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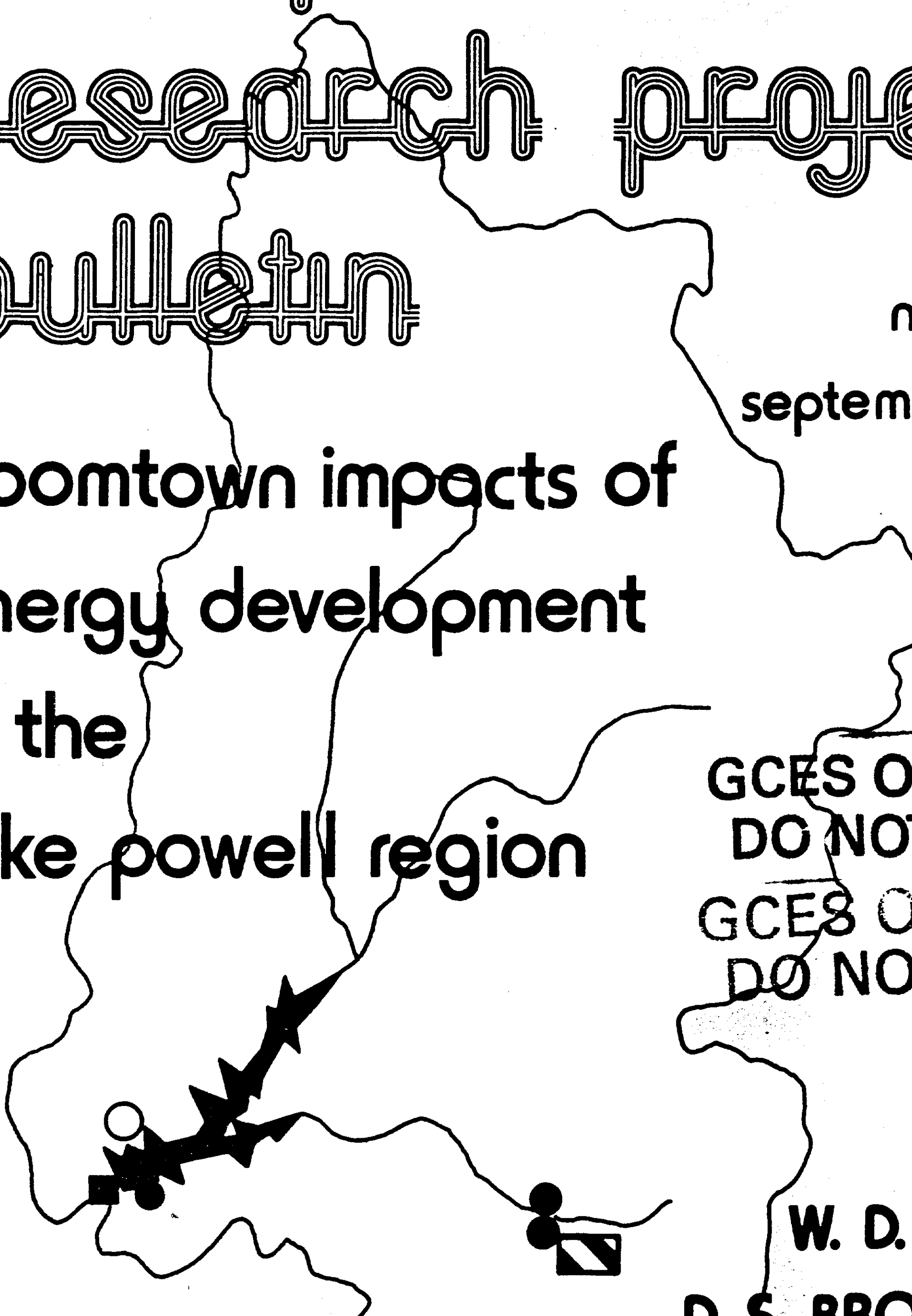

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National Science Foundation
Research Applied to National Needs

LAKE POWELL RESEARCH PROJECT BULLETIN

BULLETIN EDITORS

Jeni M. Varady and Orson L. Anderson

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COLLABORATIVE RESEARCH ON ASSESSMENT OF MAN'S ACTIVITIES IN THE LAKE POWELL REGION

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BOOMTOWN IMPACTS OF ENERGY DEVELOPMENT IN THE LAKE POWELL REGION

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LAKE POWELL RESEARCH PROJECT

The Lake Powell Research Project (formally known as Collaborative Research on Assessment of Man's Activities in the Lake Powell Region) is a consortium of university groups funded by the Division of Advanced Environmental Research and Technology in RANN (Research Applied to National Needs) in the National Science Foundation.

Researchers in the consortium bring a wide range of expertise in natural and social sciences to bear on the general problem of the effects and ramifications of water resource management in the Lake Powell region. The region currently is experiencing converging demands for water and energy resource development, preservation of nationally unique scenic features, expansion of recreation facilities, and economic growth and modernization in previously isolated rural areas.

The Project comprises interdisciplinary studies centered on the following topics: (1) level and distribution of income and wealth generated by resources development; (2) institutional framework for environmental assessment and planning; (3) institutional decision-making and resource allocation; (4) implications for federal Indian policies of accelerated economic development of the Navajo Indian Reservation; (5) impact of development on demographic structure; (6) consumptive water use in the Upper Colorado River Basin; (7) prediction of future significant changes in the Lake Powell ecosystem; (8) recreational carrying capacity and utilization of the Glen Canyon National Recreation Area; (9) impact of energy development around Lake Powell; and (10) consequences of variability in the lake level of Lake Powell.

One of the major missions of RANN projects is to communicate research results directly to user groups of the region, which include government agencies, Native American Tribes, legislative bodies, and interested civic groups. The Lake Powell Research Project Bulletins are intended to make timely research results readily accessible to user groups. The Bulletins supplement technical articles published by Project members in scholarly journals.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Benefits to local economies from energy production in the western states are being questioned by state and local planners, academic researchers, and members of the press because of environmental, social, and local economic impacts, including problems associated with the creation and maintenance of boomtowns. Construction of Glen Canyon Dam (which took place from 1957 to 1964) and of the Navajo Generating Station (1971 to 1976), both of which are located in Arizona, caused two economic booms in that area. Construction of the proposed Kaiparowits project (which would have taken from 1976 to 1982) would have resulted in a third successive economic boom within a 25-year period (1957 to 1982). Thus, a remote and scenic area in Utah and Arizona near the southwestern end of Lake Powell became the focus of a national controversy over energy development. This Bulletin quantifies the economic impact of past energy-development activity in this region and examines projected boomtown impacts of the proposed Kaiparowits project, emphasizing in both cases the effects on local economic benefits. Although the proposal for the Kaiparowits project was withdrawn in April 1976, which was after the completion of the research reported herein, several similar power projects currently are being promoted, planned, or constructed. Thus, much of the material presented here, although it relates specifically to the Kaiparowits project, is very relevant for other projects of current interest.

A model of a boomtown economy based on primary data collected from Page, Arizona, and optimal strategies for investment in boomtown communities are developed. The need for front-end capital, which traditionally has been in short supply because of institutional constraints in

the money market, is illustrated in theory. Higher interest rates are shown to cause the construction booms associated with large energy projects to be briefer and more intense and productivity to drop during the course of the boom. It is concluded that the high wages paid during the construction process tend to offset the disamenities of boomtown life for workers, but because disparities exist among family members and prior knowledge of boomtown conditions is inadequate, wage compensation for disamenities is only partial.

The near isomorphism between economic cycles in small isolated communities and the pattern of construction labor associated with large energy projects is illustrated using an input-output model of the Page area economy. Regional planning and new towns for energy development are discussed with reference to the study area. Most local benefits associated with the proposed Kaiparowits project are seen to derive from the underground coal mining associated with that project, while most boomtown and environmental projects are associated with the powerplant, due to the intense and temporary labor requirements associated with large powerplants. Economic considerations suggest that flexibility should exist in the sequencing and siting of powerplants, while shortcomings in regional planning and other institutional constraints appear to inhibit optimal project development.

1. INTRODUCTION

A great deal of attention has been focused on development of the vast energy resources of the western states. To meet national energy objectives, many large energy projects have been proposed for this region, and several have been constructed. These projects include coal-fired electric generating stations whose capacities range from 1000 megawatts (MW) to 3000 MW, and proposed coal gasification projects which would produce one-quarter billion cubic feet of synthetic gas daily. More uranium mining and milling projects are expected to follow increased exploration activities in the area, while oil shale and geothermal resource developments are also on the horizon. Projects of this scale will obviously have disturbing impacts on the quality of life and the environment in the region, including the complex set of social and economic problems associated with the creation of boomtowns.

If the western states are to be major exporters of energy and energy resources, they must import much of the capital and labor needed to construct and operate the production and extraction facilities. A single project may employ thousands of workers whose presence, along with that of their families and an associated service population, would create significant impacts on all but larger cities. In most parts of the Rocky Mountain West, the locations for such projects are dictated by resource availability and typically are isolated from towns or cities able to provide the necessary services for thousands of newly arrived people in a very short time. Of necessity, new towns may spring up almost overnight, or small agricultural towns may be adopted by industrial developers and may increase several fold in size, becoming new and different places with the influx of new people with new money looking for a supply of goods and services. The objectives in this study therefore are (a) to examine the relationships among new jobs, people, and the local economy of such boomtown communities, using Page, Arizona, as an historical example, and (b) to consider the proposed Kaiparowits project near Page in the wider context of regional economic development.

Although several boomtowns have been studied in depth--most notably Gillette, Wyoming--the economics of the boomtown phenomenon are poorly understood for two reasons [7] [9] (Ed. Note: numbers in brackets refer to literature cited). First, since boomtowns are characterized by rapid change, their economies are in disequilibrium, yet the theoretical economic models almost always treat equilibrium situations. Second, collection of the primary economic data in the private sector, especially from business, is time consuming and difficult because respondents fear that confidentiality will not be maintained and they are often unsympathetic to the perceived aims of the researcher.

Section 2 describes recent theoretical work in the area of boomtown economics towards development of an analytical framework for understanding the boomtown experience in general and the Page experience in particular[1] (Ed. Note: superscript numbers refer to footnotes). Subsequent sections present detailed analyses of the Page economy based on primary data collection, and discussions of the impact of future energy-related development of the nearby Kaiparowits Plateau as an example of the problems of planning regional energy development.

2. THE BOOMTOWN PHENOMENON

The boomtown experience is generally characterized by external economic pressure for resource development which gives rise to a rapid influx of population, an immediate shortage of public services and private goods, and a set of social and environmental problems which degrade the quality of life for both workers and their families. Though these impacts reflect a complex reality, the economic explanation centers on the existence of disequilibrium in three critical areas: the labor market, the market for private capital, and the level of public investment in social capital. We begin by examining the factors affecting the external economic forces which foster and drive localized booms.

Why the Boomtown Phenomenon?

The initial construction phase of the "typical" boomtown is associated with a remarkably rapid buildup of the local labor force and, for major projects such as the construction of powerplants or dams, takes place over a 3- to 10-year period. One could hypothesize a construction phase with a more gradual buildup of the necessary labor force spread over a longer interval, which would consequently reduce or eliminate many of the problems associated with boomtowns. The question then becomes: Why do we observe such a rapid or hurried process in the construction phase?

To answer this question we need only consider the economic incentives operating over the construction period. Clearly, the objective in any such process is to minimize the cost of construction at the date of completion. Since capital must be borrowed as construction progresses in order to cover current costs (including wages), and since these costs cannot be repaid until operations begin, labor costs accrue compound interest over the construction period as part of the total cost of construction. This implies, for example, that for a 5-year project with a 6-percent interest rate, labor which costs $10 in the first year of construction has an actual cost of $13.50, which includes compound interest, at the completion date. In contrast, $10 spent on labor during the third year only costs $11.27 at the completion date. Clearly a strong bias exists to utilize labor, and for that matter all inputs to the construction process, as late in that process as is consistent with maintaining productivity. Furthermore, the higher the interest rate, the greater the bias both to utilize inputs at the last moment and to shorten the overall construction period. Figure 2.1 illustrates the impact of imposing a positive interest rate (r) on a hypothetical labor-use pattern over time. Note that for the positive-interest-rate case (r = 6 percent), the total area under the curve, or total amount of labor used in the construction process, is larger than that for the zero-interest-rate case, which indicates a decrease in labor productivity. This occurs because of the necessity of sacrificing some labor productivity in order to reduce the total cost of construction, which now includes interest costs not previously incurred. Thus, with positive real interest rates, labor productivity will actually drop over time during the life of the construction project as a result of the bias explained above. Gilmore [8] has suggested that labor productivity drops as boomtown conditions worsen with the continued influx of new workers and population. Unfortunately, the analysis presented above confounds verification of Gilmore's hypothesis

