AN ABSTRACT OF THE THESIS OF

BRUCE ROBERT BEATTIE for the DOCTOR OF PHILOSOPHY
(Name) (Degree)
in Agricultural Economics presented on July 11, 1969
(Major) (Date)

Title: ECONOMIC EFFICIENCY AND DISTRIBUTIVE

CONSEQUENCES OF INTERBASIN WATER TRANSFERS: A

FRAMEWORK FOR ANALYSIS

Abstract approved: W. G. Brown

If informed and rational judgments are to be made concerning proposed large scale interbasin water diversions, it is imperative that competent positive analysis be undertaken by scientists of relevant disciplines. It is the primary purpose of this thesis to pull together into a single interrelated package, the economic theory needed to establish a framework for analyzing the economic efficiency and distributive impacts of interbasin water transfers. Accordingly, a model is developed such that efficiency implications of resource transfer schemes can be ascertained; the components of the model are identified so that direct regional income redistributive effects might be determined. The model is then extended to consider value in transit, intrafirm production interdependencies, interfirm production interdependencies, and indirect benefits and costs.
Finally, a method is demonstrated for estimating one component of the efficiency model. The marginal value productivity of water in irrigated agriculture is estimated from secondary data sources using least-squares regression analysis.
Economic Efficiency and Distributive Consequences of Interbasin Water Transfers: A Framework for Analysis

by

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A THESIS submitted to
Oregon State University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

June 1970
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Date thesis is presented ________________________
July 11, 1969

Typed by Clover Redfern for __________ Bruce Robert Beattie
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ACKNOWLEDGMENTS

The author is indebted to many for their contribution to this effort. In particular I am grateful to:

Dr. William G. Brown, major professor, and Dr. Emery N. Castle, thesis co-advisor, for counsel and guidance in conducting this research.

Dr. Albert N. Halter, an extraordinary teacher.

Dr. John A. Edwards, for many hours of constructive consultation.

My fellow graduate students, for encouragement and helpful suggestions. A particular debt of gratitude is owed Owen R. Morris, whose review and criticism served to clarify several of the chapters.

The Office of Water Resources Research, whose financial grant made this research possible.

My wife, Gail, whose unselfish sacrifices, in the final analysis, made graduate study possible.
ECONOMIC EFFICIENCY AND DISTRIBUTIVE CONSEQUENCES OF INTERBASIN WATER TRANSFERS: A FRAMEWORK FOR ANALYSIS

I. INTRODUCTION

Science and Social Decision-Making

The role of the scientist in the social decision-making process is, indeed, precarious. A scientist, although he may be uniquely qualified to analyze the consequences of social action given the framework of his specific academic discipline, must be particularly careful not to presume, or to leave the impression, that "socially optimum action" necessarily corresponds to optimum action as dictated by specific discipline criteria. That is to say, a scientist, whatever his academic discipline, must not be so presumptious as to assume that the set of criteria by which his discipline evaluates the relative merits of alternative actions is the unique set of criteria by which society ranks alternative actions. This position is consistent with that of Smith and Castle (1964) and Fox (1966).

1 Throughout this dissertation the term "optimum" is used in the sense of the best or most favorable degree, condition, or amount of some attribute with respect to a particular objective function.

2 The term "criterion" is synonymous with a standard, rule, or test by which a judgment of something can be formed. A criterion presupposes the existence of a specific objective function whether it be stated explicitly or merely implicitly assumed.
Probably all problems related to the allocation or use of a nation's resources have interdisciplinary aspects. The nature of few, if any, resource allocation problems is such that all relevant considerations can be totally circumscribed within the sphere of a single academic discipline. The interdisciplinary character of most resource allocation problems suggests that the technical optimum, as defined according to a criterion of a particular discipline, will not necessarily correspond to, or be compatible with, the social optimum.

If the technical criteria of various disciplines are often at odds and if the technical criteria of no single discipline adequately specify the social desirability of alternative resource allocations, what then is the role of the various disciplines concerning such matters? It is the author's belief that the scientist can best serve the social decision-making process by limiting his role to one of explaining "what is" or "what will be" (positive) the consequence of a particular alternative social action (as judged according to specific discipline criteria) rather than prescribing what social action "out to be" (normative)\(^3\) which presupposes that the social optimum corresponds to

\(^3\)Castle (1963) notes that studies are clearly normative if the "optimal plan", which is optimal only in a limited technical sense, is identified with a social optimum.
a specific technical optimum. 4/

The findings of science are obviously of value in the social decision-making process and are of normative significance in that context. However, care should be exercised to ensure that technical norms are not interpreted as being necessarily prescriptive in terms of specifying what society ought to do (Castle, 1963).

Economics and Social Decision-Making

In general terms the role of science in social decision-making has been discussed. The preceding discussion provides a convenient and useful frame of reference when considering specifically the role of economics in the social decision-making process. Frequently, questions concerning the use an allocation of a nation's resources have, among other consideration, important economic considerations.

4 John Neville Keynes (1891) distinguishes between a body of systematized knowledge concerning "what is" and a body of systematized knowledge discussing criteria of "what ought to be". The former he called "a positive science" the latter "a normative science".

The importance of distinguishing between positive and normative analysis is exemplified in the following quotation:

There is not, of course, a one-to-one relation between policy conclusions and the conclusions of positive economics; if there were, there would be no separate normative science. Two individuals may agree on the consequences of a particular piece of legislation. One may regard them as desirable on balance and so favor the legislation; the other, as undesirable and so oppose the legislation (Friedman, 1953, p. 5).
When economic considerations are involved, it seems apparent that economists "do have an obligation .... to predict the consequences of alternative policy actions in light of their own ... criteria" (Stevens, 1966a, p. 1).

A relevant question to ask concerning the role of the economist in the social decision-making process is: Are social decision-making processes best served when the economist acts in a positive sense, as an analyst and provider of information, or when he acts in a normative sense, as a salesman of the normative criteria of his particular discipline? Perhaps Stigler had some insights regarding this matter when he stated the following in his presidential address to the American Economics Association:

The essential ambiguity of general theoretical systems with respect to public policy ... has been the real basis of our troubles. So long as a competent economist can bend the existing theory to either side of most viable controversies without violating the rules of professional work, the voice of the economist must be a whisper in the legislative halls (Stigler, 1965, p. 14).

In short, the author is of the opinion that the economist's role in the social decision-making process is no different that that of a scientist of any particular academic discipline. That is to say, the economist is obligated (1) to provide positive analysis of the economic implications of alternative social actions and (2) to be careful not to imply or leave the impression that the optimum arrived at via the technical criteria of economics has any more or less normative
significance regarding the total problem than optima arrived at given the technical criteria of other disciplines. The economist must guard against any desire or tendency to identify (or to be misinterpreted as identifying) a particular technical optimum with a social optimum. This author does not believe that an economist, acting as an expert consultant to the social decision-making process, is behaving responsibly when he asserts statements such as, "...economic efficiency should be the dominant goal in resource planning" (Gardner, 1966, p. 7), \(^5\) even if he does believe it.

**A Note on Welfare Economics and Benefit-Cost Analysis**

Welfare economics is that branch of economics which deals with, among other things, the evaluation of alternative social actions. Traditionally, the application of welfare economics to specific public policy problems has entailed the prediction of economic consequences of alternative action in light of a single technical criterion--namely, economic efficiency. \(^6\) Most studies have attempted this application

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\(^5\) Underlining is mine. No doubt the economist has the right to make such statements, but, hopefully, the social decision-making process will pay no more attention than to similar claims made for the technical criteria of other professionals.

\(^6\) Economic efficiency is a nebulous and widely used term. Its meaning is discussed in some detail, and the term is given an explicit technical interpretation, in Chapter III. However, throughout this chapter and the next, efficiency is used rather loosely in the sense of maximizing the "value" of output produced given available resources.
via the instrument of benefit-cost analysis.

Amidst the profusion of literature concerning benefit-cost analysis at least four studies—McKean (1958), Eckstein (1965), Krutilla and Eckstein (1958), and Hirshleifer, DeHaven, and Milliman (1960)—are well known to most practitioners. Excepting McKean, all deal specifically with the application of welfare concepts to problems of water resource development. Baumol (1967), in discussing benefit-cost analysis as an applied arm of welfare economic theory, cites among others these four works. Regarding these and similar efforts, Baumol states:

The great contribution of the authors in this area has been to prove that one can make progress in dealing with these problems and to work out compromises which are often ingenious and highly illuminating. They have shown how specific governmental projects can be evaluated in a manner which accords at least roughly with the prescriptions of welfare analysis and which certainly seems to be a vast improvement over the rule of thumb—tradition-hallowed practices which are currently prevalent. In this process these writers have also breathed life into many of our welfare constructs even though they have been forced to treat some of them rather roughly at times. No grand generalizations or startling theorems can, in the nature of the case, be gleaned from their work. For their object was not to provide new models and new theorems but to lead the way in the application of the existing body of theory to the rather messy and chaotic problems which one encounters in real decision-making processes (Baumol, 1967, p. 23).

Despite certain shortcomings benefit-cost analysis is one technique of economic analysis which has operational significance as an analytical aid in public decision-making. However, the procedure is
still plagued by certain conceptual problems (Ciriacy-Wantrup, 1955; Castle, Kelso, and Gardner, 1963). The discount rate, externalities, and indirect benefits are topics ripe for rigorous theoretical and empirical analysis. Nevertheless, given continued effort to refine the underlying theoretical constructs and to improve the measurement techniques employed, further application of benefit-cost analysis to resource allocation problems seems certain.

The Problem

One area of public policy that has received considerable attention in recent years is that of water supply and allocation. A solution proposed by some for "felt" water needs is that of the diversion from "surplus" regions to "shortage" regions. Numerous engineering proposals have been advanced to divert substantial quantities of water from areas of "surplus" (e.g., Pacific Northwest and northern Canada) to more arid areas (e.g., Pacific Southwest)—witness the NAWAPA plan, the Pirkey plan, etc. For a summary of these and other plans, see Klingeman (1967).

Whether or not to undertake one or several such schemes is a question which has been and no doubt will continue to be considered by the social decision-making process (political process). If our decision-makers (politicians) hope to arrive at rational decisions concerning proposals for interbasin water diversions, which in some
instances call for the expenditure of several billions of dollars, a considerable quantity of information is needed. If rational decisions are to be reached, it is important that the facts provided by various experts be determined and clearly presented. Any disagreement should concern "values" rather than facts. Hopefully, positive analyses by individuals in various relevant disciplines will represent an important ingredient in ascertaining those facts.

The role of the economist, then, is to provide positive analysis concerning the economic implications and feasibility of interbasin water transfer. If the economist chooses to fulfill this role, he must first develop a framework which is relevant for considering those economic implications that he or others feel are important. An appropriate framework for analysis must permit meaningful data concerning the selected implications to be forthcoming. Only given a relevant framework for analysis can the economist provide information worthy of decision-maker's consideration. The information forthcoming can then be considered in the decision-making process, along with that provided by other consultants, in ascertaining the social desirability of undertaking a particular transfer scheme.

Such is the purpose of this thesis. Economic efficiency and distributive aspects of resource transfer are considered. A framework for analysis is developed which permits the identification of the efficiency implication of a resource transfer scheme. Furthermore,
the framework is developed in such a way that income redistributive impacts could be ascertained if desired. Although the expressed purpose is to provide a framework of analysis relevant for considering interbasin water transfers, the framework should be useful for viewing any kind of resource transfer for any level of regionalization.

**Purposes and Objectives of the Study**

This study is a portion of a research program designed to provide an integrated body of knowledge dealing with the economic theory and estimation procedures appropriate for analyzing economic implications of interregional water transfers. The overall objective of the research program is to develop operational criteria for evaluating economic consequences of particular water transfer schemes.

It is hoped that this study, as an initial phase of the research program, will contribute rather substantially toward the accomplishment of the overall program objective. The purpose of the thesis is to pull together into a single interrelated package, the economic theory relevant for the analysis of direct and indirect consequences of

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A discussion of certain key words is illuminating. An "operational criterion" is a criterion (see Footnote 2) which elicits meaningful information, and the component parts of which involve measurable magnitudes. An "economic consequence" concerns the result or effect of an action as judged in light of a particular economic objective; e.g., economic efficiency or income distribution. "Particular" refers to a specific method for accomplishing a specific purpose(s).
resource transfer proposals—specifically, interregional water transfers. Significant economic variables are identified and isolated such that all interrelationships are explicit and only truly relevant economic considerations are taken into account.

Specific objectives of this study are:

1. to develop a concise theoretical framework which will enable explicit identification of the efficiency implications of interregional water diversion projects, and which will permit identification of impact by region;

2. to demonstrate an empirical method for estimating the direct (primary) economic benefits resulting from inter-regional water diversion projects.

The first objective entails the development of a model (a framework for analysis), the estimation of which will answer the question: Is the project economically efficient? The scope of the empirical portion of this dissertation (objective 2) is restricted to proposing and demonstrating a method for estimating one component of the efficiency model—the marginal value productivity of water.

Hopefully, the theoretical framework presented is equally applicable for analyzing interregional transfers of resources other than water.
Outline of Thesis

This thesis is divided into two main parts. The first objective is addressed in Chapters II, III, IV, and V; the second is addressed in Chapter VI. Chapters II, III, IV, and V, are devoted to the development of economic theory relevant to the interregional water transfer problem. Chapter II contains a discussion of economic objectives and objective functions. Chapter III is devoted to a discussion of economic efficiency and benefit-cost analysis. In Chapter IV an efficiency model (including only direct benefits) is developed. In Chapter V indirect benefits⁹ and other extensions of the efficiency model are discussed. Chapter VI deals with empirical methodology for estimating the marginal value productivity of a factor of production—in this case, the marginal value productivity of water in irrigated agriculture. Chapter VII is a summary and statement of the conclusions of this study.

⁹Considerable discussion in the literature evolves around the concept of indirect benefits. Much confusion still exists. Hopefully, Chapter V reduces rather than increases the confusion and mystery that envelops this concept.
II. ECONOMIC OBJECTIVES AND OBJECTIVE FUNCTIONS

Whatever the particular problem, it is fairly obvious that, in choosing among alternative means to our ends, we need to scan the ends themselves with a critical eye (McKean, 1958, p. 25).

The Ultimate Goal

The ultimate goal usually suggested by economists for natural resource management is the maximization of social welfare (McKean, 1958; Gardner, 1966). However, given the present state of the arts in the field of welfare economics, the futility in attempting to work with such an objective is recognized by most economists. In a nutshell, the futility of using maximization of social welfare as a goal for natural resource management (or for that matter, in any social decision-making situation) lies in the fact that economists are unable to make (for the moment) interpersonal utility comparisons. Hence, the social welfare function remains a non-quantifiable entity. Notice that the possibility of a social welfare function is not denied. It is merely economist's inability to explicitly specify such a function that necessarily relegates the goal of welfare maximization to the position of a desirable ultimate which is not presently useful as a social decision-making criterion. 10/

10 It is important that this statement not be mistakenly interpreted. Therefore, further clarification is in order. The author is
The practical difficulty inherent in the use of maximum social welfare as an operational goal for analysis has been succinctly pointed out by Kelso:

"The concept of welfare seems to imply, as a synonym, the concept of health or happiness or prosperity. It makes little difference which term we use, for each is equally clear, equally vague, equally value-loaded, equally non-operational. To be operational a concept must be capable of measurement by observation even if only in relative magnitudes (Kelso, 1964, p. 61)."

The insusceptibility of welfare to quantification leaves it impotent as an operational criterion for economic analysis. Criteria involving measurable magnitudes must be substituted for more ultimate but non-operational criteria. Economists, wishing to apply economic technique and wisdom to real world resource allocation problems, must be satisfied (at least for the time being) to work with objectives more restricted in scope.

definitely in favor of basic and applied research tending toward the eventual usefulness of welfare maximization as a goal for social decision-making. Indeed, it is essential that theoretical optima and ultimate ends be explicitly pointed out and that efforts be expended to pursue or approach these theoretically "best" constructs in applied analysis. This philosophy is, in fact, central to the theme of this dissertation. It is the author's opinion that clear and precise theory "ought to be" a first step in the development of an applied science or applied research effort.

Merely because it is believed that the goal of social welfare maximization must be relegated, for the moment, to the position of a non-operational utopia does not imply that theoretical welfare economics and those who study it are held in disdain by the author. On the contrary, the impression the author prefers to leave is quite the opposite.
Specific Economic Objectives

What, then, might these more limited, but operational, objectives be? There are numerous specific economic objectives to which a society might aspire. Among those often suggested are (1) economic efficiency -- the production of the largest possible "social pie" (in terms of the output of goods and services) from available resources, (2) equity in income distribution -- equitable division of the "social pie" among individuals of the society, (3) economic stability -- big "social pie" year in and year out, (4) economic growth -- ever increasing size of "social pie" through time, and (5) economic freedom -- freedom on the part of individuals in the society to use and dispose of economic resources as they see fit (Taylor, 1958).

These objectives are particularly relevant when the allocation and use of scarce resources is the question under consideration. Regarding the development, use, and allocation of water resources, Castle (1964a) lists four specific economic objectives that are often reflected in the deliberations at various levels of the social decision-making process (political process). These include economic efficiency, greater equality of income distribution, economic growth of the nation or of a geographic area within the nation, and stabilization of economic activity.
A Difference of Opinion

Of the aforementioned goals certainly economic efficiency has received the most attention in water resources development literature. However, in recent years the effect of water development on income distribution has begun to attract the attention of economists and others working in this area (Haveman, 1965; Kelso, 1964; Maass et al., 1962). Although most economists agree that both efficiency and distributive consequences of natural resource development are properly within the domain of economic analysis, there is by no means unanimity as to the appropriate procedure for accomplishing the task.

There is a general consensus of professional opinion that benefit-cost analysis is an appropriate tool for analyzing the efficiency consequences of development projects. This fundamental difference of opinion reduces to a question of how to handle the distributive consequences. Professional thinking appears to be divided into essentially two opinions. One opinion is that efficiency and distributive consequences should (must) be analyzed independently, while the opposing opinion is that both should (must) be handled simultaneously\(^\text{11}\) in

\[^{11}\text{The phrase "handled simultaneously" suggests an objective function that somehow accounts for both efficiency and income distributive consequences. Two possible forms come to mind: (1) constrained maximum--maximize efficiency subject to a distributive constraint or vice versa, or (2) maximize weighted efficiency benefits where discriminative weights are attached to benefits accruing to different individuals or groups. For an example of the latter, see Weisbrod (1968).}\]
order to prevent over-emphasis of the efficiency objective.\footnote{12}{It is, indeed, an over-simplification to imply that all professional opinion concerning this matter can be divided into two mutually disjoint and exhaustive subsets. There is at least one other subset of opinion. Hammond (1966), for instance, argues that the inability of economists to handle the ultimate goal of welfare maximization is not sufficient cause to permit suboptimization over specific economic goals, for the resulting optimals suggested may in actuality lead society further away from rather than closer to maximum social welfare.}

There are numerous writings which one could cite to emphasize this dichotomy of professional opinion. Among those who have expressed the opinion that economic efficiency and income distribution must be handled separately is Kelso. He argues:

There is need ... to spell out quite clearly, as separate questions, the efficiency considerations involved in each resource development project and its income redistributive consequences. With reference to neither criterion can the economic analyst say which is best, because doing so involves value judgments as much if the criterion is "most efficient" as when it is "most equalitarian". But, for the efficiency criterion he can determine a cardinal measure of preferredness, subject to restrictive assumptions, whereas for the income redistributive consequence he can do no more than describe it. Both are, however, equally the proper domain of economic analysis (Kelso, 1964, p. 63).

