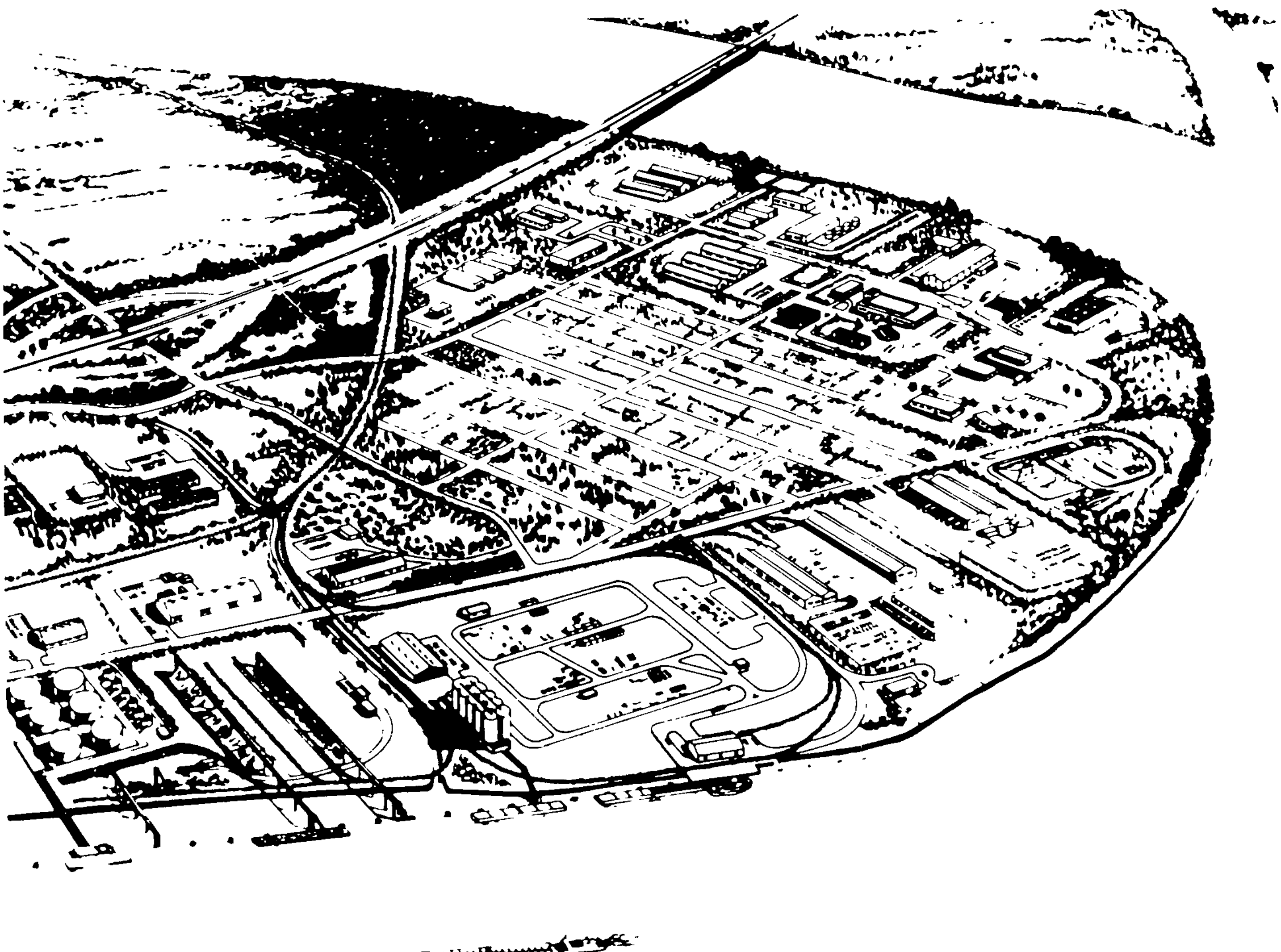

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