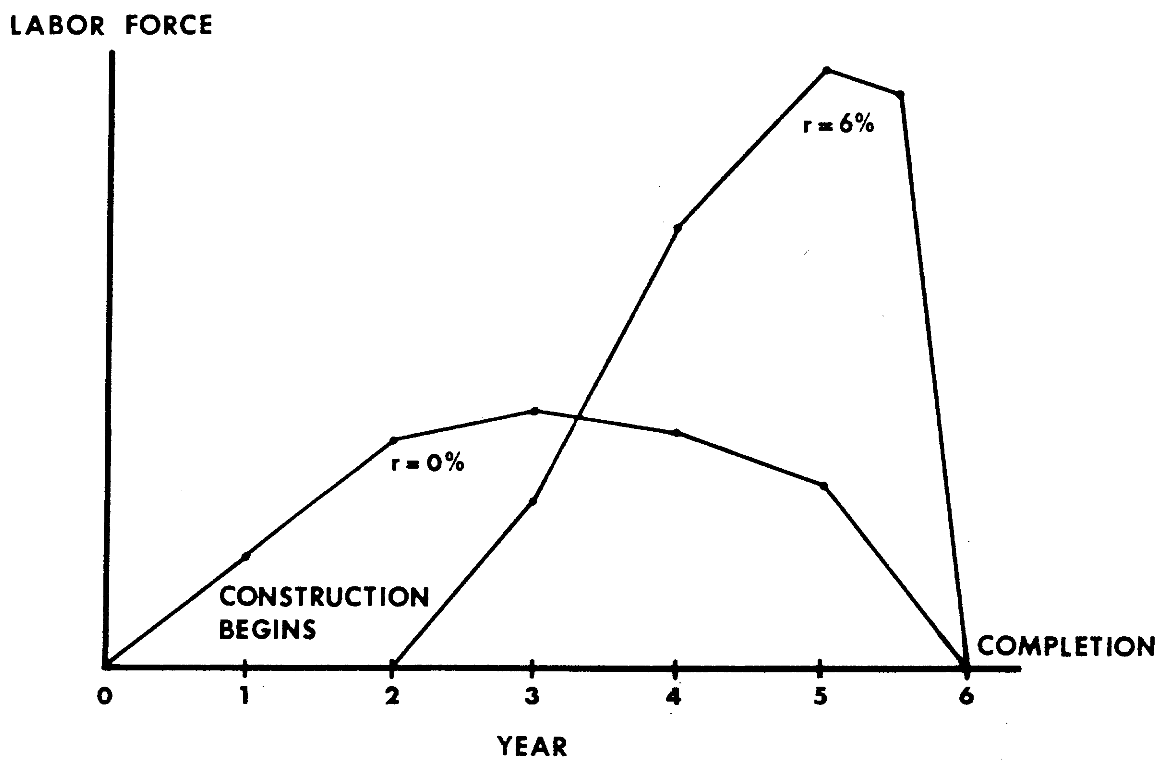

Figure 2.1: Graph of impact of imposing a positive interest rate (r) on a hypothetical labor use pattern over time

that the quality of life affects productivity, because such a productivity loss is an inherent feature of the construction process and is brought about by cumulative interest costs during construction.

Two other factors can be demonstrated to exacerbate the intensity and brevity of the construction phase associated with the boomtown phenomenon. First, the more sensitive (elastic) the labor supply is to increases in wages--in other words, the greater the number of additional workers who can be induced into a region for a given increase in wages--the more rapidly the boom will expand. Given that there has been substantial unemployment in recent years and a tradition of regional mobility in the construction trades, it is clear that the elasticity of the labor supply is high for most boomtowns.

Second, workers must be brought to the site of the natural resources (whether water, energy, or minerals) which are to be developed, and the natural environment of these sites may not favor prolonged occupation by humans. The case of the oil development and pipeline construction on the Alaskan North Slope is a good illustration of this point. In this case and in other less extreme situations, labor productivity and labor turnover may create a great incentive to hasten the completion of such projects. Thus, an inherently expensive and unhappy social proposition may be ameliorated by importing labor on a monthly, weekly, or daily basis, leaving families behind in more suitable locales. Work incentives favoring this solution might be acceptable to skilled workers with families who would accept short-term separations for temporary sources of employment at high wages rather than moving their families to an undesirable location.

In summary, the dominant forces underlying the boomtown phenomenon are those of natural (rather than human) resource development. The pattern of employment observed is affected by the interest rates on borrowing for labor and capital requirements during construction, the supply of labor to the region (which is affected by unemployment rates), the returns to scale of the construction process, and the human environmental conditions of the region containing the natural resource under development.

The development of the boomtown itself therefore can be altered directly by several policy measures, some of which may have escaped previous notice. First, low-interest loans for construction will tend to slow booms, but will also increase the likelihood of their occurrence. Second, a full-employment economy will tend to ameliorate boomtown conditions somewhat since it will be more difficult to attract labor inputs which are employed elsewhere. Finally, the development of a local town may be undesirable, and it may be prevented by the provision of rapid-transport links to other, more suitable, communities. The development of these links is, of course, a public rather than a private decision; therefore, boomtowns may develop in some cases because better alternatives are ignored by the public sector.

The Quality of Life[2]

Two underlying factors affect the quality of life of residents of boomtown communities. First, as we have noted previously, the natural environment itself may be inhospitable to human habitation. Second, boomtown communities are characterized by shortages of public and private services which in turn are closely related to the levels of cumulative investment (public capital) in municipal social infrastructure. Examples of public services include schools, parks, police and fire protection, municipal buildings and equipment, and municipal utilities such as sewers. Private community investments include business inventories, equipment, and structures, and residential housing, including permanent homes and trailers. Optimal investments in public and private capital for boomtowns are considered next.

For purposes of analysis, we assume that shortages do exist in supplies of public and private capital. It is easy under these assumptions, then, to show that high wages--relative to other communities--will prevail in boomtowns. First, under assumptions of rational economic behavior, labor will not move to a boomtown locale given the environmental, social, and private capital conditions unless the wage is sufficiently high to make decision-making units--at least according to their individual initial perceptions--as well-off as before the move. Clearly then, in a boomtown situation where (a) the environment is likely to be inhospitable, (b) prices of private goods high, and (c) police and fire protection and schools poor, wages must compensate for these factors in order to induce labor to participate. At this point, economics has little to add in explanation of the morass of social problems (including alcoholism and divorce) which accompany boomtown developments, unless one asserts that individual decision-making units (families) do in fact misperceive the realities of boomtown life. Restated, under perfect information conditions, the high wages which are necessary to induce labor to relocate should compensate in economic terms for the disamenities of boomtown life. Misperception or misinformation may result from the following divergence between male heads of households and other family members. Male heads of households are offered high wages to relocate in remote communities and may not be as affected by the few disamenities because (a) much of their time is spent on the job, and (b) outdoor recreation activities available in remote areas may substitute more adequately for a lack of municipal recreation opportunities. However, wives and children suffer disproportionately from the lack of amenities, including, for the wife, difficulty in finding job opportunities outside the home, difficulty in completing normal household activities such as shopping (due in part to poor inventory levels), and confinement to a relatively small mobile or modular home. Children suffer from the lack of adequate school facilities, parks, libraries, and other suitable recreation opportunities. Clearly the boomtown experience serves to cause a divergence in interests, both economic and environmental, between male heads of households and their families. In many cases, families are separated before or after the move to a boomtown, reflecting, in the latter case, imperfect prior information on the quality of life in a boomtown. To the economist this situation suggests that the high wages paid in boomtowns do not fully compensate for the disamenities that must be endured. The wage bill for construction or operation in a boomtown situation, then, does not reflect fully the social costs imposed on boomtown residents of undertaking such development activities.

Public and Private Investment[3]

Optimal investment strategies for boomtowns can be readily determined if one assumes that wages are made to compensate for disamenities. Therefore, in the following analysis, we assume that boomtown wages have been adjusted upward to compensate fully for environmental and social impacts which may be excluded from observed boomtown labor markets. The economic objective for society then should be to minimize not only the cost of construction of a particular project (including wages, other input costs, and interest during construction) but also the costs of social or public investments. This may seem peculiar until we include the provision that boomtown residents must be made at least as well off as they were in their previous community--a logical requirement to induce labor participation. Thus, we wish to minimize total social costs of the boomtown experience where wages reflect (by assumption) the entire disamenity costs of boomtown life as well as compensation for work.

Figure 2.2 presents optimal social or public capital stocks for a hypothetical boomtown experience based on the criterion that boomtown residents must be made at least as well off as they were in their previous community. Two types of capital are shown in the figure. Permanent capital is denoted as K_p (and by the dotted line) and represents investments which are fixed, immobile, or irreversible, i.e., if the usefulness of a unit of in-place capital ends it cannot be moved to another locale for further use. Mobile capital is denoted as K_e (and by the dashed line). This type of investment, such as construction equipment, vehicles including police and fire equipment, and mobile homes, can be utilized wherever needed, and, therefore, can follow in total quantity the exact profile of the boom as illustrated. Thus, where the construction phase occurs between time zero and T and the operation phase from time T to T' for a hypothetical energy development, mobile capital ideally remains in equilibrium and follows the total population profile while maintaining a constant level of

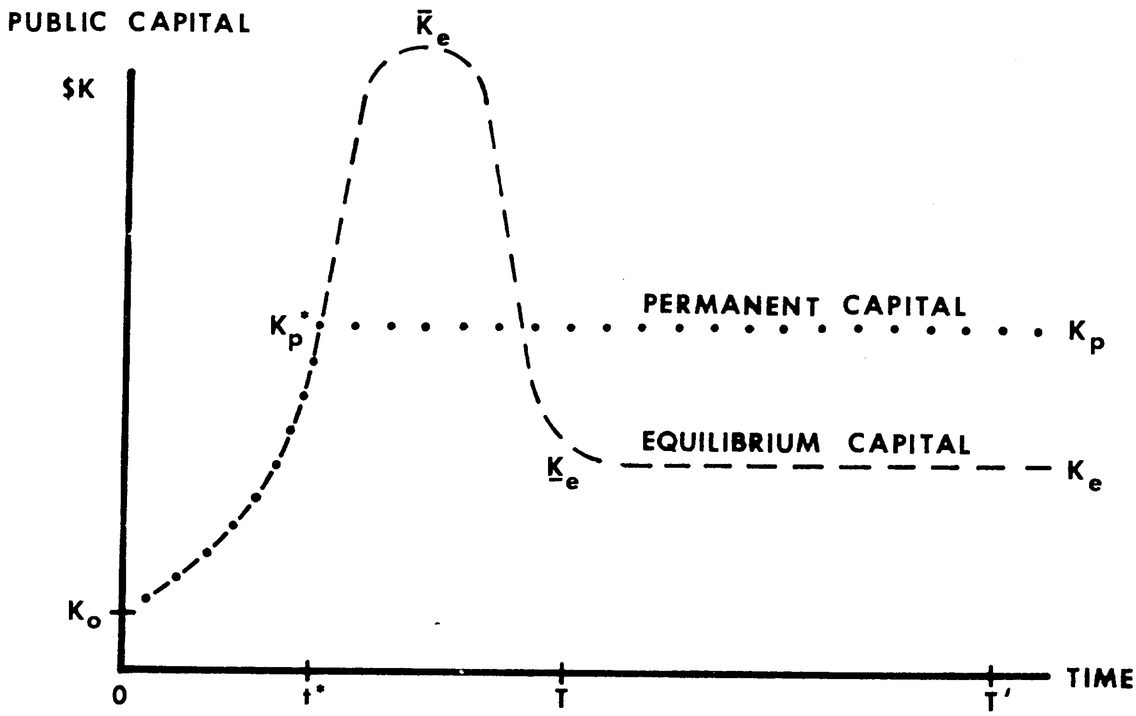

Figure 2.2: Optimal path for permanent social capital during a hypothetical boomtown experience

capital per capita comparable to the level of investment in other communities.

Unfortunately, most investment in social infrastructure is not of the mobile variety. This implies that where capital cannot be removed without loss (which suggests the impossibility of disinvestment with financial recovery of investment costs), permanent capital cannot follow the desired level which would be equivalent to an "equilibrium" community. Thus, in the ideal situation, as the boom begins, investment in permanent capital follows K_e (the same path as the equilibrium level of mobile capital) until some time t^* when investment stops at K_p^*. Clearly, then, after time t^* a permanent capital shortage will occur initially since K_e is greater than K_p. However, in the long run, during the operating phase, when the desired level of capital drops to $\underline{K}_e$, there is an excess of social capital (K_p^* is greater than $\underline{K}_e$). It can be rigorously demonstrated, given our assumption, that the "ideal" level of permanent public capital K_p^* lies above $\underline{K}_e$, the long-term demand for capital, and below $\overline{K}_e$, the peak demand for capital that occurs during the construction phase. Furthermore, investment in permanent public capital should cease when K_p rises to a level equal to the future payback ability of the community. In other words, the community, given its future tax base, must pay off or retire all borrowing for permanent public capital between t^* (when public investment in permanent capital ends) and T' (when the town presumably ceases to exist because the operating life of the energy development is completed).

In summary, the optimal boomtown investment strategy for permanent social capital is (a) to begin with enough front-end investment to start off with an "equilibrium" level of per capita social capital equivalent to other developed communities (K_o in Figure 2.2); (b) to maintain this equilibrium level by investing rapidly enough to keep pace with population growth; and (c) to cease further investment when the accumulated dollar value of public permanent capital equals the future payback capability of the community. In the long run this strategy provides important fiscal independence for the boomtown community. Investment costs are recouped through the community tax structure which affects wage levels and, ultimately, the costs of construction and operation. This allows social overhead costs to be incorporated as part of the construction and operation costs.