Arthus Maass (1966), however, feels that efficiency and distributive consequences must be treated simultaneously.\footnote{13}{Although Arthur Maass is not an economist by training, he has been intimately associated with the Harvard Water Program, and expresses an opinion which (the author believes) is also held by a number of economists working in the area.} Maass expresses the opinion that economists should determine the trade-off
ratio between efficiency and income redistribution, and then proceed
to either (1) maximize net income to a group of interest subject to
the constraint that the ratio of efficiency benefits to efficiency costs
be greater than some preassigned level, (2) maximize net efficiency
benefits subject to an income distributive constraint, or (3) maxi-
mize a weighted sum of net efficiency and distributive benefits.
Maass suggests that the trade-off ratios can be determined by exam-
ing the political process.

Why the Difference of Opinion

That there is a difference of opinion among professional eco-
nomists, as to the "best" method for relating the economic impact of
resource development projects, is apparent. It is perhaps less ap-
parent why this difference of opinion has evolved. The basic problem,
of course, lies in the fact that often the objectives under considera-
tion are not mutually compatible. Frequently, in problems of re-
source development, the goal of economic efficiency and the goal of
redistributing wealth are in conflict. That is to say, a development
project designed to improve the relative income position of a particu-
lar group will not necessarily be the project that maximizes efficiency
benefits to a particular geographic region or political sphere. Con-
versely, the optimal project from an efficiency viewpoint is common-
ly not optimal given specific redistributive objectives.
The multidimensional nature of social welfare is recognized by most economists. The "most efficient" project is not always the "most desirable". In Ditwiler's words: "Social optimality involves higher order criteria than does economic efficiency. Thus, an inefficient solution (in an economic sense) may be judged socially superior to an economically efficient solution" (Ditwiler, 1968, p. 175). This fact coupled with the fact that economic efficiency is often at odds with other dimensions, which are postulated to be important determinants of social welfare, is the basis for the difference of professional opinion. The problem is the same sort as was discussed in Chapter I where conflict due to the interdisciplinary nature of resource development was point out. In this case, however, it is the conflict of intradisciplinary objectives giving rise to the problem.

A Proposed Solution

Just as the conflict between interdisciplinary optima must be resolved by decision-makers and not by scientists, it seems obvious that the conflict of intradisciplinary optima must be resolved by decision-makers and not by scientists within that discipline. The author is of the opinion that the economist serving as expert consultant to the social decision-making process should provide information and/or a framework for analysis regarding the economic consequences (efficiency, distribution, etc.) of development projects, but
he should, and in fact must, stop short of weighting the various con-
sequences (specifying trade-off ratios) for the decision-maker. As in
the past, trade-offs must be determined by the social decision-making
process; i.e., in the political arena (Hammond, 1966; Kelso, 1966;
Seckler, 1968). The economist can and should provide analysis re-
garding other welfare determinants beyond economic efficiency, but
he can not as Maass suggests determine trade-off ratios for the
decision-maker. So long as the economist has no knowledge of the
social welfare function, which alone contains the necessary informa-
tion needed to combine knowledge about efficiency with knowledge
about other determinants such as income distribution, he must leave
the weighting of objectives to the political process. Rather than at-
tempting to estimate the weighting scheme of the political process by
observing its actions it would seem more logical and less conducive
to error to provide information concerning the consequences of alter-
native actions and leave the weighting of these consequences to the
political process—the appropriate arena. Economic analysis must
serve as an aid to decision-making, not as a substitute for it (McKean,
1958).

In reality, the economist has no choice but to look at specific
economic objectives independently. He must, given the present state
of the arts, reject objective functions involving multiple dimensions
in favor of less grandiose, single dimension varieties. Furthermore,
given the absence of a theoretically optimum income distribution, the economist should determine a cardinal measure of preferredness for those consequences which can be measured; e.g., economic efficiency, and is damned (to borrow Kelso's terminology) to merely describe those consequences which can not be subjected to optimization techniques; e.g., income distribution.

It is the purpose of this dissertation to bring together the relevant economic theory regarding efficiency and distribution and to present a theoretical framework and empirical methodology for determining and describing these two economic consequences of alternative resource allocations—specifically for interregional water transfers. To accomplish this task a model is specified, from which a necessary condition for efficiency in resource transfer is derived (Chapter IV). The model is developed in such a manner that useful information for describing regional income redistributive impacts may be elicited.

This procedure will, no doubt, be disconcerting to those who hold that such a procedure places too much emphasis on the efficiency objective and relegates distributive consequences to a secondary role. The author does not share this uneasy feeling. As Butcher puts it:

...sound quantitative economic analysis can play an important role in water resource planning.... It involves sticking to operational concepts that can be subjected to analysis and providing, not a solution, but a range of alternative... solutions that can then be analyzed by other means for their relative acceptability in trade-offs with other criteria (Butcher, 1966, p. 24).
This distinct separation of efficiency and distributive effects appears to be consistent with the position taken by several other economists concerned with the economics of resource development (Kelso, 1964; Hirschleifer et al., 1960; Eckstein, 1965; Castle and Stoevener, 1967).
III. ECONOMIC EFFICIENCY AND BENEFIT-COST ANALYSIS

Economic Efficiency

The term economic efficiency appears frequently throughout this thesis. Before proceeding with the development of an efficiency model for interregional (interbasin) resource (water) transfer, perhaps it is appropriate to pose the question: What is economic efficiency? Certainly, a discussion of this illusive concept is warranted. Hopefully, a substantive definition, possessing some degree of general applicability for economic analysis, will evolve from the following discourse.

In surveying the literature of economics, one is impressed by how frequently the term economic efficiency appears. This in itself is not distressing; however, it is distressing that definitions of economic efficiency do not so frequently appear. In much of the literature of economics, and particularly so in basic textbooks, one can find numerous statements about economic efficiency, but definitional statements are rare.

Heady (1952) provides some insight concerning the meaning of economic efficiency. In reference to agricultural production economics as a study of resource efficiency, he states, "...it is concerned with defining the conditions under which the ends or objectives of farm managers, farm families, and the nation's consumers can be
attained to the greatest degree" (Heady, 1952, p. 8).

Although Heady's statement is not presented as a definition of economic efficiency, it does identify two crucial points. The first is that a definition of efficiency requires an explicit statement of the level of aggregation being discussed; i.e., individual firm, region, nation, etc. The second point is that a definition of efficiency requires the explicit specification of the objective(s) of the unit(s) specified in the statement of aggregation. If either of these statements is ambiguous or incomplete, then any discussion of efficiency will be plagued by ambiguity and confusion.

For our purpose "efficiency" can be defined as a measure, either cardinal or ordinal, of the degree to which an objective is attained (i.e., a measure of performance). In this sense efficiency is relative. A more specific situation often referred to by economists is that of attainment of the objective to the highest possible degree. This absolute concept of efficiency, "most efficient", may be identified by stating conditions, the fulfillment of which optimizes the objective function, constrained or unconstrained. Unfortunately, it

\[ \text{The terms, constrained and unconstrained, refer to a specific mathematical form of the objective function. That is, the constrained-optimization problem involves maximizing or minimizing a function, } f(x_1, \ldots, x_n), \text{ subject to the constraint that only certain values of } x_1, \ldots, x_n \text{ are admissible, whereas a free optimization (unconstrained) problem does not involve a side relation(s) so that the independent variables are permitted to take on all possible values} \]
is common to find the concepts "most efficient" and "efficiency" used interchangeably in the literature. Gardner, for example, defines economic efficiency as "... the allocation of resources among competing ends in such a way that desired results are maximized" (Gardner and LeBaron, 1966, p. 1). In this case the term is clearly being used in the absolute sense of "most efficient". In this thesis, however, economic efficiency is used in the relative sense. That is, as a measure of the degree to which an economic objective is attained.

A Specific Interpretation of Economic Efficiency

The level of aggregation considered in formulating the basic model for this study is national. The objective of interest is the maximization of the net, present, real, market value of incremental output resulting from a resource development project. Therefore, for purposes of this study, the concept of economic efficiency is given specific content as follows: economic efficiency is a cardinal measure

(Henderson and Quandt, 1958, p. 272).

Hereafter, unless explicitly stated otherwise, whenever reference is made to an objective function it will be understood that it may be of either the constrained or unconstrained form. It is assumed that an unconstrained objective function has built into it any relevant constraints; e.g., a profit function for a firm.

15 The assumption of a national rather than a regional point of view makes considerable difference. The assumption of a regional point of view would permit, for instance, ignoring direct and indirect opportunity costs imposed outside the region. Furthermore, indirect benefits that can legitimately be counted are decidedly different depending on the level of aggregation chosen (see Chapter V).
of the degree to which the net, present, real, market value of incremental national output is changed as a consequence of a particular resource development project.

"Market value" versus "value". It is important to note that the term "market value", not simply "value", is used in the statement of the objective. The term "value" is reserved for those utopian objective functions stated in terms of utility. The author does not suffer the delusion that somehow the maximization of net market value of incremental output is equivalent to the maximization of social welfare. Equivalence would imply a single dimensional social welfare function; i.e., a welfare function which, among other things, is independent of distributive effects. If a welfare function could be specified, surely distributive considerations would be involved. Furthermore, the author is not prepared to accept many of the rather heroic assumptions required to ensure that market prices reflect social benefits and costs. As McKean has noted: "There are enough things wrong with observed prices to make one's hair stand on end" (McKean, 1968, p. 37). He mentions, among other things, monopolistic product and factor markets, price support programs, and external effects. To develop the argument that market prices represent "social benefits and costs are found in Samuelson (1948, p. 219-243)."
value" by relying heavily on rather dubious assumptions is misleading. That is, to leave the impression that market prices have general normative social significance since given particular circumstances they reflect social benefits and costs is to commit the logical fallacy of hasty generalization.

Since the argument is not being advanced that market prices reflect social benefits and costs, one might ask: Why the concern for determining the market value of incremental output resulting from resource development projects? The answer is fairly clear. To date, economists have been unable to define social benefits and costs, for a social welfare function has not been explicitly quantified. Thus, in an effort to provide some analysis relevant for social decision-making, one must reach for the best available substitute. Market prices, although not perfect indicators of social benefits and costs, are the best proxy variables available. As McKean puts it:

The only good thing one can say about market prices is that they are usually better than the alternatives--prices that are derived rather than observed. The reason is that markets provide an enormous amount of information at a relatively low cost, even though the information is still short of being perfect. This information has some relevance as long as one's preference function gives some weight to the desirability of having voluntary exchange... Because of market imperfections, there are no doubt more appropriate exchange ratios in principle, but in most cases it would be extremely expensive to acquire the improved information... the existence of defects in market prices does not mean that some other derived price or alternative procedure would automatically be better (McKean, 1968, p. 37-38).
Certainly, if sufficient controversy existed between individual members of society over whether or not market prices represented severe distortions of social benefits and costs, the present market mechanism would not be relied upon so eminantly as a resource allocator; steps could and would be taken to temper to a greater extent than currently the operation of that mechanism.

If economic analyses of resource development projects are to be undertaken at all, then analysts must resort to the most practical alternative available--namely, market values. Although market prices are not perfect indicators of social values, they are, hopefully, not completely erroneous indicators. Market values have and will probably continue to be used in project evaluation, since research economists as well as decision-makers are constrained by budgetary considerations. However, the economist can go one step further than he traditionally has in an effort to provide information relevant to decision-makers--he can provide information concerning at least one more (in addition to efficiency) important welfare determinant--namely, the income redistributive consequences of proposed projects.

Maximization of net, present, real, market value versus maximization of national income. A brief digression to consider the relationship between the proposed objective function (see p. 24) and another familiar statement of it is warranted. Frequently, in the literature, maximization of the change in national income is suggested as
the objective of interest. Caution is required to avoid the mistaken impression that a change in national income and net market value of incremental output are equivalent. Only given very special circumstances are the two concepts equivalent.

According to Ackley: "National income is nothing more than the sum of all individual incomes" (Ackley, 1961, p. 25). One way that national income may be computed is to sum up the "valued added" by each step in the production process. Gordon states:

..."value added" at any stage of production is the difference between the cost of all materials purchased from other industries ... and the figure at which that industry sells the product to someone else. This difference, or "value added", is obviously merely the sum of the incomes (including profit) going to the factors of production working in that particular industry (Gordon, 1952, p. 24-25).

Essentially the difference between a change in national income and net market value of incremental output involves two concepts---extra market goods and pecunary externalities. If the project under consideration is not expected to yield extra market benefits or costs,\textsuperscript{17} and if no pecunary externalities (spillovers)\textsuperscript{18} are

\textsuperscript{17}Extra market benefits and costs refer to the "market value" (imputed) of extra market goods or services. Such goods (e.g., recreation) are frequently not allocated by the market mechanism. Hence, market prices are not available for valuation purposes.

\textsuperscript{18}Spillovers or externalities are uncompensated impacts of actions by some decision-making units on the activities of others. External effects may be either favorable to others, external economies, or unfavorable to others, external diseconomies. As related
involved, then the change in national income resulting from the project is equivalent to the net market value of incremental output. If, however, extra market benefits are generated as a result of the project, the change in national income will be less than the net market value of incremental output, since the imputed market value of the extra market goods are included in the latter but not in the former.

If pecuniary externalities exist, then again the change in national income will not equal the net market value of incremental output, except by accident, since the former takes into account spillovers (pecuniary) whereas the latter does not. According to McKean:

> Shifts of national income as it is measured mirror the combined influence of numerous events. Instead of reflecting the change in terms of projected relative prices (the value and cost of the extra output in terms of a particular price structure), a shift in national income may reflect the change from one price structure to another (McKean, 1958, p. 145).

The net market value of incremental output was chosen in preference to change in national income as the objective of interest, primarily because it was deemed to be important to separate and identify as separate considerations the efficiency and distributive aspects of externalities. Pecuniary externalities involve uncompensated effects on the costs or receipts (level of satisfaction) of one or more firms (consumers) as the result of actions of other decision-makers (firms, consumers, or government).

Pecuniary externalities are a special kind of externality which occur as a result of shifts in product or factor prices. For example, a pecuniary external diseconomy would occur if an expansion of a particular industry causes the price of a factor used by that industry to increase (McKean, 1958).
resource transfers. Pecuniary externalities involve primarily distributive aspects. Therefore, change in national income is not an appropriate objective for isolating strictly efficiency considerations. Although extra market benefits are not explicitly considered in this research, stating the objective in terms of net market value of incremental output rather than in terms of national income allows for the expansion of the model to include such benefits if, in a particular situation, they are judged to be important.

**Benefits and Costs**

Another definitional problem closely related to the preceding discussion is the concept of a benefit. The term benefit, like efficiency, is commonplace in economics literature, and like efficiency, has both popular and technical meanings. Sewell et al., define benefits as "advantageous effects" (Sewell et al., 1965, p. 5). This definition may be refined by relating benefit to our definition of efficiency. Recall, that efficiency was defined as a measure, either cardinal or ordinal, of the degree to which an objective function is optimized. Thus, a benefit may be defined as any favorable change (increase or decrease) in the variable being optimized (maximized or minimized). Benefits are measured in the same units as the dependent variable of the objective function. Let us assume the objective is to maximize $Z = f(X)$ and that a change in $X$, say $\Delta X$, yields a change in
Z, say $\Delta Z$; i.e., $Z + \Delta Z = f(X + \Delta X)$. If $\Delta Z > 0$ the effect of changing $X$ by $\Delta X$ is beneficial. Similarly, if the objective is to minimize $Z$, then if $\Delta Z < 0$ the effect is beneficial. The magnitude of the benefit is given by $\Delta Z$ and is expressed in the same units as $Z$.

Negative benefits (disbenefits) are referred to as costs. That is, assuming one wishes to maximize (minimize) $Z = f(X)$, if a change in $X$, $\Delta X$, yields a change in $Z$, $\Delta Z$, such that $Z + \Delta Z = f(X + \Delta X)$, then if $\Delta Z < 0$ ($> 0$) the effect of changing $X$ by $\Delta X$ is costly. The magnitude of the cost is given by $\Delta Z$ and is expressed in the same units as $Z$. Costs are "disadvantages effects". That is, they are merely the antithesis of benefits.\(^{19}\)

Obviously, the term benefit (cost) is aggregation and objective specific. That is, benefit is unambiguous only when related to a particular level of aggregation and specific objective function. Specification of the level of aggregation is particularly important since sometimes one man's (region's) benefit is another man's (region's) cost and vice versa.

\(^{19}\) From the foregoing discussion it should be clear that benefits and costs are defined as gross, not net concepts—they shall remain as such throughout this thesis. Unfortunately, those writing benefit-cost literature have a tendency to start off using benefit as a gross concept and then shift, in mid-stream and without warning, to a net concept.
Classification of Benefits and Costs

The remainder of this chapter is devoted to a discussion of a benefit classification scheme. This classification is presented schematically in Figure 1. For purposes of this classification, the level of aggregation of interest is assumed to be the nation. The objective of interest is the maximization of the net, present, real, market value of incremental output resulting from a particular resource development project. \(^{20}\)

**Relevance to objective function.** Since the terms benefit and cost (Level I) are objective specific, they may be stratified into two distinct classes (Class A and Class B; Level II) as is illustrated in Figure 1. At Level II benefits and costs are broken down into two categories: (1) those for which the objective function of interest is relevant (Class A); i.e., those benefits and costs which can be expressed in the same units as the dependent variable, and (2) those for which the objective function of interest is largely irrelevant (Class B); i.e., those benefits and costs which can not and, in fact in some instances, should not be expressed in the same units as the dependent variable of the objective function (in this case, real dollars).

Class A benefits (costs) are those effects that tend to increase

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\(^{20}\) Maximization of value of incremental output is generally the objective assumed in most benefit-cost classification schemes. Consequently, it is the objective around which the basic terminology has evolved.
Figure 1. Classification of direct benefits and costs.
(decrease) the present, real, market value of incremental output.

Class B benefits and costs include those relevant to other objectives; e.g., income redistribution, provision of entrepreneurial opportunity, etc.

The following sub-stratifications are relevant to Class A benefits and costs. The terminology used in the benefit classification scheme presented herein is consistent with that which has been traditionally used in benefit-cost literature. Generally the objective to which these terms have been related is one of maximizing the net market value of incremental goods and services resulting from the project. Although the same logic might be followed, it is questionable whether the same breakdown is useful or even relevant for other possible objectives (Class B).

**Direct benefits and costs.** Direct benefits (Level III) represent increases in the present, real, market value of the immediate products and services attributable to the project. Direct costs (Level III) represent decreases in this value. These benefits and costs, which may be distinguished as being either "project" or "associated", are defined as follows:

1. **Direct project costs**--decreases in the present, real, market value of incremental national output that are incurred in order to build and maintain the development structures (reservoirs, dikes, etc.). These costs represent the
opportunity cost of not using the resources in their next best alternative, and are reflected by factor prices. Direct project costs occur during project construction (construction costs) and during project operation (maintenance costs).  

(2) **Direct associated benefits**—increases in the present, real, market value of incremental national output that are realized from the sale of the immediate products and services attributable to the project. The class of direct associated benefits exhausts the class of direct benefits, since the class of direct project benefits is empty. Hence, all direct benefits must be associated benefits. Direct benefits can not be realized until the project is operative. (This is not true, however, of indirect benefits—see Chapter V.)

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21 The class of direct project benefits is empty. Any benefit that is related strictly to the construction or maintenance of the project can not be direct.

22 In some instances the product or service in question is an "extra market good", which is not traditionally allocated by the market mechanism. In such cases (e.g., recreation), the market value of these goods may be measured in monetary terms by procedures which involve attributing a value to them (Brown et al., 1964; Stevens, 1966b). In order to develop a complete benefit classification scheme, one could separate Level III benefits into "market" ("tangible") and "extra market" ("intangible") varieties. However, for purposes of this thesis such a distinction is not essential and would only tend to confuse the issue.
(3) **Direct associated costs**—decreases in the present, real, market value of incremental national output that are incurred (beyond direct project costs) in order to realize the direct associated benefits. These costs are borne by direct beneficiaries; e.g., irrigators. Like direct project costs, these costs represent the opportunity cost of not using the resources in the next best alternative, and are reflected by factor prices.