Figure 2.3 shows how permanent and equilibrium (mobile) investment, I_p and I_e, respectively, vary over time for the capital strategy described above. Note that for the more important case of permanent investment, all such investment occurs early during the construction boom (before t*). Unfortunately, this strategy has been a fiscal impossibility for most boomtowns because of the oft-cited problems of limited bonding capacity and the inability to provide funding for front-end financial needs [1] [10] [13]. In fact, existing evidence suggests that public investments in boomtowns follow a pattern almost the reverse of that shown in Figure 2.3 for permanent investment. Public investment is most likely to occur after the peak of the boom has been reached, when a clear tax and revenue base has been established. Thus, permanent capital is provided when it is least needed, after the boom has passed. One solution is to provide boomtown communities with federal or state government loans when they are in the early stages of construction. These loans should be based on each community's long-term ability to repay

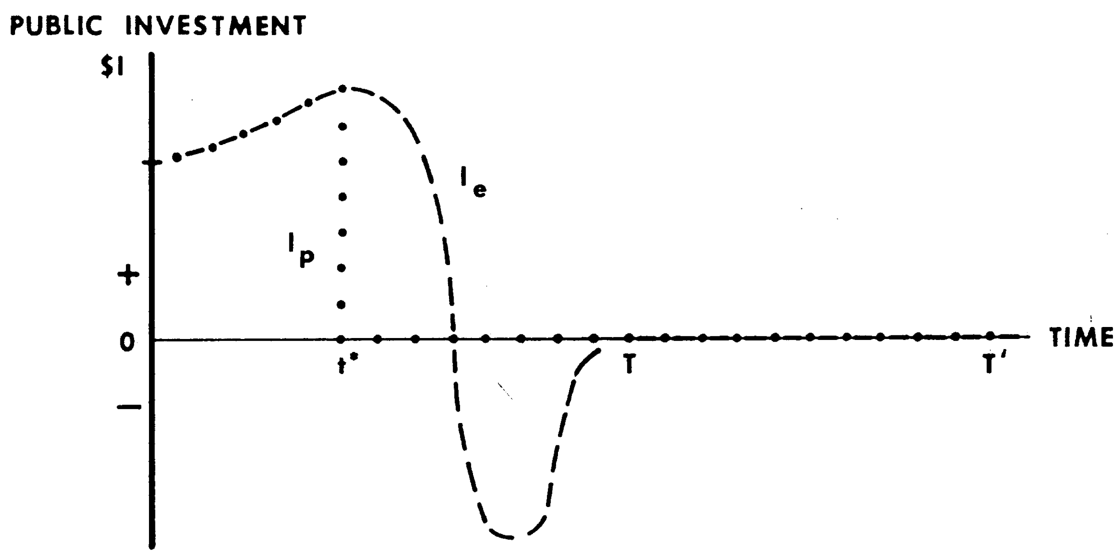

Figure 2.3: Optimal path for permanent social investment during a hypothetical boomtown experience

the loans, rather than on current bonding capacity. Another possibility is for the resource developer to underwrite loans for the necessary public facilities, an approach which economically internalizes these costs within the private market.

Not surprisingly, an almost identical analysis can be made for private investment in boomtown communities, where the implications of a shortage in private capital are exhibited in high prices or delays in obtaining goods and services, as well as in congestion phenomena. Private capital formation in boomtown communities is hindered for reasons similar to those for public capital. Uncertainty about the future of boomtown communities, the untimely delay in formation of local financial institutions, and the unwillingness of financial institutions located elsewhere to invest in homes and small businesses in a remote boomtown prevent efficient development of private capital during the initial growth phase. Again the solution lies in improving the availability of investment funds.

Finally, if a boomtown is located in an undesirable place, labor will be more expensive than it would be elsewhere. This discourages private investment in manufacturing or production of other commodities which, quite simply, can be produced less expensively in areas with lower labor costs and then imported into a boomtown. Thus, such a boomtown will not develop its private investment structure beyond that required for the minimal retail and service industries which must be located near the population served. This results in continued import dependence for most goods and in total economic reliance on resource extraction, energy production, or perhaps recreation for an export base.

Timing and Sequencing of Regional Economic Development

Although to this point we have considered only the individual boomtown situation, problems of regional energy development have become a national issue. As examples, both the existing Navajo Generating Station and the proposed Kaiparowits project illustrate that the economic and environmental impacts of development may affect several states. Electrical energy produced by a coal-fired powerplant may be consumed more than 1000 miles from both the plant and the associated social, economic, and environmental impacts. Such plants may receive ardent political support both from potential consumers and from local residents who desire regional development, but they may be vigorously opposed by environmentalists and potential recreationists in the region.

All of these forces tend to obscure the central issues of well-planned regional energy development that is consistent with maintaining both the quality of life of boomtown residents and the recreational and environmental potential of unspoiled areas. Therefore, we observe a continuing series of poorly planned developments which, though actually interdependent, are developed independently. The Lake Powell area example serves to illustrate these problems. The construction of Glen Canyon Dam made more attractive the development of both the Navajo Generating Station near Page, Arizona, and the proposal for the Kaiparowits powerplant by providing water to meet their cooling requirements inexpensively. The initial choices of locations for both plants were made primarily on the basis of the ready availability of both water and coal, which is found near the southwestern end of Lake Powell. The town of Page, which was initially associated with dam construction, as a result might have seen three successive booms over a 25-year period. Investment in the community of Page during each of the two past booms apparently has not reflected the fact that social and private investment would have greater value if successive periods of local energy development were synchronized. Furthermore, an examination of the whole range of energy and related community development alternatives for this region has not been evaluated. As a contribution to such an effort, we begin our empirical analysis with a discussion of the historical evidence for Page, Arizona, before returning to issues of regional energy development planning.

3. THE CASE OF PAGE, ARIZONA

In 1956 the Colorado River flowed unimpeded from Utah into Arizona, out of Glen Canyon, and into Marble Canyon, in a nearly deserted ranching region which included a few Navajo hogans thinly scattered about on the Navajo Indian Reservation. Economic activity was virtually nonexistent in this area. However, in 1956 the Colorado River Storage Project Act was passed by Congress; it authorized construction of the Glen Canyon Dam, which was designated as part of a large water-storage and hydroelectric generating system that included several reclamation projects in the Colorado River system. Construction of the dam and companion steel-arch bridge began in 1957. To provide housing for construction workers, the Bureau of Reclamation created the community of Page, Arizona, a few miles from the dam site. In one short year the population at the townsite went from zero to about 3000; 3 years later it had doubled to 6000, half of whom were construction workers. Following the completion of the 710-foot dam in 1964, the population dropped to 2500, and then to just half of this after the dam's 950-MW hydroelectric generating station was completed in 1966 (Figure 3.1).

Through 1970, the population of Page remained under 1500 even though the new Glen Canyon National Recreation Area was being discovered by hundreds of thousands of recreationists who were attracted to Lake Powell, which was still filling behind the dam. Page's second phase of development was thus the establishment of water-based recreation in the area, an industry which continues to grow gradually.

The dam's water-storage function also led to the third phase of development at Page: production of electricity via huge, coal-fired, steam-electric generating units. Construction activities associated with the Navajo Generating Station doubled the population in the first year, increasing it to a new peak of over 8000 in 1973. But with construction nearing completion in 1976, the population of Page fell rapidly and stabilized at about 3750 during late 1976, thus ending Page's third phase of development.

It is interesting to note at this point that Figure 3.1 also demonstrates the timing pattern of large-scale construction projects (discussed in Section 2) characterized by sharp, distinct, and dramatic peaks as opposed to a smoother, more gradual pattern of construction activities.

It is fruitful to examine the relationship between the number of construction workers and the associated population during the two booms. There were about 2.0 persons per worker during construction of Glen Canyon Dam, and about 2.7 during construction of the Navajo Generating Station. This supports the argument that the decision of families to accompany construction workers is

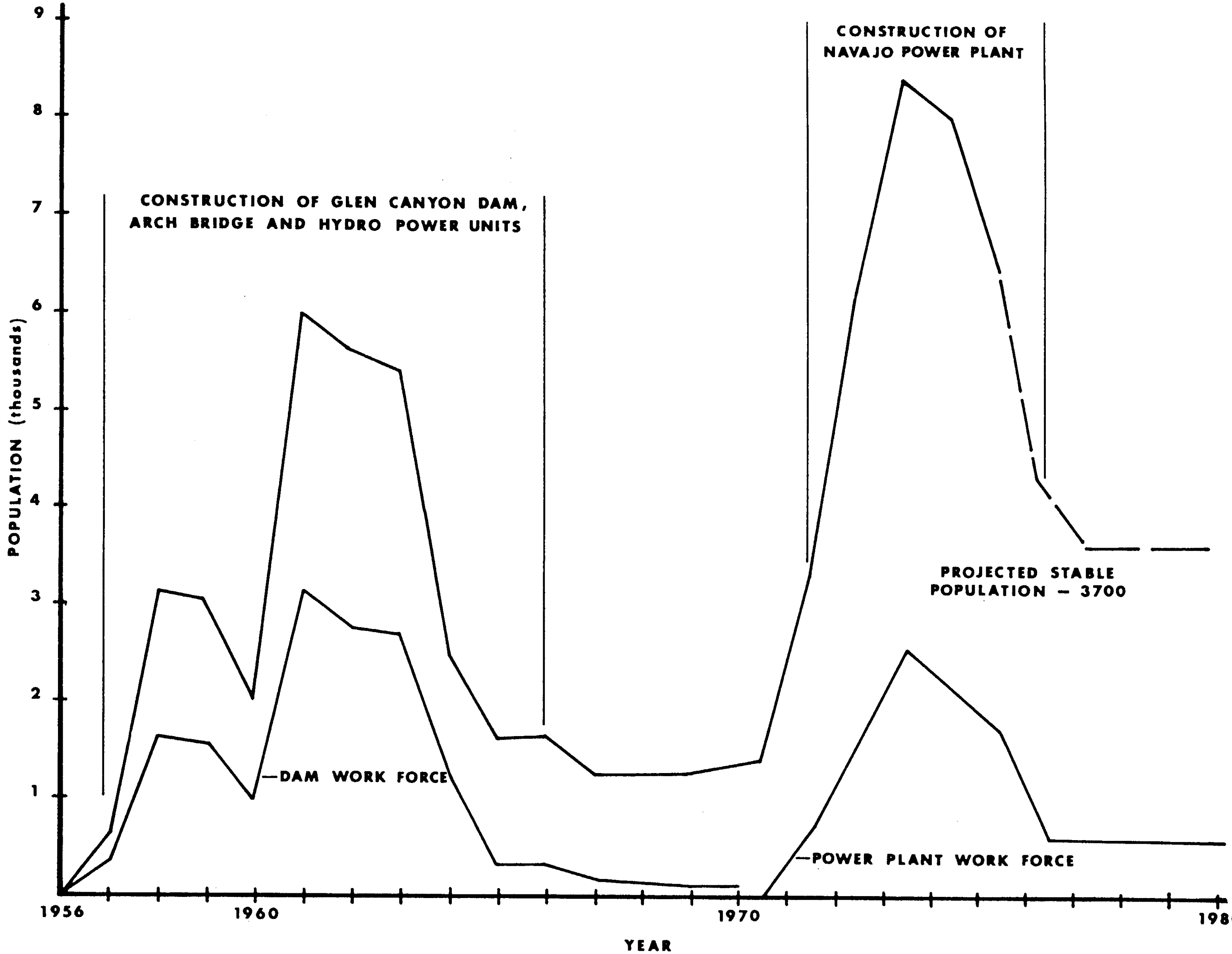

Figure 3.1: Page, Arizona, population profile from 1956 to 1980

related to the availability of private and public amenities. Note that no town existed prior to the beginning of construction activities on the dam, while Page, a small town, was present to help provide public and private services during construction of the Navajo Generating Station. Moreover, Lake Powell is an amenity which was not available during construction of the dam but which was available to powerplant workers. Together with higher wages, these factors made Page more attractive during the powerplant boom than it had been for the families of construction workers in the earlier boom period.