In terms of beneficiary income, direct benefits represent gross income accruing to those producing (consuming) the immediate incremental output of the project. For example, if the project was to provide irrigation water to farmers, direct benefits represent the increase in gross income to those farmers on the project. Direct costs would include not only those of constructing and maintaining the project (direct project costs) but also those incurred by the farmers in order to generate the increased gross income (direct associated costs).

This classification scheme is extended to accommodate indirect benefits and costs in Chapter V. In the following chapter, a model for identifying the economic efficiency consequence of resource transfer schemes is developed in terms of direct benefits and costs associated with these schemes.
IV. THE EFFICIENCY MODEL

Statement of the Level of Aggregation and Objective

The objective of interest is to maximize the net, present, real,\(^{23}\) market value of incremental output (goods and services) resulting from a resource transfer project. The objective function may be symbolically stated as

\[
\text{maximize } \sum_{t=1}^{n} \frac{B_t}{(1+\phi_B)^t} - \frac{C_t}{(1+\phi_C)^t} \quad (4-1)
\]

where \(Z\) represents the net market value of incremental output resulting from the project, \(B_t\) represents project benefits in time \(t\) (those effects that cause \(Z\) to increase), \(C_t\) represents project costs in time \(t\) (those effects that cause \(Z\) to decrease), \(\phi_B\) represents the discount rate for future benefits, and \(\phi_C\) represents the discount rate for future costs.\(^{24}\)

\(^{23}\) Due to the intertemporal nature of most resource development projects one must set aside the possibility of changes in the general price level in order to compare present values of future output streams. Whenever possible, real prices of inputs and outputs should be used. Hereafter, unless otherwise noted, it is assumed that net market value is stated in real terms and represents the present value of future benefit and cost streams.

\(^{24}\) It is important to note that the discount rate used for costs, \(\phi_C\), is different than that used for benefits, \(\phi_B\). The difference lies in the opposite relationship that exists between benefits and costs.
The level of aggregation considered in the efficiency model is national. However, a regional breakdown of benefits and costs is included in order that distributive consequences of resource transfer projects might be identified. For this purpose it is assumed that a total economy (nation) may be split into three distinct regions--

(1) a region of origin, o; that economic area from which the resource in question is diverted,

(2) a region of destination, d; that economic area to which the resource is diverted, and

(3) the remaining region, e; that economic area of the nation not included in the

with respect to uncertainty. That is, in choosing a discount rate for benefits the pure (riskless) interest rate is adjusted upward by adding a risk premium, whereas for costs the pure interest rate is adjusted downward by subtracting a risk discount. Symbolically,

\[ \phi_B = i_O + i_B \]
\[ \phi_C = i_O - i_C \]

where \( i_O \) is the pure (riskless) rate of interest, \( i_B \) is the risk premium applied to future uncertain benefits, and \( i_C \) is the risk discount applied to future uncertain costs. Since \( i_B > 0 \) and is added to \( i_O \) whereas \( i_C > 0 \) and is subtracted from \( i_O \), it follows that \( \phi_B > \phi_C \). The net effect is that the present value of future benefits is reduced more than the present value of future costs.

Furthermore, it is likely that \( i_C < i_B \) since benefit estimation tends to be more uncertain than cost estimation for most resource development projects (Haveman, 1965). This would tend to exaggerate even to a greater degree the deviation between \( \phi_B \) and \( \phi_C \).

It would be possible (although not demonstrated in this dissertation) to describe regional income redistributive effects of resource transfer schemes. From the basic efficiency model developed herein it is possible to identify certain direct benefits and costs by region of impact. Other direct benefits and costs—namely, costs of effecting the transfer (in the case of interbasin water transfer these
region of origin or the region of destination (elsewhere).

The objective function may be expanded to allow for the identification of regional benefits and costs as follows:

$$\text{maximize } Z = Z_1(B_o, B_d, B_e, C_o, C_d, C_e) \quad (4-2)$$

where

- $B_o$ represents benefits in the area of origin,
- $B_d$ represents benefits in the area of destination,
- $B_e$ represents benefits in the remaining area,
- $C_o$ represents costs in the area of origin,
- $C_d$ represents costs in the area of destination,
- $C_e$ represents costs in the remaining area.

would include costs of constructing and operating the transfer vehicle--are frequently shared by the nation as a whole and are not readily identifiable by region. However, these costs might be allocated by determining the share of the federal tax burden borne by various regions and weighting proportionately.

In addition to the direct effects, indirect effects must be accounted. The indirect effect of a resource transfer on a regional economy may be profound. The magnitude of the indirect change in a particular region's income may easily exceed that of the direct change which triggered it. Regarding the proposed Northwest-Southwest (U.S.A.) water diversion, Castle has commented: "It is obvious these indirect regional benefits are a potent political factor in the current scene" (Castle, 1968, p. 5). An accounting of respective regional indirect effects might be accomplished using regional input-output models.

Finally, a complete description of the regional income redistributive effects of resource transfer schemes would require that relevant pecunary externalities be identified. For example, if the resource to be transferred is used to produce products which compete with those of other regions, then the effect, if any, on prices received in other regions must be taken into account.
Given the level of aggregation and objective as stated, it is now possible to specify at least in general terms the direct benefits and costs that are relevant to the objective function.\textsuperscript{26} Direct benefits in the area of destination, $B_d$, would include increases in the gross market value of output attributable to the transfer project (direct associated benefits). Direct costs in the area of destination, $C_d$, would include the market value of factors used in the production of the additional output attributable to the transfer project (direct associated costs). Direct costs in the area of origin, $C_o$, would include the market value of output foregone due to the transfer of the resource out of the region (direct associated costs). Direct benefits in the area of origin, $B_o$, would include the market value of factors no longer used in the production of foregone output (direct associated benefits).\textsuperscript{27} The question as to which specific benefits (outputs) should be considered is discussed in the next section.

The cost of the physical transfer scheme, if funded (in part or in whole) by the federal government, would be shared by the nation as a whole. Therefore, other direct costs (direct project costs) in

\textsuperscript{26} Indirect benefits and costs are considered in Chapter V.

\textsuperscript{27} In accordance with the definitions given in the previous chapter, the production (consumption) of an existing output that must be foregone as a result of a resource diversion project must be charged against the project as a direct associated cost. Similarly, the cost of producing the foregone output must be credited to the project as a direct associated benefit.
the form of tax burden would accrue in the areas of destination, $d$, and origin, $o$, as well as in the remaining region, $e$. Throughout this chapter these direct project costs are lumped together and identified as costs of transfer (physical), $C_T$, and, hence, lose at least temporarily their identity as to region of impact. It is assumed that no direct benefits or costs other than a share of the tax burden accrues to the remaining region; i.e., $B_e = 0$ and $C_e = \% C_T$.

The Marginal or "Lowest Valued" Use

Given the identification of a region of origin, $o$, and a region of destination, $d$, the next pertinent question is: Which of the many products and services that are related either directly (consumptively) or indirectly (productively) to the transferred resource should be considered in assessing the direct benefits and costs of a particular resource transfer scheme? For example, if one considers the possibility of an interregional transfer of water: Which of the numerous uses of water in the regions of origin and destination should be included in assessing the net market value of incremental output resulting from the project?

For the economist the answer is clear—it is the marginal use of the resource that is relevant in assessing the efficiency implications of resource transfer schemes. The marginal use of a resource is that use having the lowest marginal value product given a particular
(e.g., the existing) allocation of the resource. For example, if use A and use B have marginal value product functions for X as depicted in Figure 2 and the existing allocation of X is such that \( X_A \) units are employed in use A and \( X_B \) units are employed in use B, then B represents the marginal use of X. The market value of aggregate output of a region may always be increased by transferring resources from uses which have low marginal value in use to those which have a higher marginal value in use. If the importation of a resource is being considered, it matters not what the stated purpose or use might be, the relevant use for evaluation purposes is the marginal use. In other words, to argue that the area of destination has a number of "high valued" uses for a particular resource is not relevant so long as the resource is being used in significant quantities in "low valued" uses in that area (Castle, 1964b).

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28 Note, the marginal use of a resource may change as the allocation of the resource changes. If a resource was allocated according to the equimarginal principle (water usually is not), then the marginal or least valuable use of a resource is that use which is first eliminated as the marginal factor cost of the resource increases.

29 For an excellent discussion of the principles and logic involved in maximizing the net market value in the use of a resource, see Hirshleifer et al., Water Supply: Economics, Technology, and Policy, Chapter 3 (1960).
The determination of the marginal use of a resource need not be limited to industry boundaries. For instance, if agriculture is determined to be the marginal user of a particular resource, then one must ask the next question--namely: Which output within agriculture represents the marginal use of the resource? Conceivably one should carry the argument to its logical conclusion. The analyst, in so far as data permits, should attempt to isolate the single product which represents the marginal use of the resource. If the total quantity of the resource used in the least valuable use is less than the quantity to be transferred, then the net market value of the residual amount (over and above that required for the least valuable use) of the resource should be evaluated on the basis of its value in the next lowest
valued use. These values should then be summed to arrive at the total value in use.

The determination of the marginal valued use of a resource is further complicated if technological interdependencies—intrafirm (joint production) or interfirm (externalities)—are involved. The efficiency model developed herein may be extended to include such complications in the analysis. These complications are considered in the next chapter.

**The Least-Cost Alternative**

Before elaborating the efficiency model (4-2), it is possible to state *a priori* one of several necessary conditions for economic efficiency in resource transfer. That condition, the least-cost condition, may be symbolically stated as follows:

\[
C_T - [TVP_o - TFC_o] \leq C_A
\]  

(4-3)

where \( C_T \) represents the present total cost of the particular transfer scheme under consideration, \( TVP_o \) represents the present total value product that would be foregone in the area of origin (a measure of \( C_o \)), \( TFC_o \) represents the present total factor costs that would have been incurred in the area of origin had not the transfer taken place (a measure of \( B_o \)), and \( C_A \) represents the present cost of the least-cost alternative (exclusive of the transfer scheme
under consideration). That is, the transfer scheme under consideration must be less costly than alternative sources of supply in the area of destination.

In most situations there exists a number of alternative ways for supplying a region with a specified quantity of a particular resource. If one is concerned with accomplishing such a task in the most efficient manner, then it is imperative that the least-cost method be employed. The second consideration regarding efficiency is, of course, the question of whether or not the net market value of incremental national output is enhanced by the transfer given that the least-cost method of delivery is employed. This question is the central issue of the efficiency model which follows.

The Efficiency Model

In discussing the objectives of this thesis, it was noted that the relevant economic variables related to interregional resource transfer issues should be explicitly identified and isolated. To accomplish this task it is imperative that the efficiency model as expressed

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30 In identifying alternative's to include in the set from which the least-cost delivery scheme is to be selected, it is necessary that all the alternatives accomplish the same task. That is, the alternatives must deliver a like quantity and quality of the resource and do so throughout comparable time spans.

31 Carlson (1939) presents an analogous argument for a firm seeking to maximize profits.
in Equations (4-1) and (4-2) be examined and articulated in considerable detail. The following notation will be used in the development of the efficiency model.

**Notation**

**Subscripts:**

- \(d\) - denotes the area of destination.
- \(o\) - denotes the area of origin.
- \(e\) - denotes that area exclusive of the area of origin and destination (elsewhere).
- \(i\) - product index, where \(i = 1, \ldots, u\).

**Note**, all products need not be produced in both the area of destination and origin.

- \(j\) - input index, where \(j = 1, \ldots, v\).

**Note**, all inputs need not be used in the production of each product; i.e., the \(k\)th input may be zero for the \(l\)th output.

- \(t\) - time index, where \(t = 1, \ldots, n\).

**Variables:**

- \(Z\) - denotes net, present, real, market value of incremental national output.

- \(B_d\) - denotes gross benefits in the area of destination.
- \(B_o\) - denotes gross benefits in the area of origin.
- \(B_e\) - denotes gross benefits elsewhere in the economy.
$C_d$ - denotes gross costs in the area of destination.

$C_o$ - denotes gross costs in the area of origin.

$C_e$ - denotes gross costs elsewhere in the economy.

$TVP_d$ - denotes total value product of the resource to be transferred if employed in its marginal use(s) in the area of destination, aggregated over firms and through time.

$TVP_o$ - denotes total value product of the resource to be transferred if employed in a curtailed use(s) in the area of origin, aggregated over firms and through time.

$TFC_d$ - denotes total factor cost associated with the production of that product(s), representing the marginal use of the resource to be transferred in the area of destination, aggregated over firms and through time.

$TFC_o$ - denotes total factor cost associated with that production foregone in the area of origin, aggregated over firms and through time.

$C_T$ - denotes total cost of transfer.

$C_F$ - denotes fixed cost of transfer.

$C_V$ - denotes variable cost of transfer.

$y_{idt}$ - denotes the $i$th product produced in the area of destination during the $t$th time period.

$y_{iot}$ - denotes the $i$th product produced in the area of origin during the $t$th time period.
Note, more than one marginal use may need to be considered in either the area of destination or origin, in that the use having the lowest marginal value given the allocation of the resource may not exhaust the total quantity of the resource to be transferred. Also, the possibility of interdependent production processes necessitates allowance in the notational scheme for more than one product (see Chapter V).

\[ x_{jt} \] - denotes the \( j \)th input used in the production of a product.

\[ p_{idt} \] - denotes the price of the \( i \)th product in the area of destination during the \( t \)th time period.

\[ p_{iot} \] - denotes the price of the \( i \)th product in the area of origin during the \( t \)th time period.

\[ r_{jdt} \] - denotes the price of the \( j \)th input in the area of destination during the \( t \)th time period.

\[ r_{jot} \] - denotes the price of the \( j \)th input in the area of origin during the \( t \)th time period.

Note, it is prices in the \( t \)th time period that are relevant for valuing products produced and factors employed during that time period. It is market value of incremental output that is important from an efficiency viewpoint—see McKean (1958, p. 140). Impacts due to product and factor price changes traceable to the project (pecunary externalities) are appropriately considered as distributive effects of the
project—see Footnote 25, this chapter.

\[ m_{idt} \] denotes the number of firms in the area of destination producing the \( i \)th product during the \( t \)th time period.

\[ m_{iot} \] denotes the number of firms in the area of origin producing the \( i \)th product during the \( t \)th time period.

Note, \( m_{idt} \) and \( m_{iot} \) represent only the number of firms involved in the production of that quantity of the \( i \)th product which is incremental with respect to the transferred resource.

Hence, \( m_{idt} \) (\( m_{iot} \)) does not necessarily equal the total number of firms producing the \( i \)th product in the area of destination (origin). It is the net increase (loss) in output resulting from the transfer that is of interest.\(^{32}\)

Functions:

\[ y_{idt}(x_1, \ldots, x_v) \] denotes a firm's production function for the \( i \)th product in the area of destination during the \( t \)th time period.

\[ y_{iot}(x_1, \ldots, x_v) \] denotes a firm's production function for the \( i \)th product in the area of origin during the \( t \)th time period.

\(^{32}\)In order to obtain the conclusions reached in this chapter, it is not necessary to assume that production functions across firms (intraregional) are identical. However, the generality that might be gained by the addition of a firm subscript to the variables is seemingly offset by the added confusion associated with a more cumbersome notation. Although identical production functions are assumed, the reader should bear in mind that the assumption is not critical with respect to the conclusions reached.
h_t - denotes the variable cost function for transferring the resource of interest during the tth time period.

k_{jot} - denotes the marginal factor cost function for the jth input in the area of origin during the tth time period.

Parameters:

\( \phi_B \) - denotes the discount rate applied to benefits.

\( \phi_C \) - denotes the discount rate applied to costs.

It should be noted, that while \( y_{idt} \) and \( y_{iot} \) where \( i = k \) represent the same product (i.e., the kth product), this product may be relevant for the area of destination--that is, it may represent the marginal use of \( x_j \) --but not for the area of origin. Hence, \( y_{kdt} \) would appear in the model whereas \( y_{kot} \) would not. Also, it is important to note, that while \( p_{kdt} \) and \( p_{kot} \) (\( r_{kdt} \) and \( r_{kot} \)) represent the price of the same output (input) they need not be equal.

Assumptions

The following assumptions are made to simplify the development and presentation of the efficiency model and subsequent derivation of a necessary condition for resource transfer:

(1) National indirect benefits and costs are zero. The relevance of incorporating indirect benefits and costs in the efficiency model is considered in Chapter V.
(2) The marginal use in the area of destination involves a single independent production process. Assume that this use is represented in the production of $y_{bdt}$ and that this use exhausts that quantity of the resource under consideration for transfer. Assume that the only use foregone in the area of origin involves the production of $y_{cot}$.

(3) The resource to be transferred has no value in transit.

(4) Perfect competition exists in all product and factor markets. This assumption is merely made to simplify and, hopefully, clarify the presentation of the model--if imperfect competition or price and cost functions were incorporated, the conclusions (a necessary condition for efficiency in resource transfer) would remain unaltered.

**The Model**

From page 39, recall that the objective is to maximize

$$Z = Z_1(B_d, B_o, B_e, C_d, C_o, C_e).$$

(4-2)

As was noted on page 41, it is assumed that $B_e = 0$ since only direct benefits are considered in the model at this point. Also, $C_e$ is represented as merely some percentage of $C_e$. Thus, (4-2) may be reduced to
Specifically, 

$$Z = Z_2(B_{d'}, B_o, C_d, C_o, C_T). \tag{4-3}$$

Substituting proxy variables for benefits and costs, the function may be transformed as follows:

$$Z = B_d - C_d - C_T - C_o + B_o. \tag{4-4}$$

Substituting proxy variables for benefits and costs, the function may be transformed as follows:

$$Z = (TVP_d - TFC_d) - [C_r + C_v + (TVP_o - TFC_o)] \tag{4-5}$$

where $TVP_d$ represents $B_{d'}$, $TFC_d$ represents $C_{d'}$, $C_T$ is represented by $C_F + C_V$, $TFC_o$ represents $B_o$, and $TVP_o$ represents $C_o$. Throughout this thesis benefits and costs are expressed as gross concepts, where benefits (costs) represent effects that cause $Z$ to increase (decrease). Hence, it follows that, as a result of the project, gross value product foregone in the area of origin ($TVP_o$) is costly whereas the cost of factors that would have been used to produce the foregone output ($TFC_o$) is beneficial. Translated, Equation (4-5) states that the net, present, real, market value of incremental national output ($Z$) is equal to the aggregate net value product in the area of destination ($TVP_d - TFC_d$) less the cost of the transfer scheme ($C_F + C_V$) less the aggregate net value product forfeited in the area of origin ($TVP_o - TFC_o$). The variables in the efficiency model (4-5) may be more explicitly expressed as follows:
\[ \text{TVP}_d = \sum_{t=1}^{n} m_{bd} \frac{p_{bd} y_{bd}}{(1+\phi_B)^t}, \]  

(4-6)

where \( y_{bd} \) represents the marginal use of the transferred resource in the area of destination. That is, the aggregate total value product in the area of destination equals the discounted total revenue stream received by a representative firm, multiplied by the number of such firms producing \( y_{bd} \).

\[ \text{TFC}_d = \sum_{t=1}^{n} m_{bd} \frac{\sum_{j=2}^{v} r_{jd} x_{j}}{(1+\phi_C)^t}; 33/ \]  

(4-7)

i.e., the aggregate total factor cost associated with the production of \( y_{bd} \) equals the discounted factor cost streams incurred by a representative firm multiplied by the number of such firms. Similarly, 

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33 The cost of the first factor—the resource under consideration for transfer \( (j = 1) \)—has already been accounted for, in the model, as \( C_T \). Hence, \( j \) is summed from 2 through \( v \), rather than from 1 through \( v \). Since, at this point, it is taken as given that the transfer scheme under consideration is the least-cost means of supplying the resource in the area of destination (4-3), it is appropriate that \( C_T \) is included in the model whereas \( r_{1dt} x_{1} \) is not. To include both in the model would be to double account for the cost of employing the transferred resource in the production of \( y_{bd} \).
\[ \text{TVP}_0 = \sum_{t=1}^{n} m_{\cot} \frac{p_{\cot} y_{\cot}}{(1+\phi_C)^t} \]  \hfill (4-8)

and

\[ \text{TFC}_0 = \sum_{t=1}^{n} m_{\cot} \frac{\sum_{j=1}^{v} r_{jot} x_j}{(1+\phi_B)^t} \]  \hfill 34/ \hfill (4-9)

Substituting (4-6), (4-7), (4-8), and (4-9) into (4-5), one obtains

\[
Z = \sum_{t=1}^{n} m_{\text{bd}t} \left( \frac{p_{\text{bd}t} y_{\text{bd}t}}{(1+\phi_B)^t} - \frac{\sum_{j=2}^{v} r_{jdt} x_j}{(1+\phi_B)^t} \right) \\
- \left[ C_F + C_V + \sum_{t=1}^{n} m_{\cot} \left( \frac{p_{\cot} y_{\cot}}{(1+\phi_C)^t} - \frac{\sum_{j=1}^{v} r_{jot} x_j}{(1+\phi_B)^t} \right) \right]. \tag{4-10}
\]

In order that (4-10) may be expressed strictly as a function of the input variables, substitutions must be made for \( y_{\text{bd}t}, y_{\cot}, C_V, \) and \( r_{\text{jot}}. \) Product and input prices (with the exception of \( r_{\text{jot}} \))

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34 Recall that \( \text{TVP}_0 \) represents output foregone as a consequence of the resource transfer; i.e., it represents a cost. Hence, the discount applied is \( \phi_C \). \( \text{TFC}_0 \) represents a benefit and is, therefore, discounted accordingly. The logic involved in using different discount rates for benefits and costs was discussed in Footnote 24, page 37.
are considered as parameters rather than as variables for the sake of simplicity. The variables listed above may be expressed as a function of inputs as follows:

The production function \( y_{bdt} \) may be expressed as

\[
y_{bdt} = y_{bdt}(x_1, \ldots, x_v). \tag{4-11}
\]

Similarly, the production function for \( y_{cot} \) may be expressed as

\[
y_{cot} = y_{cot}(x_1, \ldots, x_v). \tag{4-12}
\]

The variable costs of transfer may be expressed as

\[
C_V = \sum_{t=1}^{n} \frac{h_t(x_1)}{(1+\phi_C)^t}; \tag{4-13}
\]

i.e., variable costs of transfer are a function of the quantity of the resource to be transferred. The price (cost) of \( x_1 \) (the resource to be transferred) in the area of origin \( r_{lot} \) may very well be a function of the quantity consumed by the individual firm, just as the variable cost of transferring \( x_1 \) was hypothesized to be a function of the quantity transferred. In order to allow for this possibility and to demonstrate the applicability of the model with respect to flexible

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35 The production function gives mathematical expression to the relationship between the quantities of inputs employed and the quantity of output produced (Henderson and Quandt, 1958, p. 42).
as well as fixed input and product prices, the price (cost) of employing \( x_1 \) in its foregone use in the area of origin is expressed as a function of \( x_1 \). That is,

\[
r_{1ot} = k_{1ot}(x_1).
\]  

Incorporating (4-11), (4-12), (4-13), and (4-14) into (4-10), the efficiency model is completely specified as

\[
Z = \sum_{t=1}^{n} m_{bdt} \left( \frac{p_{bdt} y_{bdt}(x_1, \ldots, x_v)}{(1+\phi_B)^t} - \sum_{j=2}^{v} r_{jdt} x_j \right) \\
- \left[ \frac{h(x_1)}{(1+\phi_C)^t} + \sum_{t=1}^{n} m_{cot} \left( \frac{p_{cot} y_{cot}(x_1, \ldots, x_v)}{(1+\phi_C)^t} - \sum_{j=2}^{v} r_{jot} x_j \right) \right].
\]  

To summarize, the efficiency model states that the net, present, real, market value of incremental national output is equal to the aggregate net value product in the area of destination less the cost of the transfer scheme less the aggregate net value product forfeited in the area of origin, where the net value product in the area of destination is calculated on the basis of the marginal use of the resource under consideration for transfer.
Upon estimation, $Z$ represents a cardinal measure of the efficiency consequence or implication (given the national point of view) of a particular (the least-cost) resource transfer scheme. However, the empirical task of estimating $Z$ is formidable. The identification of the least-cost alternative and the subsequent estimation of the components of the efficiency model (4-15) involve numerous analytical problems. Whether or not the cost associated with the provision of a specific estimate of $Z$ for a particular resource transfer scheme is justified is certainly a relevant question to pose—particularly for an economist. That is, the economist, in an effort to provide good information for decision-makers, must be wary also of the relationship between "benefits" and "costs" in the provision of information. Only if the cost of providing the best possible information is zero does it follow that the "best" level of information is necessarily the most desirable.

The stated purpose of this thesis is to provide operational techniques for evaluating the economic consequences of resource transfer schemes. Because it is not clear that the cost required to yield information such as an empirical estimate of $Z$ is justified, perhaps the economist can provide the decision-making process with "more operational" guidelines. With this purpose in mind, the following

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36 On the other hand, neither is it clear that the "best" information (i.e., an empirical estimation of $Z$) does not justify the cost. The only point the author wishes to make is that, like most other
is offered as an alternative to the empirical estimation of $Z$.

**A Necessary Condition for Efficiency in Resource Transfer**

Our goal is to establish an operational criterion which will permit limited judgments concerning the economic efficiency implication of a resource transfer scheme. A criterion is desired that permits the identification of transfer schemes which are "clearly" inefficient. A necessary condition for efficiency in transfer is such a criterion. A necessary condition does not ensure the achievement of an objective; i.e., it does not define all the circumstances under which an objective is achieved but rather it defines (via its negation) a circumstance under which an objective is not achieved. It is this property of a necessary condition that is important for our purposes. The usefulness of a necessary condition in the context of the resource transfer question, then, is as a first phase winnowing device—it permits the sorting out of some transfer schemes (projects) which are inefficient. If a project satisfies a necessary condition, then it must be subjected to a second test—the total condition (4-15)—to determine whether or not the project is desirable from an efficiency viewpoint. The purpose, therefore, of the condition derived in this

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goods and services, information is not a free commodity. Furthermore, the cost of information may be related to its quality. See Morgenstern, p. 11-12 (1963).
chapter is to serve in a limited capacity as an identifier of inefficient projects. In terms of the objective function, an operational criterion is sought for use in winnowing out some of those projects for which the net, present, real, market value of incremental output \( Z \) is negative. Furthermore, it would be desirable to have a criterion that identifies overscaled projects; i.e., those for which the quantity of the resource to be transferred exceeds that which would maximize \( Z \).

It is important to note that the criterion sought is not a necessary condition for resource transfer per se, but rather a necessary condition for efficiency in transfer. Recall, the efficiency and distributive implications of resource transfers are considered independently (the argument for independent analysis was developed in Chapter II). The condition developed herein (see 4-19) could be interpreted as a necessary condition for resource transfer only if social welfare was determined solely by the size of the "economic pie"; i.e., only if, among other things, individual members of society were indifferent to the division and the method of dividing the "pie".

We now turn to the derivation of a necessary condition for efficiency in resource transfer. Conditions necessary for the maximization of the objective function (4-15) may be derived by setting the first partial derivatives with respect to the \( v \) input variables equal to zero. Taking the first partial derivative with respect to the resource to be transferred, \( X_1 \), and setting equal to zero, we obtain:
It is not our purpose to impose the condition that \( Z \) be maximum but rather that \( Z \) be non-negative and less than or equal to its maximum. Thus, the necessary condition for a maximum is relaxed by requiring an inequality rather than the strict equality. Re-arranging the terms of (4-16) and replacing the equality with the appropriate inequality, the following necessary condition for efficiency in resource transfer is obtained:

\[
\sum_{t=1}^{n} m_{bdt} \frac{p_{bdt} \frac{\partial y_{bdt}}{\partial x_1}}{(1+\phi_B)^t} - \sum_{t=1}^{n} \frac{\partial h_t}{\partial x_1} - \sum_{t=1}^{n} m_{cot} \frac{p_{cot} \frac{\partial y_{cot}}{\partial x_1}}{(1+\phi_C)^t} + \sum_{t=1}^{n} m_{cot} \frac{k_{lot}(x_1)+x_1 \frac{\partial k_{lot}}{\partial x_1}}{(1+\phi_C)^t} = \frac{37}{0}.
\]

(4-16)

If we let

\[
\sum_{t=1}^{n} m_{bdt} \frac{p_{bdt} \frac{\partial y_{bdt}}{\partial x_1}}{(1+\phi_B)^t} > \sum_{t=1}^{n} \frac{\partial h_t}{\partial x_1} + \sum_{t=1}^{n} m_{cot} \frac{p_{cot} \frac{\partial y_{cot}}{\partial x_1}}{(1+\phi_C)^t} - \sum_{t=1}^{n} m_{cot} \frac{k_{lot}(x_1)+x_1 \frac{\partial k_{lot}}{\partial x_1}}{(1+\phi_B)^t}.
\]

(4-17)

\[37\] The other \( v-1 \) necessary conditions for a maximum are not of particular interest for the purpose at hand.
\[
\sum_{t=1}^{n} m_{bdt} \frac{\partial y_{bdt}}{\partial x_{t}} (1+\phi_B)^{t} = MVP_{d'}
\]

\[
\sum_{t=1}^{n} \frac{\partial h_{t}}{\partial x_{t}} (1+\phi_C)^{t} = MC_{T'}
\]

\[
\sum_{t=1}^{n} m_{\text{cot}} \frac{\partial y_{\text{cot}}}{\partial x_{t}} (1+\phi_C)^{t} = MVP_{o'}
\]

and

\[
\sum_{t=1}^{n} m_{\text{cot}} \frac{k_{\text{lot}}(x_{t})+x_{t} \partial k_{\text{lot}}/\partial x_{t}}{(1+\phi_B)^{t}} = MFC_{o'}
\]

then (4-17) may be expressed as follows:

\[
MVP_{d} \geq MC_{T} + (MVP_{o} - MFC_{o})
\]

(4-18)

where \( MVP_{d} \) denotes the marginal value product of \( x_{t} \) in its marginal use in the destination area (aggregated across firms and though time), \( MC_{T} \) denotes the marginal cost of transferring \( x_{t} \) from the area of origin to the area of destination (aggregated through time), \( MVP_{o} \) denotes the marginal value product of \( x_{t} \) in the curtailed use in the area of origin (aggregated across firms and through time), and \( MFC_{o} \) denotes the marginal factor cost of \( x_{t} \) in the curtailed use in the area of origin (aggregated across firms and through time).
According to (4-18) if the net, present, real, market value of the incremental output expected from a proposed resource transfer scheme is to be positive and if the scheme is not to be overscaled, then the resource's aggregate marginal value productivity in the destination area must equal or exceed aggregate marginal costs of transfer and the "net" aggregate marginal value productivity foregone in the area of origin. The utility of this criterion is that it is not possible for \( \text{MVP}_d < \text{MC}_T + (\text{MVP}_o - \text{MFC}_o) \) and for the project to be appropriately scaled and have \( B - C > 0 \). However, it should be re-emphasized that the criterion is only a partial test for inefficiency. Although failure of (4-18) implies inefficiency, its satisfaction does not imply efficiency; i.e., the criterion does not identify every inefficient project. (A project can satisfy (4-18) and not satisfy (4-15).)

The relevant economic variables requiring quantification if this first phase test for inefficiency in transfer is to be made operable are (1) the marginal value productivity of the resource to be transferred in the area of destination, (2) the marginal costs of transfer, (3) the marginal value productivity of the resource to be transferred in the area of origin, and (4) the marginal factor cost of the resource.

As a necessary condition for efficiency in resource transfer, (4-18) is more restrictive than the traditional \( B - C > 0 \ (B/C > 1) \) criterion in that it also requires the scale of the project to be less than or equal to the "net" benefit maximizing scale.
In developing this simple efficiency model several simplifying assumptions were made. It was assumed that (1) the resource to be transferred had no value in transit, (2) there was a single identifiable independent marginal use of the resource in the destination area, (3) a single identifiable independent use was curtailed in the area of origin, and (4) no indirect benefits were attributable to the transfer scheme (the level of aggregation was national). The basic efficiency model is expanded in the following chapter to incorporate value in transit and multiple product situations. The relevance of national indirect benefits is also discussed.

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A method for estimating the marginal value productivity of a resource (water) is demonstrated in Chapter VI.
V. THE EFFICIENCY MODEL--EXTENSIONS

In the preceding chapter a basic model for judging the economic efficiency implications of resource transfer schemes was developed. In this chapter that model is expanded to consider possibilities of more than one marginal use (multiple products), value in transit, interdependent production processes (intrafirm and interfirm), and indirect benefits. The implication of these complications are considered by elaborating the model, (4-15), and showing the resulting effect on the necessary condition for efficiency in resource transfer.

Multiple Products

The need to consider more than a single product or production process in either the area of destination or origin occurs when (1) the scale of the project is sufficiently large that the marginal use in the destination area requires less than the total quantity of the resource to be transferred, (2) more than a single use is affected in the area of origin, (3) the transferred resource has value in transit, (4) intrafirm production interdependencies exist in either area, and (5) interfirm production interdependencies exist in either area. We begin by expanding the model to consider situations one and two.
More Than One Marginal Use

If the scale of the project is sufficiently large that the marginal use in the destination area requires less than the total quantity of the resource to be transferred (or if more than a single use is curtailed in the area of origin), then additional uses (production processes) must be considered. The efficiency model may readily be expanded to include such considerations. If relevant uses within the areas of destination and origin are pairwise independent, then the basic efficiency model (4-15) may be elaborated to include multiple uses as follows:

\[
Z = \sum_{t=1}^{n} \sum_{i=1}^{u} m_{idt} \left( \frac{p_{idt} y_{idt}(x_1, \ldots, x_v)}{(1+\phi_t)^t} - \sum_{j=2}^{v} r_{idt} x_{ji} \right) - \frac{40}{(1+\phi_C)^t}
\]

\[
C_F = \sum_{t=1}^{n} h_t(x_1) \left( \frac{p_{iot} y_{iot}(x_1, \ldots, x_v)}{(1+\phi_t)^t} - \sum_{j=2}^{v} r_{iot} x_{ji} \right)
\]

Note, all inputs in the area of destination may not appear in the production and cost functions for each output, \( y_{idt} \). Similarly, in the area of origin all inputs need not appear in every production function.
where the new notation $x_{ij}$ represents the $j$th input used in the production of the $i$th output. That is, the net, present, real, market value of incremental output resulting from the project equals the "net" total value product of $x_1$ in marginal uses in the destination area (aggregated across firms and through time) less costs of transfer (aggregated through time) less "net" total value product of $x_1$ in foregone uses in the area of origin (aggregated across firms and through time).

The model is now fully generalized with respect to multiple uses—u uses for $x_1$ in both the destination and origin area are, at least, theoretically conceivable. The relevant number of uses to include in the analysis depends on the scale of the particular transfer scheme being analyzed. Generally, fewer than $u$ possible uses in both the destination and origin area will be relevant.

The counterpart of a necessary condition for efficiency in resource transfer (4-18) for this formulation of the model is simply:

$$\sum_{i=1}^{u} MVP_{id} \geq MC_T + \sum_{i=1}^{u} (MVP_{io} - MFC_{io})$$

(5-2)

where $MVP_{id}$ represents the marginal value productivity of $x_1$ in the $i$th use in the destination area (aggregated across firms and through time), $MVP_{io}$ represents the marginal value productivity of $x_1$ in the $i$th use in the area of origin (aggregated across...
firms and through time), and $MFC_{i0}$ represents the marginal factor cost of $x_1$ in the $i$th use in the area of origin (aggregated across firms and through time). According to (5-2), if the net, present, real, market value of the incremental output expected from a proposed resource transfer scheme is positive and if the scheme is not overscaled, then the sum of the aggregate marginal value productivities of the resource to be transferred in relevant uses in the destination area must equal or exceed the aggregate marginal costs of transfer and the sum of "net" aggregate marginal productivities of the resource to be transferred in relevant uses in the area of origin.

**Value in Transit**

Value in transit is merely a special case of more than one marginal use. If the particular transfer scheme under consideration permits the productive use of a resource while being transferred from the area of origin to destination, then the value attributable to this use should be credited to the project.\(^{41}\)

The model and necessary condition for efficiency in resource transfer are merely extensions (simplifications) of (5-1) and (5-2), respectively. For example if we assume that a single marginal use

\(^{41}\)Value in transit is certainly a distinct possibility in the case of interbasin water transfer. Irrigation, hydroelectric power, recreation, and navigation all represent possible uses of water in transit.
is relevant in the destination area, only one use is curtailed in the area of origin, and the resource has a single productive use in transit, then a necessary condition for efficiency in resource transfer is given by:

\[ \text{MVP}_d + \text{MVP}_{TR} \geq \text{MC}_T + (\text{MVP}_o - \text{MFC}_o) \]  

where \( \text{MVP}_{TR} \) represents the marginal value productivity of the resource in transit (aggregated across firms and through time).

Production Interdependencies--Intrafirm

If the marginal use of the resource to be transferred involves a production process which is interrelated with another of the same firm, then the value of \( x_1 \) in its marginal use must be adjusted to reflect the product interdependence. That is, if firms producing the product representing the marginal use of the resource produce other products as well (joint production in the broadest possible sense), the analyst must consider the interrelationships between the production processes before electing to consider only the value of the resource in its marginal use. If the marginal use involves the production of a

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42 If the "in transit use" of the resource involves a consumption activity rather than a production activity (e.g., in the case of water transfer, recreational opportunities might be provided by the transfer vehicle), then \( \text{MVP}_{TR} \) would be represented by its counterpart in consumption--namely, a demand function.
product \( Y_A \) which enhances (impedes) the production of another product \( Y_B \), then the value of the resource should include not only its value in \( Y_A \) but also the value (disvalue) of the production of \( Y_A \) in the production of \( Y_B \). That is, MVP estimates of \( x_1 \) in the production of \( Y_A \) must be adjusted upward if increased production of \( Y_A \) enhances the production of \( Y_B \) or downward if increased production \( Y_A \) impedes the production of \( Y_B \).\(^{43}\)

Before proceeding to incorporate considerations of interdependent production into the basic efficiency model, the concept of intra-firm interdependence is discussed more fully. Let the production functions for \( Y_A \) and \( Y_B \) be given by

\[
Y_A = Y_A(x_1, \ldots, x_v, N) \tag{5-3}
\]

and

\[
Y_B = Y_B(x_1, \ldots, x_v, N) \tag{5-4}
\]

where \( N \) is a by-product of \( Y_A \) which affects the production of \( Y_B \). If \( \partial N/\partial Y_A \) and \( \partial Y_B/\partial N \) are both positive or both negative, then an increase in the production of \( Y_A \) enhances the production of \( Y_B \). However, if \( \partial N/\partial Y_A \) and \( \partial Y_B/\partial N \) differ in sign, then

\(^{43}\) If the "apparent" marginal use involves a product, the production of which enhances the production of another, then the analyst must compare the adjusted MVP with MVPs of other products to ascertain whether or not the "apparent" marginal use is truly marginal. In general an "apparent" marginal use may not, in fact, be the true marginal use if technical interrelationships are considered.
an increase in the production of \( Y_A \) impedes the production of \( Y_B \). Consequently, if \( \partial N / \partial Y_A \) and \( \partial Y_B / \partial N \) have the same (opposite) sign, then in considering the value of a resource in the production of \( Y_A \) an upward (downward) adjustment must be made to reflect the value (disvalue) of the production of \( Y_A \) in the production of \( Y_B \).