Figure 3.2 is a graph of housing by type of residence during the recent boom. The influx of mobile homes was so great that the typical ratio of mobile homes to permanent housing was inverted between 1970 and 1973, when permanent housing made up only 25 percent of the total. If the permanent housing trend continues, the ratio will revert back to near the original mix as construction workers leave Page. Note that mobile homes may be viewed as temporary (reversible) private capital, and permanent housing as permanent (irreversible) private capital. Following the conclusions of Section 2, it would have been more efficient to build at least 930 permanent housing units by mid-1971. That is to say, the optimal investment in irreversible capital in housing would be somewhat greater than 930 units. These units could have been rented to construction workers until their owners--future permanent employees--began to arrive. The market (rent) value of these homes would have been high during the construction period, allowing a more rapid amortization of the mortgages on these homes. The increase in permanent housing and the resultant decrease in the number of mobile homes required would have reduced the need

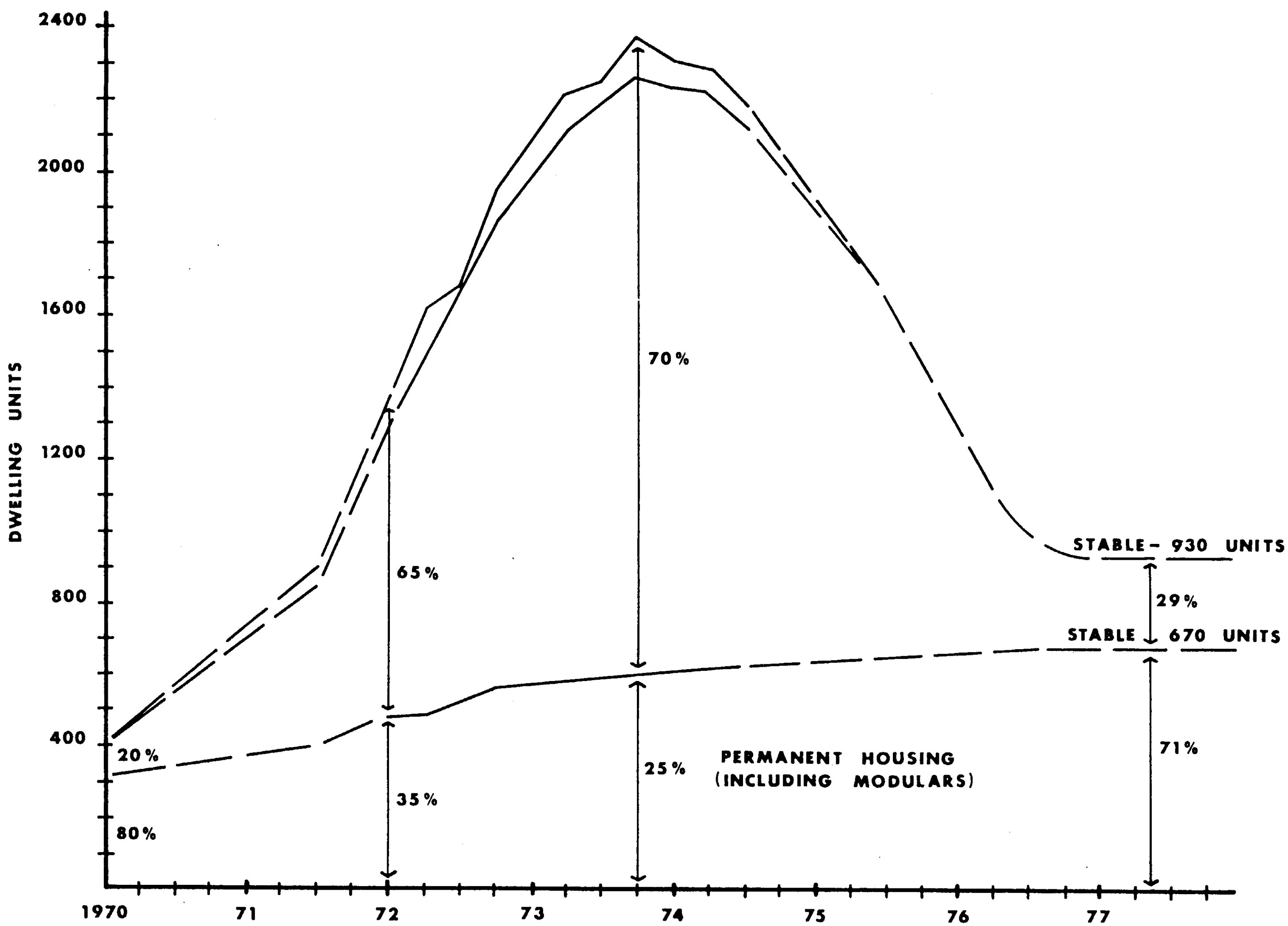

Figure 3.2: Dwelling units by type for Page, Arizona, from 1970 through 1980

for temporary utilities, lots, and other facilities for mobile homes, and also would have saved transportation costs while simultaneously improving the quality of life in the community.

The Page Area Economy

The most salient characteristic of small regional or community economies is their virtual total dependence for survival on exports from a few sectors. This applies especially to boomtown economies like Page which have grown up very rapidly in response to an undiversified set of industrial developments. Were Lake Powell to dry up, the industries of electric power, government, and recreation would vanish, and so would Page. It is essential that this dependence on a few export sectors be mirrored within the framework used to analyze such economies.

The choice and formulation of an economic model usually will depend upon the questions to be answered and the data which are available for making a model operational. Perhaps the most important question to be addressed in a model of a local economy is how personal income varies in response to changes in the levels of activity of the basic industries of the economy, i.e., the export industries. Personal income provides one measure of the effect of local economic activity, namely its monetary contribution to the welfare of individuals within the community. Each export industry injects money into the local economy by making transactions of three types: payments to local businesses, payments to local households, and payments to local government. But not all of these transaction dollars represent benefits to people in the community. For example, a $1 transaction between a visiting tourist, representing the recreation (export) industry, and a restaurant operator will result in substantially less than $1 of personal income for restaurant employees and other Page residents. This results from "leakages" in the business industry. Much of each business dollar is used to purchase goods and services from outside the local economy, with only a small fraction of each dollar reaching the paycheck of local residents. On the other hand, a $1 transaction between the Salt River Project and one of its employees at the Navajo Generating Station will result in more than $1 of personal income to Page residents, as the initial dollar of personal income is partially recycled within the local economy for consumer goods and services, and a fraction of that amount makes it into someone else's paycheck the second time around. The sum of the direct and indirect effects of each type of transaction between an export industry and the local sector of an economy is called its multiplier effect. A systematic method of accounting for these effects in one comprehensive set of multipliers is embodied in the technique of input-output analysis developed by Leontief [12].

The export industries in an input-output model of an economy export goods and services out of the local economy and import dollars in return. These dollars are imported through transactions with one or more parts of the internal sector of the local economy. The export (or exogenous) sector of the Page area economy has been defined to include the following industries: (a) the Bureau of Reclamation, which constructed and operates Glen Canyon Dam, the hydroelectric plant, and the city of Page; (b) the National Park Service, which manages and constructs facilities associated with the Glen Canyon National Recreation Area (GCNRA); (c) federal aid to the local school system; (d) state and county aid to the local school system; (e) the Salt River Project, which constructed and operates the Navajo Generating Station near Page; and (f) visiting recreationists drawn to the GCNRA. The internal (or endogenous) sector of the local economy is defined to include three subsectors: (a) all local business, (b) local households, and (c) local government, which consists only of the Page schools since other local government functions are managed and operated by the Bureau of Reclamation. The input data for the model thus must include three pieces of information for each export industry, representing the levels of transactions between that industry and each of the three subsectors of the internal economy.

The heart of the model, as indicated previously, is a set of multipliers. In general, each export industry can make transactions either directly with a given internal subsector or indirectly with the internal subsector through one of the other internal subsectors. Thus there are three multipliers for each internal subsector, for a total of nine multipliers (see Appendix A, "The Local Economic Model for the Page Area Economy").

The principal problem with input-output analysis of this type is that the multipliers are assumed to be constant. This assumption is rather severe, especially since an important use of the model, for our purposes, lies in applying the multipliers to years other than the base year for which the multipliers were estimated. In reality these multipliers are changing due to several factors, including differences in local supply conditions (costs), competition (and thus prices relative to alternative markets), and the diversity and interdependence of local businesses. As a community grows, it may come to support additional businesses which supply a larger variety of goods and services at the retail and, eventually, wholesale levels. This will increase the number of transactions among the internal subsectors of the local economy, with dollars imported by the export industries tending to circulate longer and to change hands more often within the local system. However, these changes may tend to be small in our case because of the lack of incentives for secondary economic development in boomtowns.

The multipliers used in this model are based on data for 1972, the year before the peak of the most recent boom. Thus, one might expect that these multipliers are slightly low compared to the current situation, and perhaps somewhat high compared to earlier years, such as during the construction of Glen Canyon Dam. With a substantially larger population, as would be associated with development of the proposed Kaiparowits power project, these multipliers would be expected to be somewhat higher. However, we believe that the multipliers used are fairly accurate for the period after dam construction and prior to any new large-scale developments. The extreme isolation of the economy and characteristic high wage levels tend to discourage new types of private business other than retail goods and services. While the latter may tend to increase somewhat with increased population, manufacturing and wholesale business would not be expected to increase their share, a factor which is largely responsible for the larger multiplier effects in areas such as Southern California. In any case, re-estimation of the multipliers for other years was not possible due to data limitations, and, thus, external manipulation of the multipliers was prohibited. Although this limitation prevents us from analyzing a particularly interesting aspect of a dynamic economy, the greater share of variability in such an economy rests undoubtedly on the tremendous variation in the levels of activity in the export sector. As will be seen, this aspect of boomtown economic activity has been clearly elucidated in the application of the input-output model.

Application of the Model

The input-output model was applied over the entire span of years from the inception of Page to the present, and then into the future through 1980. Input data representing payments from each of the six industries in the export sector to each of the three subsectors of the internal economy were collected. Where gaps existed in the data set, estimates were made using the best techniques which could be devised in each case. Data on recreational expenditures had to be estimated throughout, using data on recreation visitation in combination with estimates of expenditures from the results of Lake Powell Research Project investigations (Appendix B, "The Integrated Economic Model"). It is believed that the resulting data set has a fairly high degree of reliability.

The set of multipliers was recomputed for application to pre-1968 years in order to account for the absence of the *ad valorem* property tax which was established in 1968 when Page schools were included within the Coconino County School District. Thus, two sets of multipliers were applied, the first for all years from 1957 through 1967, and the second for 1968 through 1980. Since Page was only recently incorporated (in March 1975), no attempt has been made to generate new multipliers which would reflect the evolution of the new structure of the local government subsector which was still in its initial formative stage. This would include new sources of revenue from the state, utility fees, franchise taxes, and others.

The results are presented in graph form. The time profile of personal income is provided in Figure 3.3. (Points beyond 1980 can be ignored for the present.) All results were normalized to 1974 dollars, using the Consumer Price Index. The nearly isomorphic relationship between the major payrolls and total personal income, inclusive of direct and indirect effects, is obvious and dramatic. This isomorphism is characteristic of boomtowns in the extreme case, where the magnitude of the new payroll is very large relative to the original export base. In addition, the roller-coaster impression typifies abrupt booms that have a temporary construction phase which is large in terms of the required work force relative to the permanent operating work force. The latter is usually beginning to develop about the time construction is peaking.

Information on direct and indirect personal income for selected years, by export industry of incidence, is provided in Table 3.1. The years selected illustrate the changing character of the local economy. During 1961 the dam construction phase was peaking and accounted for virtually all personal income. By 1969, recreation had developed significantly, accounting for 52 percent of personal income including the National

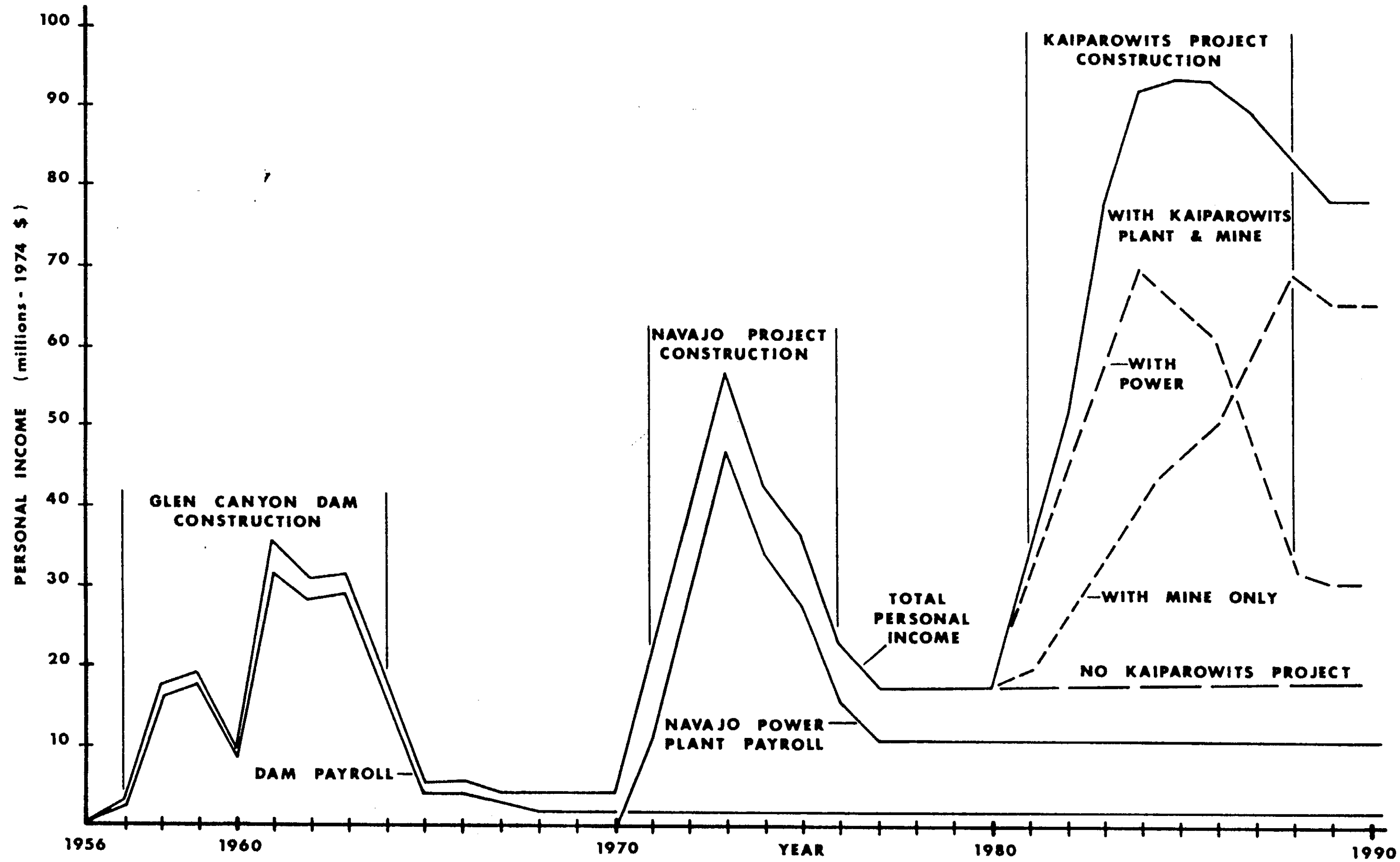

Figure 3.3: Page, Arizona, area economy with Kaiparowits project personal income and major payrolls, 1956 to 1990

Table 3.1: The direct and indirect personal income in the Page area economy by export industry for selected years (in percentages of total)

Export Sector	1961	1969	1973	1977	2000
Salt River Project	0	0	90	69	62
Bureau of Reclamation	98	37	3	9	8
Recreation					
Recreationists	0	31	3	10	16
National Park Service	0	21	2	6	9
Total for recreation	0	52	5	16	25
Other	2	11	2	6	5
Total	100	100	100	100	100
Personal income	$35,237,000	$4,120,000	$56,723,000	$17,852,000	$19,242,000

Park Service. Bureau of Reclamation activities, including operating the dam facilities and managing Page, still an unincorporated municipality at that time, were down to 37 percent. In 1973, both of these industries were dwarfed by the Salt River Project's construction of the Navajo Generating Station, which was then peaking and responsible for 90 percent of personal income. This new industry is projected to be in its stable operating phase by 1977, when it will account for two-thirds of the total personal income generated in the Page economy. Recreation and dam operation will account for about one-sixth and one-tenth of total personal income, respectively. In terms of personal income, the level of permanent economic activity in the Page area will have quadrupled since 1969.