If intrafirm product interdependencies are associated with the marginal use of the resource to be transferred in the destination area or with one of the affected uses in the area of origin, the basic efficiency model (4-15) must be appropriately expanded. The implication of product interdependence is demonstrated assuming that the marginal use in the destination area entails the production of a product which in turn affects the production of another produced by the same firm(s). (The expansion of the model to accommodate interdependencies in the area of origin parallels that of the destination area.)

Let the marginal use of \( x_1 \) in the area of destination be in the production of \( y_{b_1} dt \), which in turn affects the production of \( y_{b_2} dt \). Let the production functions for \( y_{b_1} dt \) and \( y_{b_2} dt \) be given respectively by

\[
y_{b_1 dt} = y_{b_1 dt}(x_{1b_1}, \ldots, x_{vb_1}, N) \tag{5-5}
\]

and

\[
y_{b_2 dt} = y_{b_2 dt}(x_{1b_2}, \ldots, x_{vb_2}, N) \tag{5-6}
\]
where \( x_{1b_1}, \ldots, x_{v_1b_1} \) represent \( v_1 \) factors used in the production of \( y_{b_1} dt \) and \( N \), and \( x_{1b_2}, \ldots, x_{v_2b_2}, N \) represent \( v_2+1 \) factors used in the production of \( y_{b_2} dt \), and where \( x_{1b_1} \) represents the resource to be transferred \( (x_1 \) used in the production of \( y_{b_1} dt \)).

Since \( N \) is jointly produced with \( y_{b_1} dt \), the production function for \( N \) may be represented as an inverse of (5-5); i.e.,

\[
N = N(x_{1b_1}, \ldots, x_{v_1b_1}, y_{b_1} dt).
\] (5-7)

Considering both the production of \( y_{b_1} dt \) and \( N \), the basic efficiency model (4-15) may be elaborated to accommodate product interdependencies as follows:

\[
Z = \sum_{t=1}^{n} m_{b_1 dt} \left( \frac{p_{b_1 dt} y_{b_1 dt} (x_{1b_1}, \ldots, x_{v_1b_1}, N) + p_N N(x_{1b_1}, \ldots, x_{v_1b_1}, y_{b_1} dt)}{(1+\phi_B)^t} \right)
\]

\[
\sum_{j=2}^{v_1} \frac{r_{jdt} x_{jb_1}}{(1+\phi_C)^t}
\]

\[
\sum_{t=1}^{n} h_{t(x_1)} \frac{k_{lot}(x_1) x_1 + \sum_{j=2}^{v} r_{jot} x_j}{(1+\phi_B)^t}
\]

\[
\sum_{t=1}^{n} m_{cot} \frac{p_{cot} y_{cot} (x_1, \ldots, x_v)}{(1+\phi_C)^t} - \frac{k_{lot}(x_1) x_1 + \sum_{j=2}^{v} r_{jot} x_j}{(1+\phi_B)^t}
\]

(5-8)
where $p_N$ represents a shadow price for the by-product $N$ and is given by 

$$p_{b_2} \frac{\partial y_{b_2}}{\partial N}$$ 

(this marginal value productivity of $N$ in the production of $y_{b_2}$). That is, the net, present, real, market value of incremental output resulting from the project equals the "net" total value product of $x_1$ in the production of $y_{b_1}$ and $N$ in the destination area (aggregated across firms and through time) less costs of transfer (aggregated through time) less "net" total value product of $x_1$ foregone in the area of origin (aggregated across firms and through time).

A necessary condition for efficiency in resource transfer is

$$\sum_{t=1}^{n} m_{b_1} dt \frac{\partial y_{b_1}}{\partial x_{1b_1}} + \frac{(p_{b_2} \frac{\partial y_{b_2}}{\partial N}) \partial N}{(1+\phi_B)^t} \geq \sum_{t=1}^{n} \frac{\partial h_t(x_1)}{\partial x_1} \frac{p_{cot} \frac{\partial y_{cot}}{\partial x_1}}{(1+\phi_C)^t} - \frac{k_{lot}(x_1)+x_1 \frac{\partial k_{lot}(x_1)}{\partial x_1}}{(1+\phi_B)^t}. \quad (5-9)$$

That is,

$$MVP^*_d \geq MC_T + (MVP^*_o - MFC_o) \quad (5-10)$$

where $MVP^*_d$ denotes the marginal value productivity of the transferred resource in its marginal use in the destination area, adjusted for its indirect impact on the production of an interrelated product.

The adjustment factor is given by
Accordingly, the marginal value productivity of the resource in its marginal use is adjusted upward if that production enhances the production of another product produced by the same firm; i.e., if 
\[ \frac{\partial y_{b_2 dt}}{\partial N} \text{ and } \frac{\partial N}{\partial x_{1 b_1}} \] have the same sign which implies that \[ \frac{\partial y_{b_2 dt}}{\partial x_{1 b_1}} > 0 \] (the marginal productivity of the resource, applied in the production of \( y_{b_1 dt} \), in the production of \( y_{b_2 dt} \)). Conversely, the adjustment is downward if the production of another product is impeded; i.e., if \( \frac{\partial y_{b_2 dt}}{\partial N} \) and \( \frac{\partial N}{\partial x_{1 b_1}} \) are opposite in sign which implies that \[ \frac{\partial y_{b_2 dt}}{\partial x_{1 b_1}} < 0. \]

Intrafirm product interdependencies may be of great practical importance in considering interregional water transfer schemes.

The author would advance the hypothesis that agricultural irrigation represents the marginal use of water in much of the western region of the United States. If this is so, then the possibility of intrafirm product interdependencies due to beneficial effects of crop rotation practices may be quite real. The question of whether or not complementary relationships are, in fact, important in a given situation is an empirical problem with which the analyst must come to grips.

**Production Interdependencies---Interfirm**

If the marginal use of the resource to be transferred involves a
production process which is interrelated with that of other firms, then the value of \( x_1 \) in its marginal use must be adjusted to reflect this interdependence if such effects are uncompensated. Such production interdependencies are referred to in resource economics literature (along with many other phenomena) as externalities. In this case the externality is non-pecuniary and emanates from the technological interdependence of the production processes of autonomous firms.

Interfirm production interdependence is merely an extension of the intrafirm argument to separate firms. The model and necessary condition for efficiency in resource transfer are but reformulations of (5-8) and (5-10), respectively. Again, let us assume that the production function for \( y_{b_1} dt \) (the production of which represents the marginal use of \( x_1 \) in the destination area)\(^{44} \) and for \( N \), which is jointly produced, is given by (5-5) and that the production function for \( y_{b_2} dt \) which (in this case) involves other firms, is given by (5-6). Since a by-product of the production of \( y_{b_1} dt \)--namely, \( N \)--affects the production of \( y_{b_2} dt \) and the firm producing \( N \) is uncompensated by the firm producing \( y_{b_1} dt \) or vice versa, then the

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\(^{44}\) As in the preceding case the elaboration of the efficiency model to accommodate interfirm production interdependencies is demonstrated by assuming interrelationships involving the marginal use in the destination area. Again, the elaboration for the area of origin parallels that developed herein.
basic efficiency model can once more be represented by (5-8). However, the shadow price for \( N \), \( p_N = p_{b_2} \frac{\partial y_{b_2}}{\partial N} \), represents the marginal value productivity of \( N \) in the production of \( y_{b_2} \), which, in this case, is produced by other firms.

Likewise, a necessary condition for efficiency in transfer is given by (5-9) or (5-10). The marginal value productivity of the transferred resource in its marginal use in the destination area is increased (decreased) by \( (p_{b_2} \frac{\partial y_{b_2}}{\partial N} \frac{\partial N}{\partial x_{1b_1}}) \), which represents the marginal value productivity of the resource, applied by firms in the production of \( y_{b_1} \), in other firms' production of \( y_{b_2} \). The direction of the adjustment depends upon the signs of \( \frac{\partial y_{b_2}}{\partial N} \) and \( \frac{\partial N}{\partial x_{1b_1}} \), as in the preceding case.

**Indirect Benefits**

The efficiency model in Chapter IV and the preceding extensions of that model, were developed considering direct benefits and costs only. It is the purpose of this section to consider the relevance of incorporating indirect benefits and costs into the model.

Considerable debate has permeated the economics profession in recent years concerning (1) whether or not indirect benefits and costs "exist" when a national point of view is adopted and (2) if so, can they be correctly quantified and included in benefit-cost analyses. The argument is developed in this section that (1) on theoretical
grounds national indirect benefits and costs do, in fact, exist and on balance must be greater than zero in a freely operating economy and (2) for empirical purposes the estimation of indirect benefits and costs (particularly in the analysis of the efficiency implications of interbasin water transfers) is, indeed, risky and even if properly done is of dubious merit. 45/

To accomplish this task this section is presented in three major parts. In the first part indirect benefits and costs are defined and classified. This is an extension of the benefit classification scheme developed in Chapter III. The mere act of defining and classifying sets the stage and, indeed, contributes substantially to the answer of the question posed in the second part: Do national indirect benefits exist? In the third part the relevance of expanding the model to include indirect effects is considered from an empirical point of view.

**Indirect Benefits and Costs--Definition and Classification**

Certainly much of the confusion concerning the existence of national indirect benefits could be eliminated if the underlying theory

45 From a regional viewpoint the estimation of indirect benefits and costs seem much more plausible. In fact, as was noted earlier (p. 38), indirect benefits and costs should clearly be considered in identifying and describing regional income redistributive impacts of resource transfer schemes. Although indirect benefits and costs are intimately related to both the efficiency and distributive aspects of resource development projects, their relevance to the former is the central issue of this section.
involved was more specifically developed. An integral component of
good theory is a precise set of definitions. The importance of pre-
cise definitions in scientific work can not be overstated. A good defi-
nition for scientific purposes should not be "... a mere synonym... 
which the reader may happen to know the meaning of, but a criterion
for identifying; a characterization of the thing defined" (Wilder, 1952,
p. 52).

Frequently, imprecise definitions (in some instances no defini-
tions at all) are used in benefit-cost literature. Because of dissatis-
faction with existing definitions and classification systems, the clas-
sification scheme and definitions, developed for direct benefits and
costs in Chapter III and extended to indirect benefits and costs here,
was developed. It is hoped, that in conjunction with the classifica-
tion scheme, a set of substantive definitions will evolve.

The benefit and cost classification scheme, depicted schemati-
cally in Figure 1, p. 33, is extended to accommodate indirect bene-
fits and costs as well (see Figure 3). Recall, at Level III direct
benefits and costs were distinguished as being either "project" or
"associated", and were defined as follows:

1. **Direct project costs**—decreases in present, real, market
value of incremental national output that are incurred in
order to build and maintain the development structures
(reservoirs, dikes, etc.). These costs represent the
Level | Class A | Class B
---|---|---
I
II
III
IV

**Figure 3.** Classification of benefits and costs—direct and indirect.
opportunity cost of not using the resources in their next best alternative, and are reflected by factor prices. Direct project costs occur during project construction (construction costs) and during project operation (maintenance costs).

(2) Direct associated benefits—increases in the present, real, market value of incremental national output that are realized from the sale of the immediate products and services attributable to the project. The class of direct associated benefits exhausts the class of direct benefits, since the class of direct project benefits is empty. Hence, all direct benefits must be associated benefits. Direct benefits can not be realized until the project is operative. (This is not true, however, of indirect benefits.)

(3) Direct associated costs—decreases in the present, real, market value of incremental national output that are incurred (beyond direct project costs) in order to realize the direct associated benefits. These costs are borne by direct beneficiaries; e.g., irrigators. Like direct project costs, these costs represent the opportunity cost of not using the resources in the next best alternative, and are reflected by factor prices.

At Level IV (Figure 3) indirect benefits and costs are considered. Indirect benefits are benefits resulting from the economic
activity generated in the process of realizing direct benefits. Indirect benefits (costs) are realized (borne) by those individuals who service direct beneficiaries as well as by individuals in other interdependent sectors of the economy. Given the assumed objective function, indirect benefits (costs) may be explicitly defined as effects which tend to increase (decrease) the present, real, market value of incremental national output exclusive of direct benefits (costs). Certainly, this statement is neither profound nor particularly illuminating. The concept of indirect benefits is perhaps more meaningful if one translates market value of incremental output into terms of beneficiary income.

Under this translation indirect benefits and costs may be specifically defined as follows:

(1) **Indirect project benefits**—(a) incremental gross income earned by individuals owning factors (e.g., labor) employed in the construction or maintenance of the project, as well as (b) incremental gross income earned by individuals in other sectors of the national economy that are related to the construction and maintenance sectors ("induced by"). That is, total indirect project benefits represent a summation of incremental gross incomes earned (as

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46 The concept of interest is that of real income.
a result of the project) by the construction and maintenance sectors and that earned by other interrelated sectors due to the increased spending of the construction and maintenance sectors.

(2) **Indirect project costs**--(a) the opportunity gross income forfeited by individuals owning factors employed in the construction or maintenance of the project, as well as (b) the cost of the factors required to produce the incremental gross income in those other sectors of the national economy that are related to the construction and maintenance sectors ("induced by"). That is, total indirect project costs represent a summation of incremental gross incomes forfeited by the construction and maintenance sectors as a consequence of not employing factors in an alternative use and the cost of the additional factors required to produce the additional gross income in interdependent sectors.

(3) **Indirect associated benefits**--include (1) increases in gross income (a) earned by individuals in those sectors of the economy that process the incremental output of the project, as well as (b) that earned by individuals in those sectors related to the processing sector ("stem from"); (2) increases in gross income (a) earned by individuals in those
sectors of the economy that provide the necessary inputs to direct beneficiaries for production of the incremental output, as well as (b) that earned by individuals in those sectors related to the input providing sectors ("induced by"); and (3) increases in gross income (a) earned by individuals in those sectors of the economy that provide an outlet for the additional consumption expenditures that result from the increased income available to primary beneficiaries, as well as (b) that earned by individuals in those sectors related to the consumptive goods sectors ("induced by").

(4) **Indirect associated costs**—include (1)(a) the cost of additional factors employed in those sectors of the economy that process the incremental output of the project, as well as (b) the cost of additional factors employed in those sectors related to the processing sectors ("stem from"); (2)(a) the cost of additional factors employed in those sectors of the economy that contribute necessary inputs to the direct beneficiaries, as well as (b) the cost of additional factors employed in those sectors related to the input providing sectors ("induced by"); and (3)(a) the cost of additional factors employed in those sectors that provide an outlet for the additional consumption expenditures that
result from the increased income available to primary beneficiaries, as well as (b) the cost of additional factors employed in those sectors related to the consumptive goods sectors ("induced by").

In all of the above, the statements denoted, (a), represent what one might call the first iteration of the incremental gross income (cost) effect, whereas statements denoted, (b), represent the second through the \( n \)th remaining iterations of the multiplier effect.

Traditionally, a distinction is made between "induced by" and "stemming from" indirect benefits. Induced benefits (costs) usually refer to increases in gross incomes (additional costs) that accrue to individuals supplying inputs and consumption items to primary beneficiaries, whereas stemming benefits (costs) refer to increases in gross incomes (additional costs) that accrue to individuals in product processing and marketing industries (Eckstein, 1965). This interpretation clearly refers to only the first iteration effect. Such a distinction makes little or no sense beyond the first iteration. As nearly as the author can tell, most writers use this scheme to identify how economic activity on the part of primary beneficiaries initiates changes throughout the rest of the economy. If this judgment is correct, then the distinction between "induced by" and "stemming from" indirect benefits is essentially of no practical value, in that it neither clarifies nor adds precision to the concept of indirect benefits.
However, for purposes of this thesis, the terms "induced by" and "stemming from" indirect benefits will be used, but in a slightly different context. The terms shall refer not only to the first iteration effects but to the second through nth iteration effects as well. Given this expansion of these terms, they now represent true classes since taken together they are exhaustive of the universe (which they are not as traditionally interpreted) and they are mutually exclusive (Conklin, 1960).

Hopefully, the following discussion will serve to clarify the indirect benefit classification scheme. Starting at the far left (Level IV, Figure 3) observe induced indirect project benefits. These benefits, which are initiated as a consequence of expenditures for factors required to construct and maintain the project, represent incremental gross income payments to the construction and maintenance sectors as well as to other interrelated sectors. Induced indirect project costs represent foregone gross income payments to the construction and maintenance sectors plus costs of producing the incremental gross income in other related sectors. 47/

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47 Castle, Kelso, and Gardner (1963) have suggested that induced indirect project benefits (used, in this case, as a net concept) be deducted from costs rather than added to benefits when benefit-cost ratios are considered. However, for purposes of this thesis the question is not critical, since the objective of interest is stated in terms of benefits less costs. Either interpretation produces identical results.
Indirect associated benefits may be either "induced by" or "stem from" the project. Induced indirect associated benefits, which are initiated by increased expenditures for factors of production and consumption items on the part of primary beneficiaries, represent incremental gross income payments to the consumptive goods and factor supplying sectors as well as to other interrelated sectors. Induced indirect associated costs represent costs of producing the incremental gross income in the consumptive goods, input supplying, and related sectors. Stemming indirect associated benefits, which are initiated by the sale of the primary beneficiaries' product to processing and/or marketing firms, represent incremental gross income payments to the processing and marketing sectors as well as to other interrelated sectors. Stemming indirect associated costs represent costs of producing the incremental gross income in the processing, marketing, and related sectors.

With this discussion as background, the disagreement concerning the existence of national indirect benefits is readily resolved. We proceed, then, directly to that issue.

Do National Indirect Benefits Exist?

Now that indirect benefits have been explicitly defined, it should be possible (and relatively easy) to answer the question: Do national indirect benefits exist? Since indirect benefits and costs are
considered as gross concepts in this thesis, one must rephrase this question. The question that we want to consider is: Are indirect benefits net for the national account? The question as posed will be considered subject to the restrictive assumptions that (1) all resources in the economy are fully employed, (2) no excess capacity exists, and (3) all resources are mobile. It is recognized by most economists that indirect benefits would be net to the nation if any of the above assumptions did not hold. However, most economists argue that given the above assumptions, indirect benefits can not be net for the national account. This conclusion is seemingly plausible. However, the author is confused by the arguments which are frequently presented in order to support this conclusion. The source of confusion lies in the fact that the author is unable to ascertain whether the argument that net indirect national benefits must be zero involves an empirical judgment or is a consequence of the theoretical construct. Let us, therefore, digress briefly in order to emphasize the difference between theoretical and empirical arguments.

Theoretical import versus empirical significance. Seemingly, much of the apparent confusion concerning the existence of net national indirect benefits is attributable to the intermingling of theoretical

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48 Haveman and Krutilla (1968) have suggested a technique for quantifying net induced indirect project benefits (during project construction) when the economy is experiencing less than full employment. Their analysis relates to first iteration effects only.
and empirical arguments by those writing on the subject. The co-mingling of empirical and theoretical considerations in economic research is not distressing—empirical and theoretical arguments are essential and complementary ingredients in an applied science. However, it is distressing when these considerations become so entwined that the identity of each as a distinct type of argument is lost. When this occurs, empirical arguments are easily mis-interpreted as being a logical component or implication of the theoretical construct.

It is the author's opinion that the body of knowledge, upon which a discipline draws, is less likely to become a bundle of confusion for most practitioners if theoretical blueprints are clearly and explicitly developed prior to developing the empirical prototypes for the analysis of specific problems. What is being expressed is the belief that if scientists are truly interested in seeking knowledge and communicating with one another concerning this knowledge, then theory, explicitly stated, tightly reasoned, and pursued to its logical conclusion(s), must proceed application, both in conducting research and in presenting the results of that research. This position seems consistent with that of Heady (1949). Furthermore, in developing the theoretical model from which the operational version is to follow, it would seem most appropriate if specific empirical considerations (for example, assumptions about specific magnitudes) are incorporated into the model ex post rather than ex ante or concurrently with the
development of the theoretical model. That is, when constructing a theoretical model parameters should be expressed as such rather than being replaced by specific values from their respective parameter spaces. Likewise, general relationships should be expressed as such rather than being replaced by specific functional forms. After the theoretical model has been developed, then and only then, should empirical arguments and considerations be injected and their consequences pursued. In this regard, it appears that in considering the possibility of net national indirect benefits, applied economists have perhaps abandoned their theoretical ships prematurely.

The question of the existence of net national indirect benefits under conditions of full employment, no excess capacity, and resource mobility is clarified by considering the concept of full employment. Two cases are considered: full employment--perfectively competitive general equilibrium, and full employment--approximate.

**Full employment--perfectly competitive general equilibrium.** Writers who argue that full employment implies net national indirect benefits equal zero, must be referring to an economy that is perfectly competitive and that is in a state of static general equilibrium. The perfectly competitive general equilibrium state implies that the marginal value product of each resource in each alternative use is everywhere equal throughout the economy. If one assumes that this state is static; i.e., economic disturbances of various kinds such as
changes in consumer tastes and preferences, technological developments, and changes in the stock of resources are not permitted, then

...the attainment of general equilibrium would provide the greatest possible measure of consumer satisfaction which the given distribution of resource ownership would allow. No consumer could gain by exchanging quantities per unit of time of one product for another. No transfer of a resource from one employment to another could increase net national product since the value of marginal product for any given resource would be the same in its alternative uses (Leftwich, 1955, p. 373).

One could most assuredly argue that net indirect national benefits resulting from a resource development project would be exactly equal to zero—it is axiomatic. Furthermore, it is axiomatic (given a static, perfectly competitive, full employment, general equilibrium) that net direct national benefits resulting from a resource development project would be exactly equal to zero as well. That is, given this economic utopia, any reinvestment of resources represents only a transfer of income from one user to another, and at best net national product can be no greater than before the reinvestment.

Certainly, it would seem only consistent that those who argue for ignoring net national indirect benefits on the basis of this theoretical economic state should extend the argument to direct benefits as well, in which case they could deduce that all resource development projects are nonsensical and that benefit-cost analysis is an exercise in futility. To summarize, in a perfectly competitive, fully employed economy in static general equilibrium, no net national
benefits, be they direct or indirect, may result from investment in resource development projects--it is not an empirical question, but a consequence of the theoretical construct.

**Full employment--approximate.** Fortunately, the theoretical case for net national indirect benefits (and for that matter, net national direct benefits) is not as bleak as the foregoing might suggest. For as Leftwich puts it:

...this economic utopia [perfectively competitive, static, general equilibrium state] will never be achieved. Various deviations from pure competition in both product and resource markets prevent the free enterprise system from allocating its resources perfectly among different uses. ... Additionally the real world is a dynamic one with changes occurring constantly in such basic factors as consumer tastes and preferences, the range of available productive techniques, the quantities of available resources, the kinds of resources available, and the distribution of resource ownership. All of these prevent the attainment of equilibrium positions (Leftwich, 1955, p. 373-374).

Regarding specifically full employment and net national indirect benefits, Hammond states:

...The possibility of national secondary [indirect] benefits can scarcely be denied; the argument used by some writers, that under conditions of full employment secondary benefits associated with a project would be cancelled by adverse effects elsewhere in the economy, seems purely a priori and applicable as well to primary benefits. (Full employment is seldom that full, anyway) (Hammond, 1966, p. 212-213).

The upshot of the comments by Leftwich and Hammond is that in reality the economy can only approximate full employment; can only
approach general equilibrium; and will never achieve a static state. Changes in consumer tastes and preferences, new technology, the availability of new resources, and the whole host of forces that give rise to a dynamic economy have and will continue to prevail. Marginal value productivities of resources are not and will not be simultaneously equal among all uses throughout the economy. Even if they were, in a dynamic economy forces exist that make resources suddenly more productive in alternative uses, which throws the system out of equilibrium. Hence, the possibility for net national direct and indirect benefits from investment in resource development projects can not be denied.

For example, consider the case where an economy is in dynamic general equilibrium. Suppose that a water transfer project is undertaken and that as a result the marginal value productivity of water in some new use is greater than the existing equilibrium marginal value productivity of water. As a consequence, water, as well as other resources, will be diverted from previous uses to the new use. As a result the gross market value of incremental output will have increased in the area to which the resources were transferred. Likewise, gross market value of incremental output will have decreased elsewhere. However, theory does not tell us that the magnitude of the increase is exactly equal to the magnitude of the decrease. In fact, theory tells us that we should expect the net effect to be positive
or otherwise the changes in resource use would not have taken place.

The above argument refers to direct benefits. However, exactly the same reasoning holds in the case of indirect effects. All that one must do is follow the argument through the subsequent 1 through n iterations of the multiplier effect. For example, consider the first iteration. Suppose, as a result of the new use, a plant locates (relocates) near the project to process the product of the direct beneficiaries. If the owner expects to hire resources in order to operate the plant, he must be in a position to offer a higher price for those factors—that is, he must bid them away from their previous uses. Only if marginal value productivity is greater in the new alternative will the plant owner be able to attract factors. If he is successful in this effort, gross market value of incremental output will have increased in the area to which the resources have migrated. Likewise, gross market value of incremental output will have decreased elsewhere. Again, theory does not tell us that the magnitude of the increase is exactly equal to the magnitude of the decrease. What theory does tell us is that we should expect the net effect to be positive.

Conclusion. In considering the relevance of indirect benefits and costs in resource development, it is important to identify and isolate theoretical and empirical arguments. The only purely theoretical argument that could lead one to the conclusion that net national
indirect benefits are zero requires such stringent assumptions that in the process net national direct benefits must also be denied. In the real world, (full employment--approximate) the case for or against net national indirect benefits must be made on the basis of empirical judgment or considerations. It may very well be that, in many instances, net national indirect benefits are not empirically significant--that is to say, in magnitude they may not be significantly different than zero. However, as far as the author is concerned, this is decidedly different than to argue that this result is an implication of economic theory.

Empirical Significance of Incorporating Indirect Effects into the Efficiency Model

It is the author's contention that the case for extending the basic efficiency model (developed in Chapter IV) to accommodate indirect benefits and costs is not persuasive. Since the plausibility of net national indirect benefits can not be refuted on theoretical grounds, the above assertion must be (and, in fact, is) based on empirical considerations.

Except for the special situation when resources employed due to the transfer scheme would otherwise be unemployed, the empirical estimation of indirect benefits and costs is difficult. If a particular resource would remain unemployed in the absence of the project,
then estimation of indirect benefits and costs related to its employment is possible and relatively straightforward. Because no losses occur due to displacement of such resources, the full increase in real, present, market value of incremental output attributable to these resources including the 2nd through nth iterative effects may be credited to the project. Of course, the project must be debited for the cost of employing such resources—namely, their price, which for the first iteration is exactly equal to the amount credited. For the 2nd through nth iterations one would expect that indirect benefits should be greater than or equal to corresponding indirect costs.

However, if the hypothesized indirect benefit occurs due to the dislodging of a resource from its present employment, then only a portion of the increase in real, present, market value of incremental output attributable to these resources may be credited to the project. It cannot be overemphasized that if the estimation of indirect benefits is undertaken, then likewise the determination of indirect losses occurring elsewhere due to the dislodging of resources from their current employment must be undertaken. (Recall, in developing the efficiency model, losses occurring in the area of origin were included as a direct cost of the project. The argument is equally applicable to indirect effects.) Failure to account for indirect losses can result in significant overestimation of net national project benefits. The
identification and measurement of indirect losses would be a monu-
mental empirical task to say the least.

In the absence of wide scale unemployment or significant under-
employment of resources the argument for empirical estimation of 
indirect benefits and costs seems weak. Even if indirect benefits and 
costs were properly accounted (including 2nd through nth iter-
ative effects), as an economy tends toward full employment of all re-
sources indirect benefits over and above indirect costs must become 
small. Whether or not true net indirect benefits are sufficiently 
great to justify cost of estimation is of course in itself an empirical 
question. However, the hypothesis is advanced that in the absence of 
large scale under or unemployment the magnitude of true net indirect 
benefits is not sufficiently great to justify the cost of including them 
in analyses of the efficiency implications of resource transfer 
schemes. It is, therefore, the author's opinion that the determina-
tion of the efficiency implication of resource transfer schemes should 
for practical purposes be limited to the consideration of direct ef-
facts.

Note, this is an empirical judgment, not a consequence of the 
theoretical construct. As such, it is merely a hypothesis. A test of 
this hypothesis is conceivable, even if difficult and expensive. It 
seems reasonable that such a test should be undertaken on a more 
limited scale for a less ambitious project than interbasin water
transfer.

Conceptually, the basic model (4-15) and necessary condition for economic efficiency in resource transfer could be expanded to reflect indirect effects. A complete theoretical efficiency model should, in fact, reflect indirect benefits and costs as explicit components. However, this rather cumbersome expansion of the model was not undertaken since the possibilities for empirically relevant operational prototypes of such a complete model seem remote.
VI. THE MARGINAL VALUE PRODUCTIVITY OF WATER IN IRRIGATED AGRICULTURE

In the statement of a necessary condition for economic efficiency in resource transfer (p. 62), four critical economic variables were identified: (1) the marginal value productivity of the resource to be transferred in the area of destination, (2) the marginal value productivity of the resource to be transferred in the area of origin, (3) the marginal cost of transfer, and (4) the marginal factor cost of the resource to be transferred in the area of origin. The empirical portion of this research is limited to demonstrating an empirical technique for estimating the marginal value productivity of water in irrigated agriculture.

Numerous attempts have been made to arrive at a value for water in irrigated agriculture. Noteworthy, but by no means exhaustive, are studies by Hartman and Anderson (1962), Grubb (1966), Brown and McGuire (1967), and Young and Martin (1967). The MVP estimates from these studies ranged from approximately $3 per acre-foot in northeastern Colorado to approximately $27 per acre-foot in the Texas High Plains (see Table 1).

49 Howe (1968) provides an excellent review of the results of these and other MVP studies.
Table 1. Average MVP estimates for irrigation water from four empirical studies. *

<table>
<thead>
<tr>
<th>Location</th>
<th>Average MVP per acre-foot of water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeastern Colorado</td>
<td>$3</td>
</tr>
<tr>
<td>Texas High Plains</td>
<td>27</td>
</tr>
<tr>
<td>Kern County, California</td>
<td>19</td>
</tr>
<tr>
<td>Central Arizona</td>
<td>21</td>
</tr>
</tbody>
</table>

* Summarized from Howe (1968).

Ruttan (1965) also tried to derive a pecuniary value for water used in irrigated agriculture. He used production function analysis to estimate the marginal value productivity of irrigated acreage. In the foreward of Ruttan's book, Krutilla notes:

The significance of this study lies more perhaps in the framework of analysis than in the particular empirical results. There remains much room for more intensive analyses by individual scholars in the several water resource regions to further improve the quality of the estimates and increase the precision of the results (Krutilla, 1965, p. vi).

Following Ruttan, an attempt is made (in this research) to estimate the parameters of a regional agricultural production function and to subsequently derive the marginal value productivity of the input representing the irrigation component. Since this author concurs that Ruttan has identified an appropriate framework for analysis, the empirical portion of this investigation is undertaken to suggest and implement methodological changes and alterations that should improve
the "quality" of the estimates. Consequently, it should be viewed as an attempt to add refinement to the basic method offered by Ruttan. 50/ In his review of Ruttan's book, Hock (1967) calls attention to "a number of difficulties" that tend to discredit the empirical results. Hoch notes three problems inherent in Ruttan's production function estimation procedure: (1) intraregional heterogeneity, (2) over aggregation and (3) omission-of-variables. A fourth problem involves Ruttan's choice of the county rather than the average firm as the unit of analysis.

The problem of intraregional heterogeneity is a difficult one in production function estimation--particularly, when cross-sectional data are used. Ruttan's principal data source was the U.S. Census of Agriculture. These data are reported in their least aggregate form as county totals. Unfortunately, as observational units for regional production function estimation, counties are not often sufficiently homogeneous in their agricultural composition to provide the most reliable results. In many western states where counties are frequently large, diversity of agriculture, not only among but also within county observational units, is typical. Consequently, 

50 It is noted later that empirical results of this analysis, like Ruttan's may be subject to rather considerable skepticism as to their validity. In the concluding section of this chapter, recommendations regarding possible steps to increase the validity of marginal value productivity estimates for policy purposes are made.
regional production function coefficients derived from such data may not necessarily be relevant to non-homogeneous individual firms within a given region.\(^{51}\) It is the author's opinion, nevertheless, that information useful for policy purposes can be generated using such data. If useful and reliable results are to be obtained, study areas must be carefully selected to ensure relative homogeneity of observational units. Herein lies the difficulty in using cross-sectional data for production function estimation. The researcher must be careful to select, on the one hand, a study area that is as homogeneous as possible to ensure meaningful results; yet, on the other hand, he must be certain that the study area is sufficiently heterogeneous in other respects to permit results to be obtained. Exact homogeneity in all respects implies no variation which in turn implies no results (Griliches, 1962). The challenge to the researcher is to find the appropriate middle ground.

The aggregation problem in production function estimation occurs when two or more factors (products) are represented as a single input (output) variable. As a consequence, the estimates of the function coefficients are likely to be biased (Plaxico, 1955). Ruttan chose dollar value of county agricultural output as the dependent variable in

\(^{51}\) To assert that coefficients derived from cross-sectional data were applicable to individual firms would be to commit the logical fallacy of division.
his model. This variable represents a composite of many agricultural products. Likewise, some of Ruttan's input categories are composites of several physical inputs. Furthermore, the aggregation problem was no doubt aggravated because in many of the regions studied a wide variety of agricultural products were produced. Although aggregation problems can never be eliminated, they can be minimized by careful selection of study areas.  

The problem of omission-of-variables is critical in marginal value productivity estimation. If relevant variables are omitted from the model, estimated coefficients of remaining variables may be biased. Only if omitted variables are independent of remaining variables will the estimated coefficients be unbiased (Brown, 1969). In his original formulation, Ruttan hypothesized a priori that six inputs (for which secondary data were available) were important variables to include in the production model. However, only a subset of the original six independent variables were included in the final formulation for several of the regions. In the South Pacific region only two independent variables were retained in the final version of the model. As Hoch noted this may lead to serious omission-of-variables.

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Footnote: 52 Although some peripheral improvements are offered (less heterogeneous study area; restriction of dependent variable to value of crops produced rather than value of all agricultural products produced), the basic aggregation problems encountered by Ruttan remain in this research as well.
specification bias, which could severely distort marginal value productivity estimates.

Brown has demonstrated very clearly the potential bias which may be imposed on individual parameter estimates due to omission of relevant variables. By "recasting" a very well specified production function model reported by Knight (1968a) into a form comparable to Ruttan's "abbreviated South Pacific region model", Brown was able to show a nearly four-fold upward bias on the parameter estimates for owned and rented land. Furthermore, Brown states: "Most misleading of all is the apparent, but not real, precision of estimation of the parameters in the poorly specified model..." (Brown, 1969, p. 11). Brown's work lucidly demonstrates that ignoring or eliminating relevant variables can severely distort parameter estimates of variables remaining in the model. Although omission-of-variables is not particularly harmful when the estimated relation is used to predict values of the dependent variable, it can be disastrous when interpretation of particular parameter estimates is required; e.g., marginal value productivity calculations from an estimated production function.

Another rather subtle problem in Ruttan's empirical method involves his choice of the county rather than the "average" firm within the county as the unit of analysis. Interpretation of results is difficult when the unit of analysis is the county aggregate. The results of
regression analysis can only be stated (or interpreted) in terms of
the units from which they were compiled. Ruttan's results relate to
the "average" county. Had his analysis been based on data pertaining
to the "average" firm per county, inferences to a more relevant popu-
lation would have been possible. That is, interpretations could
be made in terms of the relevant decision-making unit; i.e., "aver-
age" firms.

Although the use of secondary data sources (particularly, U.S.
Census data) often limit the options open to a researcher regarding
his choice of aggregation level, careful empirical methodology can:
(1) increase reliability and relevance of estimates by (a) selecting
study areas that are relatively homogeneous with respect to type of
farming and (b) converting data to a per firm basis and (2) minimize
potential bias in estimates due to omission-of-variables.

The Study Area

The principal source of data used for this study was the 1964
Census of Agriculture (U.S. Bureau of the Census, 1964a, 1964b);
this source is hereafter referred to simply as "the Census". The
observational unit was the average firm of a county. This choice was

53 It would be possible to make inferences from county aggre-
gates to "average" firms only given the unlikely assumption that the
number of firms in each county was the same and given that the con-
stant term was appropriately adjusted.
made to improve the applicability of the research to individual firms—an inherent weakness of Ruttan's study. The study area (Figure 4) includes 20 counties of the Texas High Plains and five counties in eastern New Mexico.

These 25 counties were purposively selected to ensure that the agriculture of the study area was mostly irrigated and primarily crop based. (In Appendix Table 1 the percent of total cropland harvested that was irrigated and the percent of value of all farm products sold from crops are shown for each county in the study area.) For the entire study area, 77 percent of all cropland harvested was irrigated and 73 percent of the total value of farm products sold was derived from the sale of crops (U.S. Bureau of the Census, 1964a, 1964b). Principal crops of the area are grain sorghum, wheat, and cotton. These crops are "low-valued" relative to other crops found in the Southwest such as horticultural and citrus crops.

**Total Value Product Function**

In Chapter IV the aggregate total value product in destination was given as

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55 The notation and indicies used in this chapter were discussed in Chapter IV.
Figure 4. The study area.
\[
TVP_d = \sum_{t=1}^{n} m_{bdt} \frac{p_{bdt} y_{bdt}}{(1+\phi_B)^t}
\]  

(6-1)

where \( y_{bdt} \) represents the product having the lowest marginal value in use for the transferable resource, \( b \), during the \( t \)th time period, \( t \), in the area of destination, \( d \); \( p_{bdt} \) represents the price of \( y_{bdt} \); and \( m_{bdt} \) represents the number of firms involved in the production of that quantity of \( y_{bdt} \) which is incremental with respect to the transferable resource. All \( m_{bdt} \) firms were assumed to have identical production processes of \( v \) variable inputs for the output \( y_{bdt} \). Thus,

\[
TVP_d = \sum_{t=1}^{n} m_{bdt} \frac{p_{bdt} y_{bdt}(x_1, \ldots, x_v)}{(1+\phi_B)^t}
\]

(6-2)

The problem of interest was to estimate the aggregate total value product of the marginal use of water in the area of destination as depicted in (6-2). However, it was not possible to estimate the components of (6-2) directly, as separate sources of information for \( p_{bdt}, x_1, \ldots, x_v \) were not located. The Census data selected did, however, contain information which permitted the estimation of a total value product function of the form
\[ TVP_d = \sum_{t=1}^{n} m_{bdt} \frac{y_t(x_1, \ldots, x_v)}{(1+\phi_B)^t} \]  

(6-3)

where

\[ y_t(x_1, \ldots, x_v) = p_{bdty_{bdt}}(x_1, \ldots, x_v). \]

The loss of product price as an explicit component of the model is a shortcoming of this empirical effort, for not only is straightforward analysis of changes in product price precluded, but prices, which may not be determined by freely operating markets, are locked in. Given the particular problem setting, product price may turn out to be a critical economic variable.