Total business receipts are presented in the same fashion in Figure 3.4. The pattern here is markedly different, however, because of the large impact which imported recreation dollars have on business receipts relative to the personal income generated by these transactions. Thus, while recreation is relatively big business in the Page area, leakages in the industry cause most of these recreation dollars to be exported so that they never reach the household subsector. There appears to be great potential for increasing personal income due to recreation if more support services can become established, thereby retaining and recirculating a larger portion of recreation business receipts within the local economy. This depends to some extent on the administrative policies of the National Park Service which controls services in the immediate area of Lake Powell. Support services are likely to increase naturally, however, as recreational visitation continues to increase.

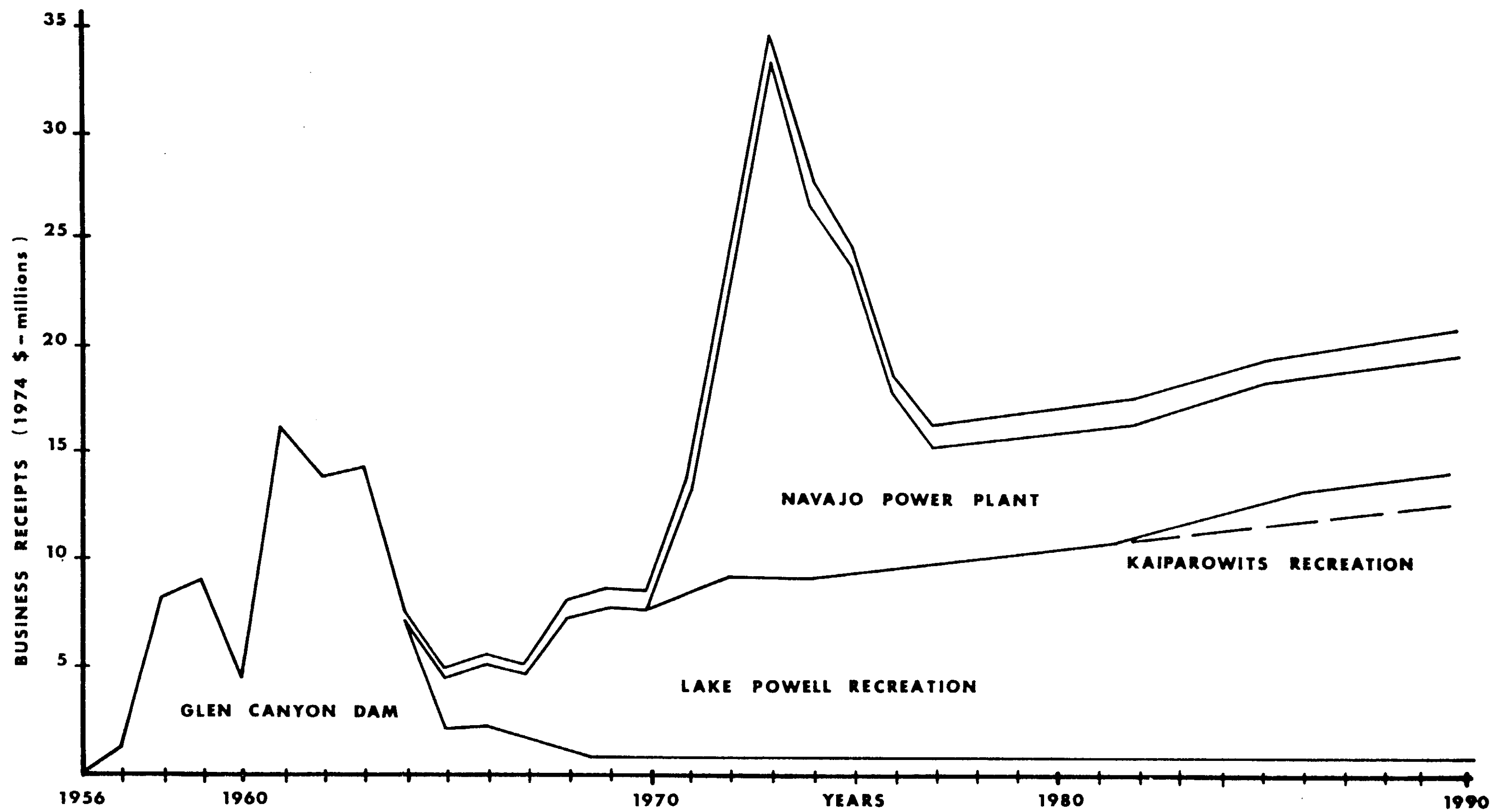

Figure 3.4: Page, Arizona, area economy business receipts by export incidence, 1956 to 1990

Business receipts due to recreation differ from those originating in the power industry in that the former are largely direct effects--the expenditures of recreationists at motels, restaurants, tourist shops, and lake concessions--while the latter include a substantial portion of the indirect expenditures of the local household subsector. It would have been desirable to disaggregate the local business subsector into two subsectors--recreation business and services to the local population--in order to capture the difference in the multipliers. However, data collection constraints made this impossible.

As discussed previously, until recently the only local government entity which operated as an independent, fiscally responsible unit was the Page school system. Page itself did not become an incorporated municipality until 1975, previously having been under the management of its founder, the Bureau of Reclamation. Originally, the Page school system consisted of an accommodation school, funded with a combination of county and state monies together with federal public law monies. Not until 1968, when it was established as part of an existing school district, was an *ad valorem* property tax, or levy, instituted and available as a source of funding. The levy was built into the model through the multipliers on payments from business and households to local government for the years after 1967. Beginning in 1970, the Salt River Project began making direct payments to the school district, since the Project was being treated as a quasi-public organization not subject to *ad valorem* taxation.

Figure 3.5 gives the funding history of Page schools by incidence in the export sector. It should be noted that the total direct and indirect effects attributed to

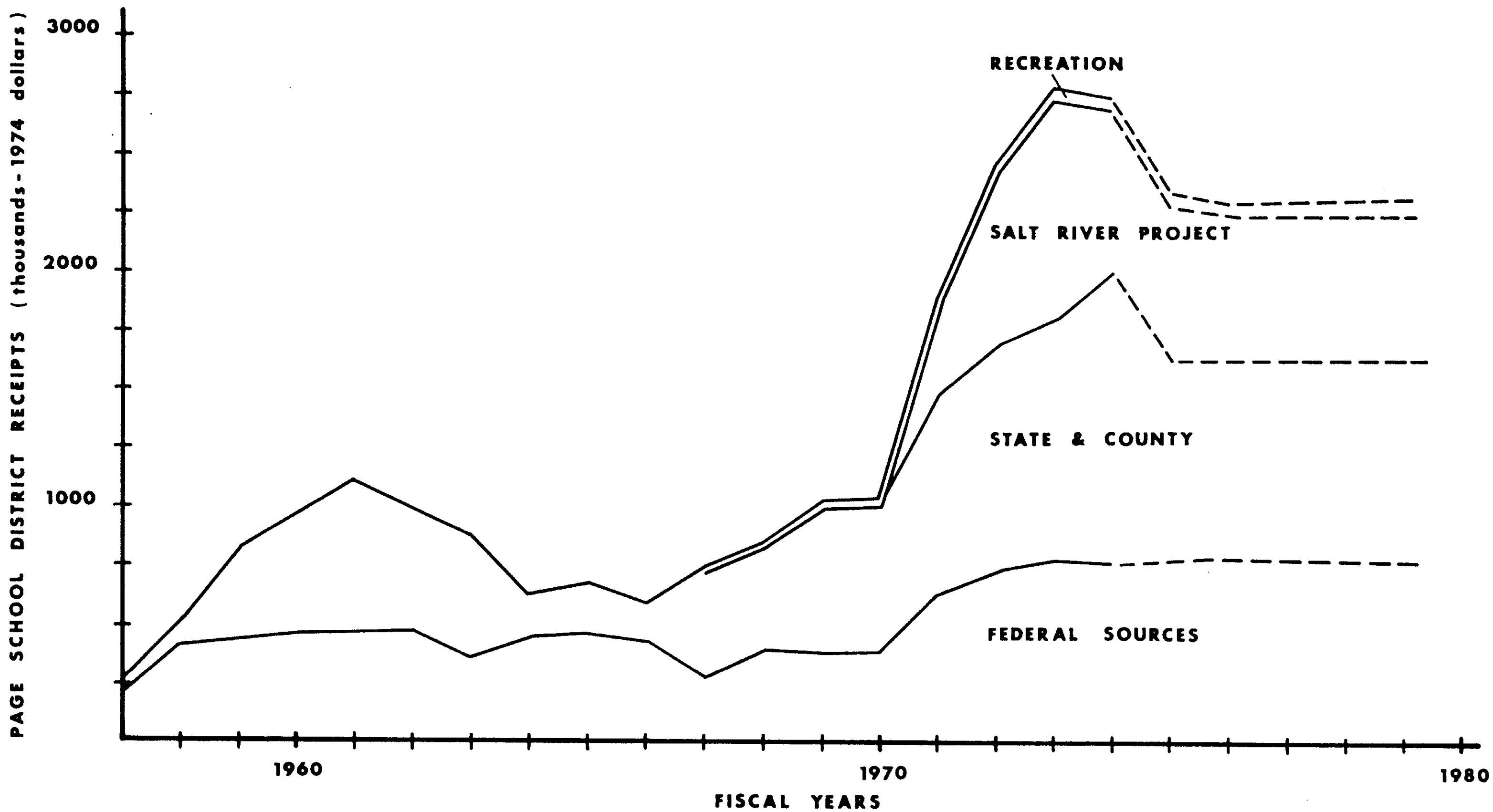

Figure 3.5: Page, Arizona, school funding by export incidence, 1957 to 1980

the Salt River Project are somewhat underestimated, since portions of the government funding come indirectly from the Salt River Project by way of state and Federal taxes. The structure of the model prohibited separating this because the school district was the only endogenous government subsector. The same argument applies to the recreation industry which contributes far more to the local schools than the amount indicated, which includes only direct and indirect payments, due to the existence of the ad valorem tax after 1967. This shortcoming in the model is a serious one with respect to analyzing direct and indirect financial flows in the school system. If Page had been an incorporated municipality, local government as a whole could have been included as an endogenous subsector, and these and other indirect effects would have been reflected in the multipliers and in Figure 3.5.

Projected Impact for Kaiparowits

The analytical results from the Page model provide a source of information which, with the qualifications discussed above, may be useful in estimating local impacts of future energy development projects. One such project, which had been the subject of intense debate until it was postponed indefinitely in April 1976, is the Kaiparowits project, proposed for south-central Utah, just north of Page, Arizona. As proposed, the Kaiparowits project would have included a 3000-megawatt coal-fired powerplant adjacent to an underground coal mine. The generated electricity would have been exported to Southern California and Arizona by the developers, a consortium of private electric utilities. Here we consider the local impacts of Kaiparowits project alternatives; the next subsection will examine these alternatives in a regional planning context.

The local impacts of the proposed Kaiparowits project will be projected by way of a straightforward application of the Page model. Since the Kaiparowits project would have been similar to the Navajo Power Project and in close proximity to it, Kaiparowits is the best possible candidate for application of the Page model. Figure 3.6 presents three sets of population projections for the Page area economy, one for each of the three Kaiparowits alternatives: (1) construction of both the powerplant and the underground mine, (2) construction of the powerplant only, and (3) construction of the coal mine only. Referring again to Figure 3.3, personal income in the Page area economy including a Kaiparowits boomtown is seen to follow a pattern similar to the corresponding population projection for each development alternative.