The relevant production time dimension in the study area is one year. The firm's total value product for a particular year, say \( t = t_0 \), is given by

\[ V = V(X_1, \ldots, X_v) \]  

(6-4)

where \( V \) represents the total value product for the \( t_0 \) production year for the "average" firm in the study area and \( X_1 \) through \( X_v \) represent the variable factors used in the production of \( V \). Recall, ideally the product comprising \( V \) represents the marginal use of water in the area of destination. Given the data source used in this study, it was not possible to estimate individual commodity production
functions, although an attempt was made to partition the irrigation component of the model. Hence, Equation (6-4) is differentiated from (6-3) in that $V$ now relates to the total value product of all crop enterprises in the area and the input categories, $X's$, likewise, relate to this aggregate. (Note, the conversion from a single (6-3) to a multiple (6-4) product total value production function is denoted by the change from lower case, $x's$, to upper case, $X's$.)

It is the annual total value product function of the "average" firm, (6-4), not (6-2), that was estimated. The question of the appropriate procedure for aggregating across firms and through time, including problems of projecting price changes, projecting changes in the structural form of the production function, and choice of the appropriate discount rate, is beyond the scope of this thesis.

**Statistical Model**

The generalized form of the statistical model selected for this study was

$$V = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \epsilon$$

where $\epsilon$ represents a stochastic disturbance term (error). This particular form for the value product function was chosen for two reasons: (1) this writer like others (Hoch, 1967; Krutilla, 1965) was dissatisfied with the empirical results obtained by Ruttan (1965)
(Ruttan used a Cobb-Douglas type function); (2) Knight (1967, 1968a, 1968b), using this form in estimating coefficients for several agricultural production functions in Kansas, obtained some rather impressive empirical results.

Parameters of the following equation were estimated using simple least-squares estimating procedures: 56/

\[ V = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \epsilon \quad (6-6) \]

In the ensuing discussion each variable in the above expression is defined and the procedure used to obtain a measure of each is explained. 57/ In each case the characteristic measured was that of the "average" firm in the county. The measurement for each observational unit was obtained by dividing the county total for each variable by the appropriate number of firms. Following the discussion of the variables the fitted model is presented.

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56 A step-wise multiple regression program was used.

57 In the statement of procedures, the numbers in parentheses indicate the table in the Census, from which the data were accumulated. Accompanying each table number is either a county or state designation. In each volume of the Census there are two sets of tables: a set of tables relating to an entire state and a set of tables relating to individual counties. The notation, (County, 6), denotes that the required data are reported in Table 6 of the "Statistics for Counties" section of the Census.
Variables

Total value product, \( V \). Total value product is defined as the value of all crops harvested in 1964. Since, in the Census, data are reported by county for value of all crops sold (or to be sold) rather than for value of all crops harvested, the required data were generated indirectly. The value of all crops used for on-farm livestock feed was added to the value of all crops sold.

The following procedure was used to measure \( V \) for each observational unit. First, the value of all crops sold, \( v_1 \), was recorded (County, 6).

Secondly, the value of hay and silage crops harvested for livestock feed, \( v_2 \), was calculated (on an individual crop basis) by subtracting tons sold from tons harvested\(^{58/}\) (County, 13) and multiplying by the appropriate price. The price for each hay and silage crop was calculated by dividing the value of crop harvested by quantity harvested (State, 9) on a statewide basis.

Thirdly, the value of feed grain crops harvested for livestock feed, \( v_3 \), was calculated (on an individual crop basis) by: (1) subtracting bushels sold from bushels harvested (County, 13); (2) from

\(^{58/}\) It was assumed that hay and silage harvested but not for sale was produced for livestock feed. In any event, whatever the purpose, the value of the residual is properly credited to value of crops harvested.
this difference, projected bushels for seed (if greater than zero) were
subtracted;\(59/\) (3) this residual was then multiplied by the appropriate
price (calculated as above; State, 9). The resulting value was re-
corded as value of feed grains for livestock feed, \(v_3\).

Finally, the total value of all crops harvested per farm for each
county was recorded as the sum of all crops sold, the value of hay
and silage crops for livestock feed, and the value of feed grain crops
for livestock feed, divided by the number of farms in the county, \(n_i\).
That is, for each county,

\[
V = \frac{v_1 + v_2 + v_3}{n_i}.
\]

Two inadequacies could not be eliminated in determining \(V\)
for each county. The revenue produced from cropland used for pas-
ture was not included in \(V\); however, in certain input categories
costs related to this use could not be excluded. Also, value of crops
for home use was not included in revenue but for certain input cate-
gories costs related to this use could not be excluded. On balance,

\(59/\) For each crop, except corn and sorghum, projected bushels
for seed was calculated by multiplying acres harvested in 1964 by the
appropriate seeding rate. The seeding rate used for each crop was
determined by taking the mid-point of the range given by Martin and
Leonard (1949). Implicit in this procedure is the assumption that
acres harvested in year, \(t_1\), is an adequate predictor of acres to be
planted in year, \(t_2\). Value for seed is not included in the determina-
tion of \(V\), since on the input side the opportunity cost of using farm
produced seed is not included as an operating expense.
one would expect values of $V$ to be biased slightly downward.

**Non-cotton irrigated acres, $X_1$.** Non-cotton irrigated acres is defined as the number of irrigated cropland acres harvested, exclusive of acres in cotton. The procedure used to measure $X_1$ was to subtract the number of irrigated cotton acres harvested (County, 14) from the number of irrigated cropland acres harvested (County, 2), and divide by $n_i$.

**Irrigated cotton acres, $X_2$.** Irrigated cotton acres is defined as the number of acres of cotton harvested from irrigated land. To obtain data for $X_2$, the number of irrigated cotton acres harvested (County, 14) was divided by $n_i$ and recorded for each county.

Numbers of irrigated acres harvested were split into cotton, $X_2$, and non-cotton, $X_1$, categories in order that the value productivity estimate for water in the production of cotton might be derived separately from the value productivity in "lower valued" uses. If the study area was properly chosen, cotton should represent the highest valued agricultural use (of consequence) for water; i.e., the estimated coefficient for $X_2$ should exceed the coefficient for $X_1$.

**Non-irrigated cropland acres, $X_3$.** Non-irrigated cropland acres is defined as the number of acres of cropland harvested which were not irrigated in the census year. Data for $X_3$ were derived

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60 Numbers of irrigated acres relate to numbers actually irrigated in the census year rather than acres irrigable.
by subtracting the sum of $X_1$ and $X_2$ from total cropland acres harvested (County, 1) per firm.

**Operating expenses, $X_4$.** Operating expenses is defined as cash expenditures for items related to crop enterprises (including hay, silage, and feed grains for on-farm livestock feed) exclusive of labor and machinery. Data for $X_4$ were derived by summing cash expenditures for (1) seed, bulbs, plants, and trees purchased, (2) fertilizer purchased, (3) gasoline and petroleum products purchased, and (4) machinery hired (County, 9), and dividing by $n_i$.

There are several shortcomings in the procedure for determining $X_4$. The dependent variable, $V$, of the equation to be estimated represents the value of farm products attributable to crop enterprises (including hay and silage). Income related to livestock enterprises is not included. Ideally, all independent variables should relate only to crop enterprises. In so far as it was possible, factors relating to livestock enterprises were excluded from independent variables; e.g., $X_1$, $X_2$, and $X_3$ relate only to cropland, and the more obvious livestock expense categories (feed purchased and livestock and poultry purchased) were excluded in calculating $X_4$. However, for those expense categories included in $X_4$, it was not possible to eliminate that portion attributable strictly to livestock enterprises. Specifically, for those expenditure categories included in the computation of $X_4$, one would expect the contribution of each to be
overstated for the following reasons:

(1) for seed, bulbs, plants, and trees purchased, expenditure for grass seed for pasture (if any) was included;

(2) for fertilizer purchased, expenditures for fertilizer applied to pasture (if any) was included;

(3) for gasoline and petroleum products purchased, gasoline expenses chargeable to livestock enterprises was included.

The machine hire category is not likely to be overstated because it does not include strictly livestock expenses. (Contract trucking of livestock is not included in this category.) On balance, one would expect an upward bias in $X_4$ (downward bias in the estimate of the coefficient on $X_4$). Another rather obvious shortcoming is that all categories of expense are not included in the computation of $X_4$ (e.g., machinery and equipment maintenance expenses are not included).

Numbers of wheel tractors, $X_5$. Numbers of wheel tractors needs no definition as the name is self-explanatory. Data for $X_5$ was recorded directly from the Census by dividing the total number of wheel tractors for each county (County, 8) by the appropriate number of firms, $n_i$. The inclusion of such a variable in the model, no doubt, needs some justification. This variable was included to serve as a proxy for the annual equivalent value of investment in farm machinery and other durable resources\footnote{Carlson defines durable resources as "productive resources which yield services for more than one [production] period" (Carlson, 1939, p. 104).} which a well specified
model "should" include. After failing in the search for data needed to measure the desired variable, numbers of wheel tractors was chosen as a proxy. In the unlikely event that numbers of wheel tractors were exactly related to the investment in all farm machinery and equipment, then \( X_5 \) would be a perfect proxy.\(^{62}\)

The shortcoming discussed under "operating expenses, \( X_4 \)" holds as well for \( X_5 \). It was not possible to sort out the effect related to livestock enterprises.

Labor, \( X_6 \). Labor is defined as the man-year equivalents of labor employed. The total labor input per farm was determined by converting operator labor per farm, family labor per farm, and hired labor per farm, to man-year equivalents, assuming one man-year equivalent of labor to be 300 days.\(^{63}\) The following procedure was used to determine the man-year equivalents of labor for each observational unit.\(^{64}\)

First, man-year equivalents of operator labor, \( \ell_1 \), were calculated. The number of operators less than 65 years of age was recorded with the assumption that an operator in this age category

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\(^{62}\) A variable, say \( X' \), is a perfect proxy for another variable, \( X \), if \( X = cX' \). That is, parameter estimates of other variables in the model are unaffected by the inclusion of \( X' \) rather than \( X \).

\(^{63}\) The assumption that one man-year equivalent of labor is 300 days is consistent with Griliches (1963).

\(^{64}\) The author is indebted to Milton Holloway, who suggested the rudiments of this procedure.
accounts for one man-year (County, 6). The number of operators age 65 and over was recorded (County, 6). This number was weighted by a factor of six-tenths, assuming that each operator age 65 or older is equivalent to 60 percent of one man-year.\(^{65}\) The number of days worked off farm by operators was recorded (County, 7) and divided by 300 to obtain man-year equivalents of off-farm operator labor. Total operator labor per farm, \(l_1\), was recorded as the sum of man-year equivalents of operators less than 65 years and man-year equivalents of operators 65 and over less man-year equivalents of operator off-farm employment, divided by \(n_1\).

Secondly, the man-year equivalents of family labor, \(l_2\), (that is, individuals residing in the house of the operator) was calculated. The procedure used was as follows. All working aged individuals (those older than 15 years) residing in the house of the operator (exclusive of the operator) were divided into four age categories (County, 7). The number in each age category was multiplied by the percent males living in the house of the farm operator (County, 7) and recorded.\(^{66}\) The number of males age 15 but less than 20 was

\(^{65}\) The assumption that each operator (or member of operator's household) age 65 or older is equivalent to six-tenths of a man-year is consistent with Griliches (1963).

\(^{66}\) It was necessary to weight by percent males so as not to include females in the labor data. Percent males living in operator's house was calculated as total number of males less number of operators divided by total number of males and females less number of operators.
weighted by a factor of four-tenths to obtain an estimate of the number of man-year equivalents of labor contributed. The number of males age 20 but less than 25 was weighted by a factor of one to obtain an estimate of man-years. The number of males age 25 but less than 65 was, likewise, weighted by a factor of one. The number of males age 65 or older was weighted by a factor of six-tenths to obtain an estimate of man-years. The number of days worked off farm by persons living in farm operator's household (County, 7) was multiplied by percent males and divided by 300 to obtain an estimate of man-years equivalents of off-farm labor of males living in the operator's house. Total family labor per farm, \( l_2 \), was recorded as the sum of man-year equivalents for the four age categories discussed above less man-year equivalents of off farm work, divided by \( n_i \).

Thirdly, man-year equivalents of hired labor, \( l_3 \), was calculated by dividing per farm expenditures for hired labor (County, 9) by an annual wage rate typical of the area. The rate used was $2569. This was the rate used by Davis and Madden (1965) in a study.

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67 The factor four-tenths was arrived at assuming that high school aged males would work on the farm three summer months (.25 man-years) and a limited amount during the school session (.15 man-years).

68 Individuals in this category are considered as full man-year equivalents, since, in the Census, college students are not considered as living in operator's house.
involving cotton farms of the Texas High Plains.

Finally, the total man-year equivalents of labor per farm was calculated as \( l_1 + l_2 + l_3 \) and recorded. That is, total labor represents operator, family, and hired labor employed.

Several limitations involved in this technique for measuring the labor input should be noted. To the extent that labor is employed strictly in livestock enterprises, \( X_6 \) is overestimated. (Recall, \( V \) relates only to the value of crops produced.) Other shortcomings of perhaps lesser consequence, but which no doubt limit the extent to which \( X_6 \) actually represents total labor employed, involve assumptions required to translate reported Census data into a form useful for the purpose at hand. Some of those assumptions include (the negation of the assumption would tend to bias \( X_6 \) in the direction indicated in parentheses): (1) no female labor employed (downward), (2) no salaried laborers (including family) living in the house of the operator (upward), and (3) no unsalaried labor contributed by individuals not living in operator's house (downward). Unfortunately, the effect on \( X_6 \), given the negation of each assumption, is not the same (direction). These latter shortcomings are no doubt of minor significance and, on balance, \( X_6 \) is overstated due to the inclusion of labor related to livestock enterprises.

The discussion now turns away from the details involved in measuring each of the variables, and focusses on the results obtained.
The Fitted Equation: Results

Using least-squares curve fitting procedures, estimates for the parameters in Equation (6-6) were obtained:

\[
V = -9673.28 + 56.65 X_1 + 95.70 X_2 - 28.86 X_3 - 0.15 X_4
\]

\[
+ 5215.58 X_5 + 4953.34 X_6, \quad R^2 = 0.977. \quad (6-7)
\]

All estimates except \( \hat{\beta}_4 \) were significant at the one percent level.

The numbers within the parentheses, beneath the estimated \( \beta \) values, are the corresponding standard errors of the estimates. Simple correlation coefficients and other statistical information are contained in Appendix Table 2. Interpretation of \( \hat{\beta}_1 \) and \( \hat{\beta}_2 \) (the coefficients of particular interest in this study) is deferred to the next section.

Before discussing the estimates, \( \hat{\beta}_3, \hat{\beta}_4, \hat{\beta}_5, \) and \( \hat{\beta}_6 \), a word of caution is in order if interpretive errors are to be avoided. In interpreting these estimates, one must continually bear in mind that they were obtained from data relating to county aggregates ("average" firm per county) and not to individual firms. This fact alone considerably strains the methodology and demands that the validity of these results be questioned. Skepticism seems warranted when one compares the results with a priori notions concerning signs
and relative magnitudes of particular parameter estimates.

Since $X_4$, $X_5$, and $X_6$ are only proxy variables, discretion should be exercised so that little or no economic meaning is attached to $\hat{\beta}_4$, $\hat{\beta}_5$, or $\hat{\beta}_6$. If prior information were available relating the desired economic variables to their proxies, then and only then could these estimates be given economic meaning. The estimate $\hat{\beta}_4$ represents the expected return for an additional dollar invested in seed, fertilizer, petroleum products, or machinery hired. However, as was pointed out earlier (page 113), expenditures in some of these categories are likely to be overstated. It is not surprising, therefore, that $\hat{\beta}_4$ is less than one. Including $X_5$ and $X_6$ in the model as proxy variables was done to improve the reliability of the estimates $\hat{\beta}_1$ and $\hat{\beta}_2$; no meaning in an economic sense should be attributed to their coefficients.

The estimate of $\hat{\beta}_3$ ($-$28.86) is baffling. This estimate supposedly represents the expected return from an additional acre of non-irrigated cropland. Although intuitively $\hat{\beta}_3$ should be less than either $\hat{\beta}_1$ or $\hat{\beta}_2$, its negative value is inconsistent with a priori notions that individual entrepreneurs behave rationally. That is, it is assumed that entrepreneurs do not as general practice knowingly commit resources when the expected return is negative. However, expectations and realization frequently differ. If realized rainfall or product prices were considerably less than expected, then the
negative estimate obtained for dryland cropland would be plausible. Prices received by farmers in the study area were slightly above normal (1959-63) in 1964--based on cotton and grain sorghum prices only (U. S. Dept. of Agriculture, 1966). However, total precipitation in the study area was below normal (1931-60) in 1964 (U. S. Weather Bureau, 1964a, 1964b). The 1964 precipitation of about 12 inches was approximately five inches below the 1931-60 normal. Whether or not the slightly higher prices received and lower precipitation, on balance, accounts for the rather large negative estimate is not known. However, it is known that the negative estimate for non-irrigated cropland conflicts with other MVP estimates for non-irrigated acres in the study area (Moore et al., 1962, 1964; Grubb, 1966). The author doubts that a negative coefficient as large as -$28.86 can be totally explained by "low" rainfall. The following explanation of the negative coefficient for non-irrigated cropland appears more defensible.

Kehrberg (1961) notes that treating the entire complex of products produced as a single dependent variable can yield erroneous results; e. g., "wrong" signs. He explains with use of an example:

69 These data were calculated on the basis of 1964 precipitation and departure from normal for the High Plains Division, Texas and Northeastern Plains Division, New Mexico (U. S. Weather Bureau, 1964a, 1964b).
If two products, A and B, are aggregated into a single value product category, one can easily obtain biased estimates of the production coefficients, especially labor. For, if the cross-section sample is one in which considerable substitution of the two products has occurred one (B) may be a larger user of labor than the other (A). The use of labor may be correlated with the substitution of this product (B) for the other (A). If prices of the products are such that product B leads to lower total value from the same resources, it is possible as B increases in the cross section data, other resources constant, that gross income decreases; i.e., those farms with other resources comparable but having more labor may tend to substitute B for A. A cross-section estimate of the production function will often show negative labor coefficients in this case although the addition of a unit of labor in the production of either product may be positive and the marginal value product of a unit of labor used in B higher than the corresponding marginal value product in A (Kehrberg, 1961, p. 147-148).

The case of non-irrigated cropland appears to corroborate Kehrberg's argument. In the cross-section data used, the proportion of irrigated crops to non-irrigated crops produced varies considerably from one observation to another (percent of total harvested cropland irrigated in 1964 varies from 42.4 to 99.9--Appendix Table 1). The return to irrigated versus non-irrigated areas in the study area is such that as non-irrigated acres increase in the cross-section data, other resources constant, gross income decreases. Cotton, the highest valued product (of consequence) in the area, is generally irrigated and is subject to a price support and acreage control program. A profit motivated enterpreneur will allocate limited water, limited irrigable acres, and other scarce resources to those crops (e.g., cotton) from
which he expects the greatest return. Presumably, irrigated acreage in excess of the cotton allotment and non-irrigated acres would be planted to the next most profitable commodity(s). Given these assertions, then to paraphrase Kehrberg: The cross-section estimate of the production function shows a negative non-irrigated cropland coefficient, although the addition of an acre of either irrigated or non-irrigated cropland may be positive and the marginal value product of an irrigated acre is higher than the marginal value product of a non-irrigated acre.