The Kaiparowits project powerplant by itself would have created a 69-percent increase in personal income (direct and indirect). Underground coal mining by itself would have resulted in a 259-percent increase in personal income. If both the powerplant and coal mining had been included in the Kaiparowits project, personal income would have increased by 331 percent. Thus it is evident that the major portion of the local economic impact from the project would be associated with coal mining.

Local business receipts would follow a similar pattern for each alternative. In Figure 3.4, however, business receipts for Page have been isolated under the assumption that a new community would impact Page business

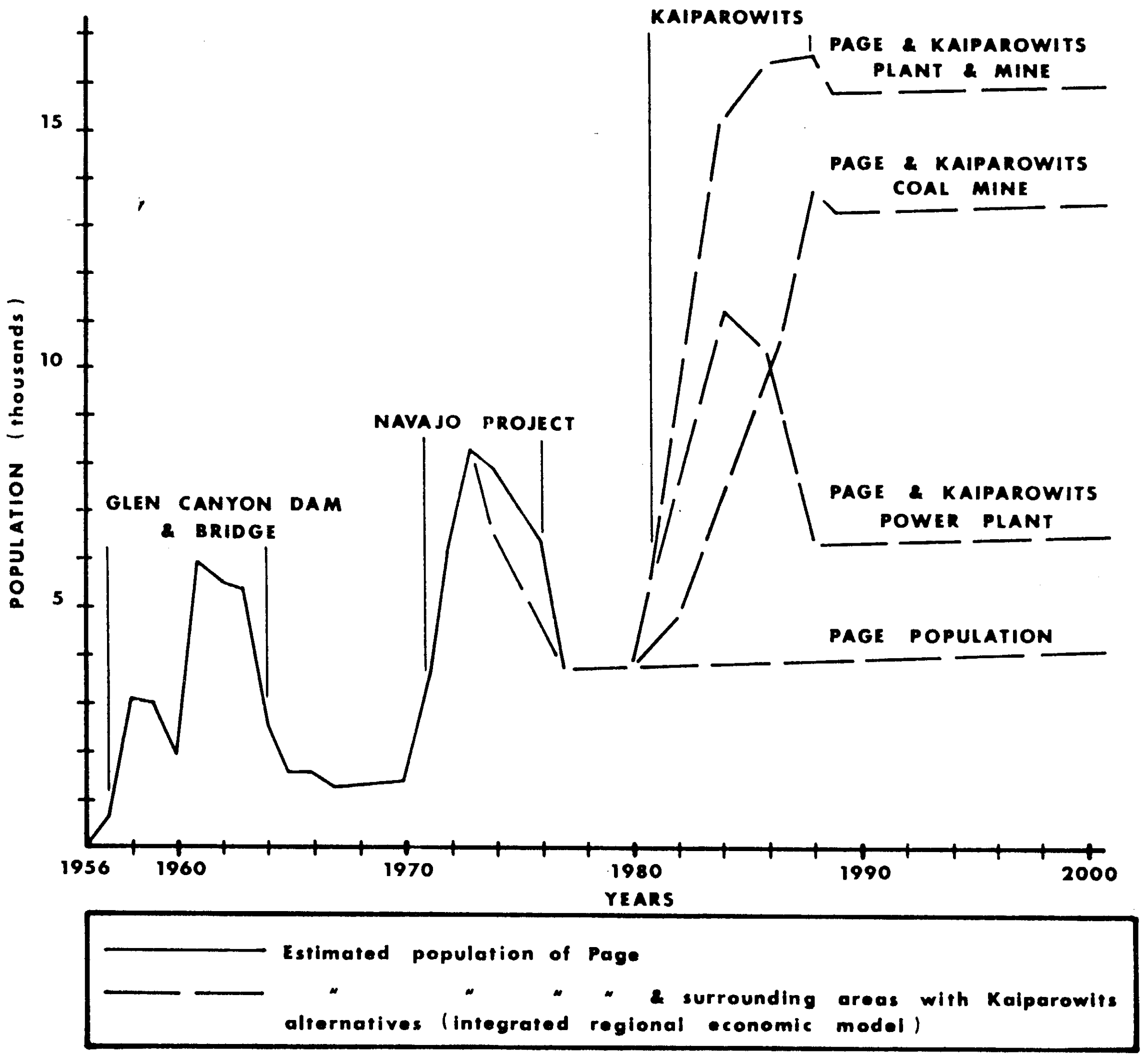

Figure 3.6: Population projections for Page, Arizona, and surrounding area, with Kaiparowits alternatives, 1956 to 2000

receipts through increased recreational expenditures associated with visitation to Lake Powell by the new population at Kaiparowits.

4. KAIPAROWITS IN A REGIONAL PLANNING CONTEXT

Several major issues are involved in the decision-making process which either approves or rejects projects such as the Kaiparowits project. A project's rejection or approval--including the form in which it may be approved--must be decided on the basis of the impacts corresponding to each of the possible development alternatives. Several issues that should be considered are (1) local socioeconomic impacts, including the desirability of a new town, (2) energy production objectives and constraints, (3) environmental protection, including aesthetic values and recreational resources, and (4) water consumption requirements. For example, because of the relatively high cost of producing coal from underground mines, there is some uncertainty regarding the economic desirability of utilizing a local underground coal supply for electricity generation rather than importing coal which has been strip-mined elsewhere at a lower cost. On the other hand, if policy-makers or the courts decide against degradation of the air quality in the region, it is possible that the coal could be mined and exported to electric generating plants in another region. In this section we will first examine the need for a new town in connection with the Kaiparowits project development alternatives. We will then consider the advantages of producing coal for export, vis-a-vis mine-mouth generation of electricity, addressing in a regional planning context the issues enumerated above.

A New Town?

A unique feature of the Page experience is worth re-emphasizing at this point with respect to the question of whether a new town would be desirable in the development of the Kaiparowits Plateau. Page was an unincorporated municipality until March 1975, having previously been under the management of its founder, the Bureau of Reclamation. Unfortunately, this situation has precluded an analysis of financial flows within the municipal government, a subject of great interest in the study of boomtown problems. The people of Page, however, have been extremely fortunate in this regard, since they have thus been spared the agonies of providing and managing public services in a rapidly changing boomtown. It is during such periods that revenue availability typically lags behind the immediate need for government services. Further, the uncertainties regarding growth rates during these periods add anxiety to the situation since it becomes difficult to anticipate the level of services which will be needed.

Page is now past the peak in its recent power development boom, and has thus been spared the problems of meeting the service requirements associated with the peak of construction activities. Instead, Page is in the fortunate situation of having had all the public capital facilities associated with basic services turned over to it by the Bureau of Reclamation, free of charge, without the burden of municipal indebtedness. The next stage of development for Page involves asserting its fiscal responsibilities as a newly incorporated municipality, planning for a period of stabilization, and anticipating any future developments. The people of Page are, of course, well aware of the potential for development on the other side of Lake Powell, on the Kaiparowits Plateau, and, for the most part, they view this development favorably, with or without the creation of a new town. The question we would like to address is: Is a new town economically desirable?

The answer to this question may not be necessarily the same as that provided by political institutions concerning its political desirability. Utah, for example, has been promoting energy development on the Kaiparowits Plateau for several years, with the hope of establishing a more prosperous economy in its south-central region which is sparsely populated by ranchers at present. Utahans in general would stand to benefit from increased tax revenues and employment in the area.

Presently, within commuting range of the Kaiparowits coal deposits, there are no Utah towns large enough to absorb new developments on this scale without in effect creating a new town. The closest town which would be able to provide some potential for utilizing existing public and private services is Page, Arizona. Page is 15 to 20 miles (24 to 32 kilometers) from the proposed site of the new town, and is presently undergoing a population decline on the order of 5000 persons. When it became incorporated in 1975, Page had no municipal indebtedness, and, moreover, was servicing a population of over 8000. Looking at Figures 3.3 and 3.6, it is clear, nevertheless, that there would be a definite need for substantial increases in services if the Kaiparowits impact were concentrated on Page rather than on a new town. Even without the coal mine, the construction peak would push the population of Page up to slightly above 11,000, some 2500 more than its recent peak. Page would be able to accommodate the permanent increase in population associated with the Kaiparowits powerplant (no mine) with only a minimum of disruption. A shuttle service for shifts of commuting workers would very likely be economical and convenient. Front-end money might not be difficult to come by, as substantial excess bonding capacity exists. Some private services are already established at Page, and the prospect of substantial permanent growth probably would bring a somewhat greater variety of public and private services to the area's population than would two smaller communities.

On the other hand, the argument for a new town becomes very strong when coal mining is included in the Kaiparowits project, either with or without the powerplant. Approximately 9500 persons would be associated with the underground coal mine proposed by the interested companies. With the 3000-megawatt powerplant included, the total population impact would be about 12,000. On the face of it, it would be inadvisable for a potential community of this size to be situated within a community initially only one-third as large, causing thousands of persons to commute daily.

From this brief overview of the numerous factors which influence the desirability of creating new towns for large development projects in rather isolated rural areas, it is evident that each factor must be evaluated in the context of the particular proposal for development. In the case of Kaiparowits, it is questionable whether new benefits would accrue to the population of a new town associated only with the creation of a new powerplant; however, with underground coal mining a new town appears to be necessary and inevitable.

Coal Mining versus Power Production

One development alternative which has not received much emphasis by industry, government, or the press is the possibility of mining Kaiparowits coal for export to other regions where power production activities may be more suitable. We will now examine the local economic impacts of this alternative, and then will consider several other relevant issues.

Figures 4.1 and 4.2 present the projected population impacts of the three Kaiparowits alternatives, dividing the total population into construction and permanent components. Three important observations can be made readily upon examination of these figures. First, the construction impact is tremendous when the powerplant is included in the project. This temporary population impact peaks at near 8000, accounting for nearly 80 percent of the total construction impact of the combined powerplant and mine. Second, the construction impact when only the mine is included in the project is quite moderate, peaking at about 2000 people. Third, the mine by itself accounts for nearly 80 percent of the permanent population impact. The economic impacts follow the same pattern. Thus, most permanent local benefits may be obtained with the development of the mine only, without the problem of severe transient effects associated with the powerplant.

These examples serve to illustrate two distinct varieties of boomtown situations (Figure 4.2). One variety is characterized by a dominant construction peak followed by sharply decreasing employment. The other is characterized by continually increasing employment, to a stable situation which is approximately equal in magnitude to the construction peak in the first case. These two types

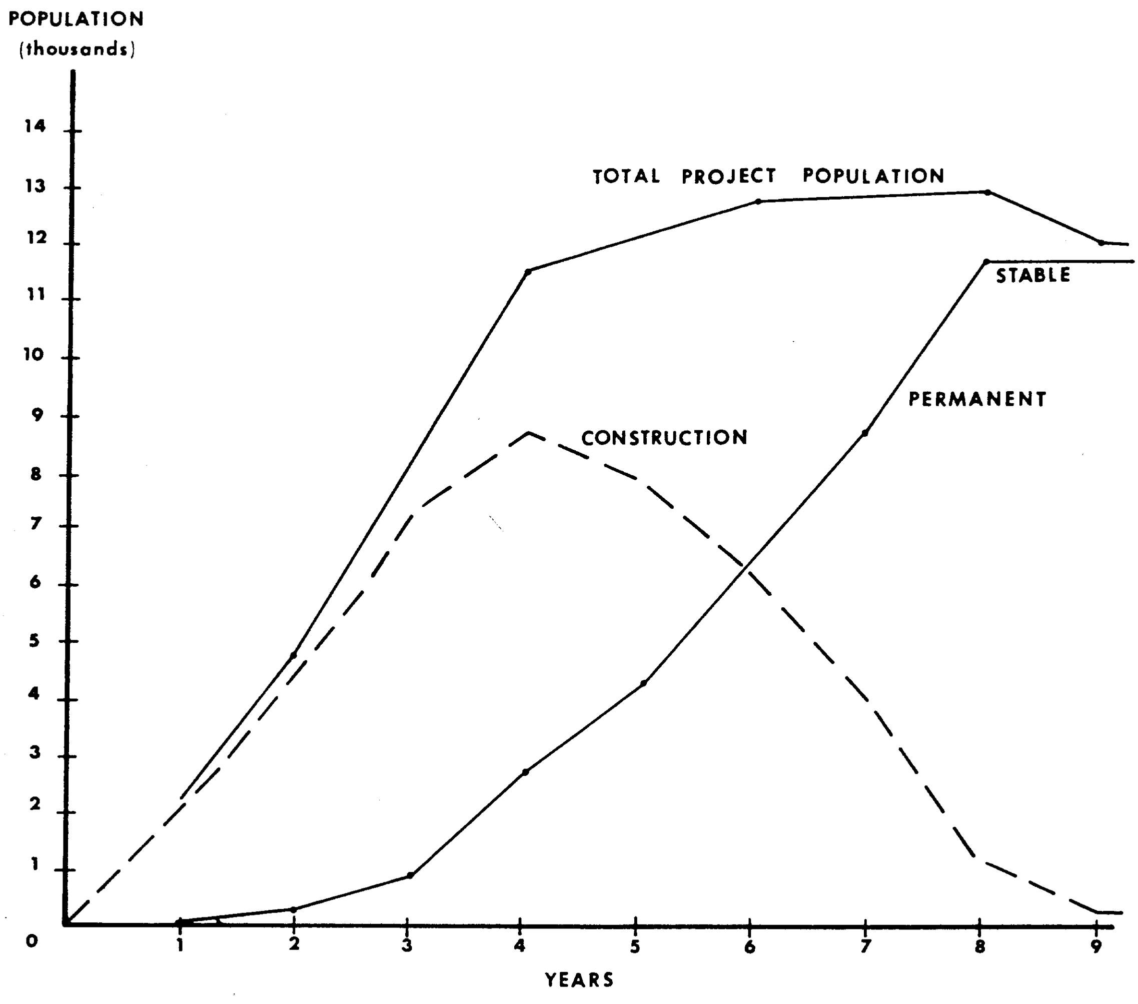

Figure 4.1: Permanent and construction populations associated with Kaiparowits project (powerplant and mine)

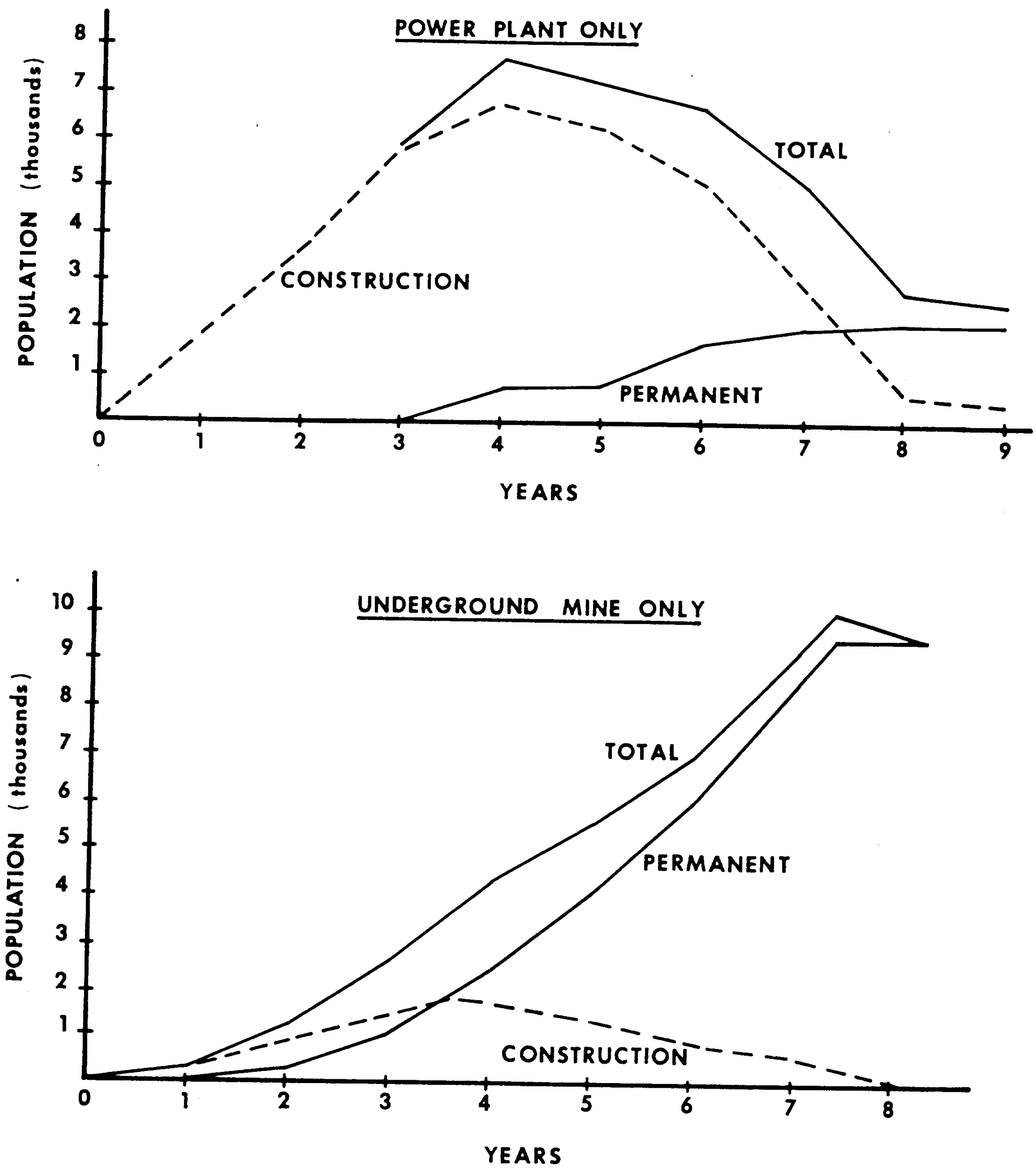

Figure 4.2: Permanent and construction populations associated with Kaiparowits project

of boom situations may be termed as the "temporary peak" and "stable peak" varieties, respectively. (We note in passing that strip coal mining is much less labor intensive; booms resulting from construction of generating stations in combination with strip mines would thus be dominated by powerplant construction, which creates booms of the temporary peak variety.)

If one assumes that both temporary and permanent populations may be serviced by identical capital facilities, the combined project (as in Figure 4.1) may be characterized as a stable peak situation. To the extent that differential capital investment is needed to service each population, the combined project becomes a dual situation with the powerplant and mine populations following the temporary peak and stable peak varieties, respectively.

Both varieties pose problems with respect to the front-end money requirements of boomtowns. The stable peak variety, however, is preferable to the temporary peak variety, in that the level of public and private services needed during the peak does not greatly exceed what will be needed in the stable phase following the completion of construction activities. Thus, adequate services are expected to be more easily provided for the stable peak since they will be needed permanently. Public and private service demands would increase rapidly but steadily, while the problem of temporary peaks and the need for reversible capital investment would be substantially eliminated. If sufficient front-end money can be obtained to achieve the optimum level of investment in irreversible capital, then the problem of servicing both stable and temporary peaks may be minimized.

Other Important Considerations

The "coal mine only" alternative offers the additional advantage of greatly reducing the negative environmental impact associated with a Kaiparowits-type project which includes a large coal-fired powerplant. Namely, the effect on air quality and visibility could be virtually eliminated by building the powerplant elsewhere, rather than in a region which is so highly prized for its scenic beauty by residents and millions of recreationists who visit the numerous national and state parks, forests, monuments, and other recreation areas. The value of the aesthetic damage which would accrue to recreationists at the Glen Canyon National Recreation Area alone, over the 35-year life of the plant, has been estimated to be approximately $21 million [3]. When all visitation to national recreation sites within 100 miles (160 kilometers) of the proposed powerplant site is included, the figure becomes $122 million [15].

With respect to national and regional energy production goals, the "mine only" alternative would cause no sacrifice, since it is the exploitation of the coal resource which is the limiting factor. In addition, with respect to production cost constraints, it has been shown that, mile for mile, coal transportation costs are becoming more competitive with transmission costs for electricity. Thus, electricity production costs are not very sensitive to powerplant site selection, except within very broad geographical constraints. Southern California, Arizona, and southern Nevada would almost certainly have economically feasible powerplant sites which would be more suitable given that Southern California is to be the principal recipient of the electricity generated.[4]

Coal can be transported by either rail or slurry pipeline, with the latter consuming less local water than would the powerplant being fueled by the coal. If the creation of a water supply to a potential powerplant site is not economically feasible, slurry transportation would be a means of supplying both coal and water simultaneously.[5]

We would urge other researchers and policy makers to consider both the political and the economic acceptability of such alternatives within the context of a broad planning perspective. While the present study has focused on the boomtown aspects of energy development, we have attempted to place these findings within the framework of an integrated economic approach to this region.

ACKNOWLEDGMENTS

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FOOTNOTES

1. This framework has been developed by the Economics Subproject of the Lake Powell Research Project as part of the overall Southwest regional research effort supported by NSF-RANN and Resources for the Future and by a parallel effort regarding investments in boomtowns in the Cummings and Mehr work [5] sponsored by the Los Alamos Scientific Laboratory.

2. This subsection owes much to Allen V. Kneese. See for example reference [11], which stresses problems of women in boomtown communities.

3. This subsection draws heavily on a rather difficult analysis that uses optimal control theory presented in Cummings and Schulze [6], which is an outgrowth of the innovative approach taken by Cummings and Mehr [5]. See also Mehr [13]. Research by Cummings and Mehr has been supported by the Los Alamos Scientific Laboratory.

4. Suitable sites along the California border with Arizona and Nevada are effectively prohibited at present due to California air quality standards.

5. For an excellent discussion of the energy transportation issue, see "Utah Coal for Southern California Power" by Orson L. Anderson, Lake Powell Research Project Bulletin Number 13, November 1975, pp. 57-60.

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GLOSSARY

boomtown	a town generally characterized by boomtown impacts and instability
boomtown impact	impacts of (usually) economic developments which stress a socioeconomic system by forcing growth at a rapid rate such that the capacity of private and/or public institutions is exceeded, often in association with social instability (e.g., excessive divorce rate, alcoholism) and a variously degraded lifestyle
coefficient (of a model)	a parameter which is in a multiplicative relationship with a variable in an equation of a model
congestion variable	a variable used as a measure of the potential for interference between entities of interest, e.g., $b \equiv$ boats per acre
d.f. (degrees of freedom)	the number of independent observations, or pieces of information, that are available in the mathematical estimation of a statistic

(e.g., t or R^2) or parameter (e.g., the mean) of a population; the level of significance associated with hypotheses involving the estimated value as compared to a hypothetical value is constrained by the degrees of freedom

diffusion model	a system of equations in which a number or concentration of entities is mathematically distributed from a point of emission or origin to various locations of interest, utilizing certain theoretical precepts and empirically determined parameters
direct income	income in an economic system which derives directly from the exchange of goods or services produced by a local export industry for outside dollars
disamenities	the generally undesirable aspects of a natural or social environment (with which real losses in personal utility are associated, but which frequently are not quantified in economic analyses)

dynamic model	a system of mathematical equations that has one or more variables the values of which are determined using feedback mechanisms (see feedback mechanisms)
endogenous	internally determined by the system (or model) under consideration
exogenous	externally determined with respect to the system (or model) under consideration
feedback mechanism	a link in a dynamic model which consists of an equation that uses certain of the model's output values as input values in an earlier stage of the model
front-end investment	with respect to boomtowns, the investment of money, from private or public sources, into a fund which is available for financing social capital at the beginning of an economic boom (front-end capital)
indirect income	income in an economic system which derives only indirectly from export industry sales, having subsequently been exchanged (multiplied) one or more times between sectors of

	the local economy in transactions for goods or services
initialize	to set the initial values of certain endogenous variables on the first iteration of a dynamic model prior to their first determination through the internal feedbacks of the model
input-output model	a model which uses a matrix of coefficients to relate transactions of buying industries (inputs) to transactions of selling industries (outputs), thus accounting for the origin, flow, and the destination of money among the parts of the economic system
integrated model	a model which consists of component models or submodels that are integrated or coupled by using output values from some component models as input values in other component models
isomorphism	close similarity in the observed form

least-squares regression techniques	a statistical procedure that "explains" variation in the values of the dependent variable by attributing it to variation in the values of dependent variables by a systematic means of selecting their coefficients such that the sum of the squares of the unexplained variation between the calculated values and the data is minimized
level of significance	a statistical term referring to the probability (e.g., 95 percent or 0.95) that an (empirically tested) hypothesis is not the work of chance, i.e., a result of the particular random sample selected for analysis
mean	the simple arithmetic average of a sample of observed values equal to their sum divided by their number
parameter	a quantity or constant whose value varies with the circumstances of its application
primary data	data which are collected directly from observation or querying of the actual event,

	object, person, etc., being investigated
R^2 (coefficient of determination)	the fraction or percentage of the variation in a (dependent) variable which may be attributed to variation in one or more (independent) variables; it is said to measure "goodness of fit," and it ranges from 0.0 to 1.0
recursive	the endogenous variables are determined one at a time in sequence, such that the first endogenous variable is determined from the first equation, independent of the other endogenous variables; its solution then appears in the second equation to determine the value of the second endogenous variable, and so on
returns to scale (of construction process)	the relation between quantity of output of a construction process and the various factors of production used in obtaining that output; the relation indicates variation in the degree of productivity as the process is accelerated

scenario	a possible outcome (of development) which is specified on the basis of facts and uncertainties and which is used in an analysis to assess the range of (future) possibilities
secondary data	data which have been compiled previously in some form and which are reassembled without reference to the actual event, object, etc., being investigated
standard error	the error of estimation for a paramater which defines an interval (about the estimated value of the parameter) within which the true value of the parameter may be said to lie with a 68-percent level of confidence; an interval of two standard errors on either side of the estimated parameter bounds the true value with a 95-percent level of confidence
t-statistic	the number of standard errors by which an estimated parameter differs from zero or some other specified value

APPENDIX A: THE LOCAL ECONOMIC MODEL FOR THE PAGE AREA ECONOMY

The principal component of the integrated economic model for analyzing local boomtown impacts is the local economic model. The analytical framework chosen for this component is open input-output analysis adapted for a community economy, in this case Page, Arizona, and the Wahweap recreation area. The local households and local government (schools only) are included in the endogenous part of this local economic system.