If \( \hat{\beta}_3 \) is a biased estimate of \( \beta_3 \) (which is the author's belief), then the question arises: How are the estimates, \( \hat{\beta}_1 \) and \( \hat{\beta}_2 \), affected by the bias in \( \hat{\beta}_3 \)? Since \( X_1 \) and \( X_3 \) and \( X_2 \) and \( X_3 \) are (for practical purposes) statistically independent, the bias in \( \hat{\beta}_3 \) should exert no influence on \( \hat{\beta}_1 \) and \( \hat{\beta}_2 \). The simple correlation coefficients between \( X_1 \) and \( X_3 \), and between \( X_2 \) and \( X_3 \), are .021 and -.022, respectively (from Appendix Table 2). Had \( X_1 \) and \( X_3 \) and \( X_2 \) and \( X_3 \) been highly correlated, then bias in \( \hat{\beta}_3 \) most certainly would have been reflected in \( \hat{\beta}_1 \) and \( \hat{\beta}_2 \) as well. When high correlation exists between a variable, \( w \), for which its corresponding estimate, \( \hat{\beta}_w \), is biased, and another variable, say \( z \), then the estimate of \( \beta_z \) will be biased. It is not being argued that \( \hat{\beta}_1 \) and \( \hat{\beta}_2 \) are necessarily unbiased; rather, the argument is that the estimates \( \hat{\beta}_1 \) and \( \hat{\beta}_2 \) are not subject to
bias due to bias in $\hat{\beta}_3$.

The Marginal Value Product of Irrigated Cropland

The MVP for a factor of production, $X_i$, is given by the first partial derivative of the total value product function. That is,

$$\frac{\partial V(X_1, \ldots, X_v)}{\partial X_i}$$

for $i = 1, \ldots, v$. (6-8)

Since the total value product function in (6-7) is a first degree polynomial in the independent variables, $X_1, \ldots, X_6$, and since no interaction terms exist, the estimated marginal value product of $X_i$ is simply $\hat{\beta}_i$; that is,

$$\text{MVP}_{X_i} = \hat{\beta}_i$$

for $i = 1, \ldots, 6$. (6-9)

For a production function which is a first degree polynomial of the independent variables and which has no interaction terms, all factors are technically independent and all inputs have constant marginal productivities for all levels of input use.

Since the purpose of this empirical work was to demonstrate a procedure for estimating the marginal value productivity of irrigation water, the coefficients of interest are $\hat{\beta}_1$ and $\hat{\beta}_2$. These estimates serve as a starting point for the estimation of the marginal value productivity of irrigation water. The estimated MVP for
non-cotton irrigated acres was $56.65 (\hat{\beta}_1); for irrigated cotton acres, the MVP estimate was $95.70 (\hat{\beta}_2).

Estimates of the MVP of irrigation water per se ("net" MVP of an irrigated acre), were obtained by adjusting the MVP estimates for irrigated acres. "Net" MVP estimates for non-cotton were determined by reducing corresponding MVP estimates of irrigated acres by .606 and .617, respectively; that is,

\[
\text{"net" MVP}_{X_1} = \hat{\beta}_1 - .606\hat{\beta}_1 = $22.32
\]
and

\[
\text{"net" MVP}_{X_2} = \hat{\beta}_2 - .617\hat{\beta}_2 = $36.65. \quad (6-10)
\]

The estimated "net" MVP of non-cotton irrigated acres was $22.32; the estimate for cotton was $36.65.

The adjustment factors were calculated from data contained in Importance of Irrigation Water to the Economy of the Texas High Plains (Grubb, 1966). These adjustment factors reflect the value of output which could be produced on a presently irrigated acre if dry-land practices were used and water was not applied. The difference between the value of output under irrigation and the value of output under assumed dryland conditions and practices, represents the "net" productivity of irrigation water.\(^{70}\) The data used to calculate the

\(^{70}\) The concept of "net" MVP is analogous to Grubb's irrigation-output.
adjustment factors are reported in Table 2. The factors were calculated by dividing adjusted gross dryland value per acre by adjusted gross irrigated value per acre.

Table 2. Gross value, acres, gross value per acre, cost of irrigation inputs per acre, and adjusted gross value per acre for non-cotton irrigated, non-cotton dryland, cotton irrigated, and cotton dryland, 42 county area, Texas High Plains, 1959.

<table>
<thead>
<tr>
<th></th>
<th>Non-cotton</th>
<th></th>
<th>Cotton</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irrigated</td>
<td>Dryland</td>
<td>Irrigated</td>
<td>Dryland</td>
</tr>
<tr>
<td>Gross value</td>
<td>141,692,058</td>
<td>85,735,640</td>
<td>202,283,880</td>
<td>52,628,670</td>
</tr>
<tr>
<td>(dollars)</td>
<td>2,371,760</td>
<td>3,719,377</td>
<td>1,323,753</td>
<td>773,462</td>
</tr>
<tr>
<td>Acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross value per</td>
<td>59.74</td>
<td>23.05</td>
<td>152.81</td>
<td>68.04</td>
</tr>
<tr>
<td>acre (dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of irrigation inputs per acre (dollars)</td>
<td>21.72</td>
<td>-----</td>
<td>42.58</td>
<td>-----</td>
</tr>
<tr>
<td>Adjusted gross</td>
<td>38.02</td>
<td>23.05</td>
<td>110.23</td>
<td>68.04</td>
</tr>
<tr>
<td>value per acre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(dollars)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Data in this table were compiled from Tables 3, B1, B3, and B4 of Importance of Irrigation Water to the Economy of the Texas High Plains (Grubb, 1966).

+ These costs "refer to dollar values of those inputs that are required as a consequence of irrigation. They are costs of additional inputs per acre above inputs used on comparable dryland" (Grubb, 1966, p. 11). Costs accounted for include costs of additional fertilizer, fuel, labor, harvesting and hauling, ginning, poison, depreciation of irrigation equipment, and depreciation of farm machinery. Additional costs for irrigated cotton were taken directly from Table 3 (Grubb, 1966). Additional costs for irrigated non-cotton was derived as a weighted average of grain sorghum, wheat, and soybean categories.
To express the MVP estimates for water in the appropriate units of measure—dollars per acre-foot—the "net" MVP estimates for irrigated cropland were divided by 1.1. An irrigation rate of 1.1 acre-feet per "composite acre" is representative of the study area (Grubb, 1966).\(^71\) The estimated MVP of an acre-foot of irrigation water applied on .91 acres of non-cotton cropland was $20.29; for cotton the estimated MVP was $33.32 (see Figure 5).\(^72\)

![MVP Chart](image)

**Figure 5.** Average MVP of irrigation water applied to non-cotton and cotton acres, 1964.

---

\(^71\) Grubb's "composite irrigated acre" includes 32 percent cotton, 38 percent grain sorghum, 21 percent wheat, and 9 percent other crops. The application of a composite irrigation rate of 1.1 acre-feet per acre to both cotton and non-cotton categories may be less than appropriate for this study. For example, if, in the "composite acre", cotton is irrigated at a rate greater than the average for other crops, then the estimate of MVP of water on cotton would be biased upward and the estimate of MVP of water on non-cotton biased downward.

\(^72\) Note, it is not possible to integrate, over a specific domain of the input, either MVP function depicted in Figure 5 and obtain an estimate of total value product \((V)\), as is true of a Cobb-Douglas form. To obtain estimates of \(V\) for a specific level of input use, it is necessary to use Equation (6-8).
In developing these MVP estimates an irrigation rate was implicitly assumed (i.e., the average rate). Therefore, the MVP functions depicted in Figure 5 should not be interpreted as the expected return of an additional acre-foot of water applied to an existing irrigated acre(s). (The question of how MVP per unit of land varies as the irrigation rate varies was not examined.) Rather, they may only be interpreted as the expected return to an additional acre-foot of water and an additional .91 acres of cropland, ceteris paribus. The empirical method used in this study requires that water and land be considered as a single input comprised of a fixed proportion of each. The conversion from acres given 1.1 acre-feet per acre to acre-feet given .91 acres per acre-foot was made so that the estimates would be comparable to cost of transfer data, which are usually available in terms of acre-feet.

To summarize, the estimated "average" MVP of an acre-foot of water and .91 acres of land in the production of crops other than cotton in a 25 county area of northern Texas and eastern New Mexico was $20.29. It is hypothesized that this estimate reflects the value of an additional acre-foot of water and .91 acres of land in its marginal use. The estimated "average" MVP of an acre-foot of water and .91 acres of land in the production of cotton in the study area was $33.32.
Limitations and Recommendations

Limitations (and recommendations for improvement) of this empirical work are divided into two categories--(1) those which are possible to correct or improve upon given the same basic method and data sources and (2) those which can be corrected only by using a different approach or data sources.

Limitations of the first type involve (a) weaknesses in the model specification and (b) imperfect measurement of relevant variables. There are two deficiencies in the specification of the model--the variables $X_4$ and $X_5$ are too narrowly defined (see pages 113 and 114). Operating expenses, $X_4$, includes only a part of operating expenses related to the production of crops. For example, expenses for maintenance of machinery and equipment were not included. Numbers of wheel tractors, $X_5$, is particularly suspect. Ideally, $X_5$ would represent the annual equivalent investment in all durable resources involved in the production of crops. Perhaps these shortcomings in model specification could be eliminated if suitable data were located to supplement the basis Census data.

Obtaining reliable measures of relevant variables is frequently difficult in economic research. In this study variables $X_4$, $X_5$, and $X_6$ were imprecisely measured. The variables $V$, $X_1$, $X_2$, and $X_3$ relate only to crop production activity in the study area.
Variables $X_5$ and $X_6$ relate to total farm input and, therefore, are overstated to the extent that livestock production is involved. This is also true, although to a lesser degree, with the measurement of $X_4$. Perhaps this limitation could be alleviated by developing a weighting procedure to reduce $X_4$, $X_5$, and $X_6$ by an amount representing the livestock share.

Another limitation of the first type involves the choice of irrigation rates for cotton irrigated acres, $X_1$, and non-cotton irrigated acres, $X_2$. In this research an irrigation rate of 1.1 feet per acre was assumed for both to convert the MVP estimates for acres given acre-feet of water to acre-feet of water given acres. Perhaps differential rates would be more appropriate—if so, then different conversion factors could and should be applied.

An important limitation, which falls in the gray area between those which can be corrected given the same basic approach and type of data and those which cannot, involves the aggregation problem. Specifically: Is the negative MVP estimate for dryland cropland erroneous? If so: Is this attributable to the estimation of a composite value product function for a multiple product study area? If these questions are answered affirmatively, then the only type one solution to the problem is to choose observational units such that each has relatively the same proportion of $X_3$ (non-irrigated cropland) to $X_1 + X_2$ (irrigated cropland) (Kehrberg, 1961, p. 118). However, the
author is not optimistic that this solution is practical when counties are used as observational units. The county observational units selected for study in this research probably are as homogeneous with respect to their agricultural composition as can be found in the arid Southwest. Seemingly, elimination of this problem requires that the unit of analysis be smaller than a county; furthermore, it would be preferable to estimate single product production functions (if practical).

An important limitation previously noted was the loss of product price as an explicit variable in the model. The approach used (i.e., a composite dependent variable) essentially precludes the analysis of the effect of changes in the price of specific products. A production function model in which individual products are identifiable (or the estimation of individual product production functions) would be more fruitful for such analysis.

A limitation imposed by the data source entails the intermediate aggregation and disaggregation required to obtain a relevant observational unit. Regressing on a population of "average" firms buries much of the variation inherent in the parent population, leaving one with a false sense of statistical precision.

In light of the many limitations of this empirical effort, the temptation is great to agree with Hoch: "The development of individual farm estimates appears more defensible..." (Hoch, 1967, p. 471).
However, in evaluating the reliability and usefulness of empirical estimates for a particular purpose, it is important to bear in mind that the question of information quality is basically an economic one. Only if alternative procedures have the same cost does it follow that the "best" quality information is optimal. Since the irrigated acreage MVP estimates obtained are consistent with results obtained in comparable studies (Grubb, 1966; Brown and McGuire, 1967; Young and Martin, 1967), and not knowing costs of developing individual farm estimates, it is not possible to reject \textit{prima facie} the approach demonstrated herein.  

\footnote{However, the author must confess that he would feel more at ease with MVP estimates derived from individual commodity production functions based on individual farm data.}
VII. SUMMARY AND CONCLUSIONS

The social decision-making process has and continues to grapple with the question of whether or not to transfer substantial quantities of water from so-called "surplus" regions to so-called "shortage" regions of the United States. If rational decisions are to be made, then positive analyses of the many aspects of this issue must be provided by the several relevant disciplines. If the economist chooses to participate, objectively and effectively, in the decision process as but one of several expert consultants, then his identification and quantification of economic implications must be preceded with the development of a relevant framework for analysis. Accordingly, the purpose of this thesis was to pull together into a single interrelated package, the economic theory needed to establish such a framework. Specifically, two objectives were proposed: (1) to develop a concise theoretical framework which would enable explicit identification of the efficiency implications of interregional water diversion projects, and which would permit identification of impact by region, and (2) to demonstrate an empirical method for estimating the direct (primary) economic benefits resulting from interregional water diversion projects.

The results and suggestions for further research fall conveniently into two groups according to these objectives—(1) the framework and (2) empirical methodology.
The Framework

In developing an appropriate framework for analysis of economic consequences of interbasin water transfer, economic efficiency and distribution were considered. Since economists are unable to specify a social welfare function, the only practical solution available is to look upon efficiency and distribution as separate and distinct issues. Accordingly, a model was developed such that efficiency implications of resource transfer schemes could be ascertained. The components of the model were identified so that direct regional income redistributive effects might be identified.

In developing the efficiency model the level of aggregation chosen was national; the objective considered was the maximization of net, present, real, market value of incremental output resulting from a resource transfer project. A basic efficiency model was developed under the assumptions that (1) the resource had no "in transit" value, (2) the quantity of the resource to be transferred was consumable in destination by a single marginal use, which involved the production of an independently produced product, (3) a single use was affected in origin, which involved the production of an independently produced product, and (4) national indirect benefits and costs were zero. The basic efficiency model states that the net, present, real, market value of incremental national output is equal to the aggregate net
value product in the area of destination less the cost of transfer less the aggregate net value product forfeited in the area of origin, where the net value product in the area of destination is calculated on the basis of the marginal use of the transferred resource.

A necessary condition for economic efficiency in resource transfer was subsequently derived—the aggregate marginal value productivity of the transferred resource in the area of destination must equal or exceed the marginal cost of transfer plus the net aggregate marginal value productivity foregone in the area of origin.

The assumptions made in developing the basic model were relaxed and the model and resulting necessary condition for efficiency in transfer were fully developed to consider "in transit" use, intra-firm production interdependencies, and interfirm production interdependencies. Conditions under which indirect benefits and costs might appropriately be included in the efficiency model were discussed and identified.

In the statement of a necessary condition for efficiency in resource transfer, four economic variables were identified. Estimation procedures must be developed for ascertaining their magnitudes if reliable and relevant information is to be forthcoming.

**Empirical Methodology**

A critical economic variable is the marginal value productivity
of the resource in both the origin and destination area. A procedure was demonstrated for estimating the marginal value productivity of water in irrigated agriculture. Data from the 1964 Census of Agriculture (U.S. Bureau of the Census, 1964a, 1964b) were used to estimate a value of crops harvested function for an area of the Texas High Plains and eastern New Mexico. The units of observation consisted of the "average" farm of 25 counties. Parameter estimates for six independent variables were obtained using least-square estimation procedures. Marginal value productivity estimates for irrigated cotton acreage and irrigated non-cotton acreage were derived from the estimated model.

The basic procedure and data source was the same as that used by Ruttan (1965). Several improvements were incorporated that should tend to improve the "quality" of the estimates over those obtained by Ruttan. Ruttan's work had been criticized on four counts: (1) omission-of-variables, (2) over aggregation, (3) intraregional heterogeneity, and (4) choice of counties rather than firms as units of analysis. In each instance improvements were incorporated in the empirical work reported in this thesis. Although several complications in the method of estimation remain, the results obtained were consistent with those of comparable studies and seemed plausible in light of prior knowledge. Although conceptual difficulties remain in the procedure which preclude its recommendation, neither can it be
rejected as being useful—particularly, in view of its rather low cost.

Recommendations for Further Research

Further research in several areas is suggested by the results of this effort. There is need to develop further the framework for describing the regional income redistributive impacts of resource transfer schemes. In addition to the direct effects identified (by region) in this thesis, the following should be considered: (1) regional indirect benefits and costs (Regarding the issue of interbasin water diversion, interest in indirect regional benefits and costs accounts for much of the political commotion one observes, both pro and con.), (2) share of federal tax burden by region (No doubt large federal expenditures will be involved if interbasin water diversions are to become reality.), and (3) pecuniary externalities (If a transfer scheme is massive in its scale, product and factor markets could be affected such that beneficial or detrimental effects are imposed upon producers outside the region of destination.).

In the above and in the estimation of components identified in the efficiency model (including extensions), numerous empirical challenges exist. Much empirical work is needed if operational prototypes of the theoretical models are to be developed.
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Table A-1. Characteristics of the study area by counties, 1964.

<table>
<thead>
<tr>
<th>County</th>
<th>Percent of total cropland harvested that was irrigated</th>
<th>Percent of value of all farm products sold from crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Mexico:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chaves</td>
<td>99.7</td>
<td>46.3</td>
</tr>
<tr>
<td>Curry</td>
<td>61.8</td>
<td>41.4</td>
</tr>
<tr>
<td>Eddy</td>
<td>99.9</td>
<td>60.0</td>
</tr>
<tr>
<td>Lea</td>
<td>96.8</td>
<td>53.1</td>
</tr>
<tr>
<td>Roosevelt</td>
<td>42.4</td>
<td>44.1</td>
</tr>
<tr>
<td>Texas:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bailey</td>
<td>57.6</td>
<td>62.3</td>
</tr>
<tr>
<td>Briscoe</td>
<td>54.1</td>
<td>76.9</td>
</tr>
<tr>
<td>Castro</td>
<td>95.9</td>
<td>79.8</td>
</tr>
<tr>
<td>Cochran</td>
<td>57.3</td>
<td>94.2</td>
</tr>
<tr>
<td>Crosby</td>
<td>70.9</td>
<td>94.0</td>
</tr>
<tr>
<td>Deaf Smith</td>
<td>88.1</td>
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</tr>
<tr>
<td>Floyd</td>
<td>81.6</td>
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<td>50.6</td>
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<td>Hockley</td>
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<td>94.8</td>
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<td>Lamb</td>
<td>78.9</td>
<td>74.9</td>
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<tr>
<td>Lubbock</td>
<td>81.2</td>
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<td>Moore</td>
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<td>61.1</td>
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<td>Parmer</td>
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<td>Randall</td>
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<tr>
<td>Sherman</td>
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<td>Swisher</td>
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</tr>
<tr>
<td>Terry</td>
<td>62.9</td>
<td>96.3</td>
</tr>
<tr>
<td>Yoakum</td>
<td>47.4</td>
<td>85.2</td>
</tr>
<tr>
<td>Mean:</td>
<td>67.4</td>
<td>68.3</td>
</tr>
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</table>
Table A-2. Values and correlations for variables used in the regression analysis, 25 counties ("average" firms), 1964.

<table>
<thead>
<tr>
<th></th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
<th>$X_5$</th>
<th>$X_6$</th>
<th>$Y$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Values</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Means</td>
<td>169.08</td>
<td>72.54</td>
<td>87.76</td>
<td>6823.40</td>
<td>2.49</td>
<td>2.40</td>
<td>28155.28</td>
</tr>
<tr>
<td>Estimated coefficients</td>
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<td>95.70</td>
<td>-28.86</td>
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<td>T values</td>
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**Simple correlation coefficients**

$X_1$ = Number of non-cotton irrigated cropland acres.

$X_2$ = Number of irrigated cotton acres.

$X_3$ = Number non-irrigated cropland acres.

$X_4$ = Dollars operating expenses.

$X_5$ = Number of wheel tractors.

$X_6$ = Man-year equivalents of labor.

$Y$ = Value of crops harvested.