In terms of the usual input-output notation, the income (or output), Y, of the sectors of a community economy are expressed as

$$Y = (I-A)^{-1}X$$

where X is a vector of export industry transactions which bring income to the local sectors by selling goods and services to outsiders. A in the above expression is a matrix of coefficients reflecting the direct distribution of a dollar of income of each local sector among the local sectors. Dollars brought in from outside the community system, X, generate direct and indirect income (or output), Y, within the community as they circulate before leaking out to pay for imports. The factor $(I-A)^{-1}$ accounts for total income (or output) that is generated by each dollar unit of export activity.

The Lake Powell area economy is, and will be for the foreseeable future, largely dependent upon three sources of external income. These external dollars arrive largely in the form of wage payments from (1) the power industry, (2) governments (federal, state, and county), and (3) sales to tourists. Other local industry is primarily supportive, consisting mostly of retail and service businesses. There are at present (1976) no manufacturing, agricultural, or extraction activities in the region which affect Page.

The local economy under study can be separated into three sectors: (1) business, (2) household, and (3) local government. Although a detailed industry classification is not necessary (due to the structure of the economy and also for the purpose of the study), a separate sector for the recreation-related business activities would have been desirable for the study. However, the data problems encountered, including the problem of disclosure, forced aggregation of the recreation sector into a single business sector. The power industry is not included in the endogenous part because there will be no sales to the local units; therefore the power industry can be treated exogenously.

The coefficients, A , were estimated from the information collected from sample firms, a household survey, and secondary data. The community income-output multipliers, $(I-A)^{-1}$, are presented in Table A.1. Each column entry in the $(I-A)^{-1}$ matrix indicates total income generated in the row sector by each dollar of transactions between that (endogenous) column sector and an (exogenous) export industry. For example, $1 received from an export sector by the local business sector will create $1.17 income in the same sector, $0.22 income for the households, and a half cent in local government revenue (for 1972).

Table A.2 shows income from the outside sources for the three sectors in the study year (1972). Data were collected directly form individual outside agents except

Table A.1: The Page area direct and indirect effects multipliers, 1972

	Business	Household	Local Government
Business	1.1696	0.4904	0.3098
Household	0.2237	1.0964	0.6002
Local Government	0.0054	0.0071	1.0040

for tourist expenditures, which were estimated in the recreation study [2].

As Table A.2 shows, virtually all of the outside dollars ($34.1 million) came from three sources: $25.7 million from the power industry, $5.2 million from recreationists, and most of the remaining $3.2 million through federal government offices operating in the region. Local households earned nearly 80 percent ($26.6 million) of the total external income of the region. Tourist expenditures ($6.2 million) accounted for nearly 90 percent of the total business sales to units outside the region.

From Tables A.1 and A.2, total output and income of the region have been estimated. The totals for each sector (rows) and their breakdowns by the external sources are presented below for the study year: the sales or outputs of the business sector were $20.7 million; households earned $31.4 million; and local government revenue was $1.4 million. The data in Table A.3 indicate that the power industry counts for a considerable portion of these totals--more than 60 percent of total business sales and approximately 85 percent of local household income.

Table A.2: Direct effects of exports, 1972
(in thousands of dollars)

	Power	Recreation	Federal Government	State/ County	Others	Total
Business	846.9	5,205.5	153.1	0.0	0.0	6,205.5
Household	24,797.5	0.0	1,888.6	0.0	0.0	26,686.1
Local Government	16.8	0.0	413.5	767.1	21.40	1,218.8
Total	25,661.2	5,205.5	2,455.2	767.1	21.40	34,110.4

Table A.3: Direct and indirect effects of exports
(in thousands of dollars)

	Power	Recreation	Federal Government	State/ County	Others	Total
Business	13,156.3	6,088.6	1,233.3	237.7	6.6	20,722.6
Household	27,388.3	1,164.8	2,353.2	460.4	12.8	31,379.5
Local Government	197.9	28.1	492.4	770.2	21.5	1,447.1

Tourist expenditures contributed 30 percent and 4 percent respectively of business sales and household income. Six percent of the business sales and 7 percent of the household income are attributed to federal government expenditures.

Construction and operation of the Navajo Generating Station has created a boomtown economy in and near Page. In the study year, when the construction phase of the Project peaked, approximately 60 percent of the population of Page (where most of the local household and business firms are located) was directly associated with the Project.

APPENDIX B: THE INTEGRATED ECONOMIC MODEL

Overview of Model Components

The Integrated Economic Model (IEM) ties together five component models developed by the Economics Subproject of the Lake Powell Research Project. Figure B.1 presents a conceptual diagram of the model, illustrating the flows and linkages which are assumed to exist among energy development, the local economy, recreation, and the environment. It is used specifically in this Bulletin to predict recreational visitation and values as they are affected by energy development alternatives.

The model was initiated for 1970 and applied recursively to forecast over a 30-year period. The IEM begins with the 1970 transactions of the export industries which create monetary flows into the Lake Powell region. In Figure B.1, "recreational expenditures" represents the amount which non-local visitors spent while visiting the GCNRA; it is an endogenous function of recreational visitation. "Government expenditures" includes a set of exogenous inputs; for example, county and state contributions to local schools, and local federal government expenditures such as those involved in the operation of Glen Canyon Dam. "Energy development expenditures" includes construction and operation of powerplants and coal mining, all of which are exogenously specified.

The local economic model is a simple, open, input-output (I/O) model constructed for Page and is used also for the hypothetical Kaiparowits City. Export industry transactions with local households, businesses, and government are traced and multiplied to provide estimates of total direct and indirect personal income, business receipts, and government

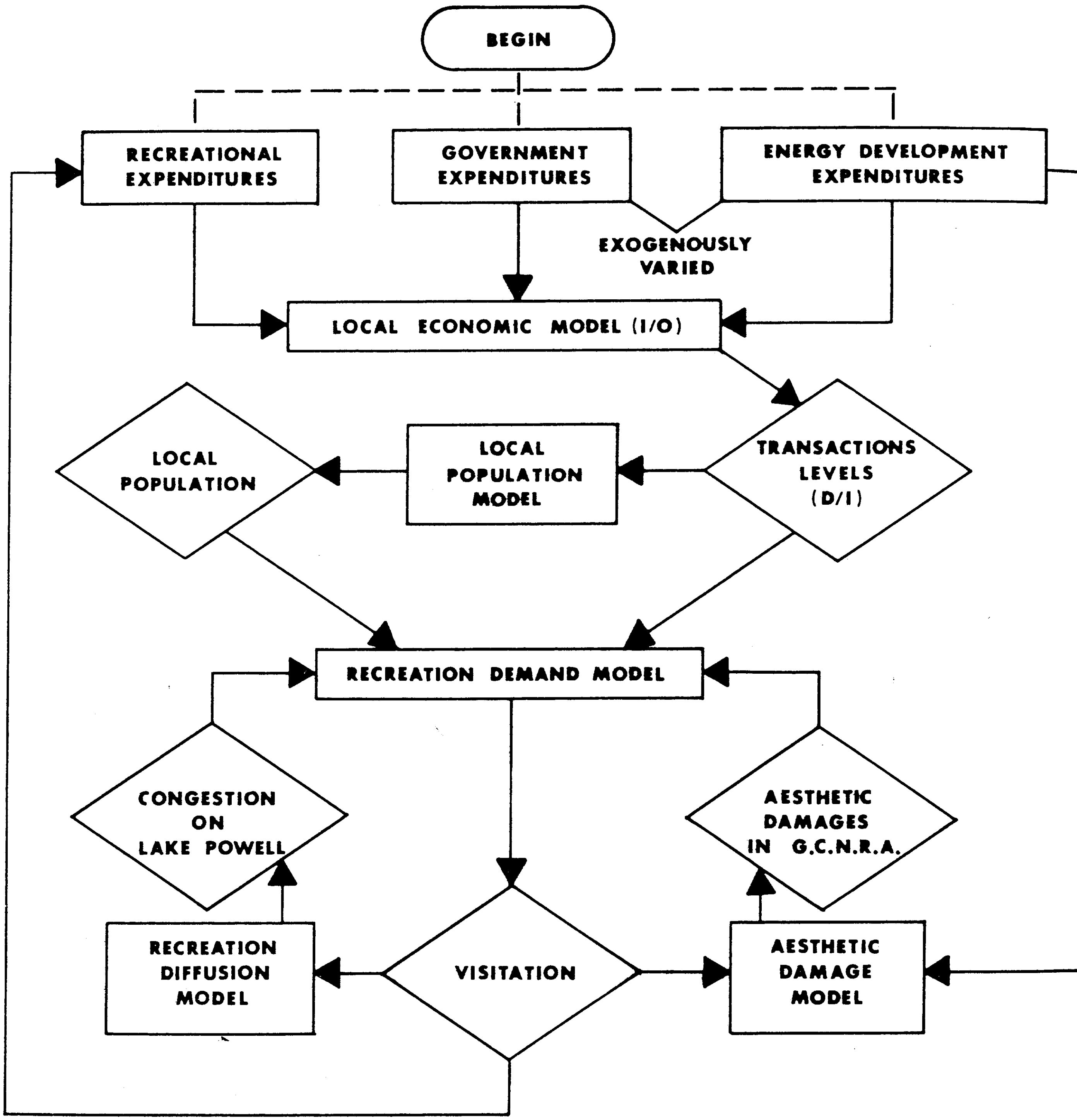

Figure B.1: Flow diagram of the integrated economic model (G.C.N.R.A. = Glen Canyon National Recreation Area) revenue. Using this model, it is seen that the Page and Kaiparowits economies are driven by energy development activities, namely the Navajo Generating Station and the proposed Kaiparowits project. Additional detail on the Page I/O model may be found in Appendix A.

The local population model utilizes the relationship between projected total personal income for past years and observed population to predict future population on the basis of income projection (direct and indirect transactions). This is not to be confused with the demographic relationships presented in Appendix C which follows.

Predicted population and personal income are inputs to the recreation demand model which is discussed in detail in [4], especially Appendix A of that report. Using the two-lake concept of Lake Powell, the recreation demand model estimates visitation when the parameters of each lake are specified. Visitation levels are inputs into the recreation diffusion model, which is also discussed in [4] (see especially Appendix B). One output of the diffusion model--congestion--is also an independent variable in the recreation demand model, to which it is fed back for the next year's demand calculation.

Visitation is also an input to the aesthetic damage model. This model calculates the value of aesthetic environmental damages to recreationists when the number of powerplants is specified in a particular energy development scenario. This value is then fed back to the recreation demand model, in which it is treated as a recreation cost. The theory and application of bidding games for valuation of aesthetic preferences is discussed in [3] where model parameters originated.

Recreational expenditures are a function of visitation as calculated by the recreation demand model; the expenditure parameters originated in [2].

APPENDIX C: DEMOGRAPHIC RELATIONSHIPS

The objective of Appendix C is to explain fluctuations in demographic variables by relating them to changes in employment in the power industry. The analysis consists of a short-run time series application of the ordinary least-squares estimation procedure. Using permanent and construction employment at the Navajo Generating Station as independent variables, an equation was estimated for each demographic (independent) variable, including population, number of dwelling units, and average membership in Page schools. The same technique was applied in estimating the relationship between payroll for the Project employees and employment.

The results of this procedure are summarized below, with the variables defined as follows:

POP = Page population mid-year estimate

PE = permanent employment at Navajo Generating Station, mid-year

CE = construction employment at Navajo Generatting Station, mid-year

DU = dwelling units, mid-year

PAYR = payroll at Navajo Generating Station, construction and operation

ADM = average daily membership at Page schools, school year

PEAV = average permanent employment, school year

CEAV = average construction employment, school year

The estimated regression equations, with t-statistics below them in parentheses, are:

$$POP = 1471 + 3.72\ PE + 2.82\ CE$$

$$(4.68)\quad (3.15)\quad (12.51)$$

$$R^2 = 98.8\%\quad d.f. = 3$$

$$DU = 389 + 0.933\ PE + 0.779\ CE$$
$$(3.41)\quad (2.18)\quad (9.50)$$
$$R^2 = 89.8\%\ \ d.f. = 3$$

$$ADM = 878 + 2.28\ PEAV + 0.54\ CEAV$$
$$(3.49)\quad (3.92)\quad (3.44)$$
$$R^2 = 89.8\%\ \ d.f. = 3$$

$$PAYR = 15{,}540\ PE + 17{,}974\ CE$$
$$(4.37)\quad (24.53)$$
$$R^2 = 97.5\%\ \ d.f. = 3$$

Constant terms were included in the first three equations to account for the pre-existing level of these dependent variables due to the Glen Canyon Dam project, but since the Navajo Project payroll was zero prior to Project employment, no constant term was required in the payroll equation. With only one exception, all constant terms and regression coefficients are significant at the 95-percent confidence level. The exception is the coefficient relating permanent project employment to dwelling units, which was significant at the 85-percent confidence level. To improve upon these coefficients, it probably would be necessary to pool time series and cross-sectional data from several communities, since the time series approach is inherently limited to the few years typical of construction periods.

The population equation indicates that each permanent project employee is associated with a population of 3.72 persons, and construction employees with only 2.82 persons. These coefficients do not necessarily indicate average family size, but rather they include indirect population effects as well.

Compare also the coefficients in the equation for school membership. From this equation, it would appear that permanent Project employees are associated with 2.28 school children, whereas temporary construction employees are associated with only 0.54 school children. This result, however, is undoubtedly spurious, as may be seen from checking the equation for consistency. From the population equation, each construction employee is associated with an estimated 2.82 increase in population. Roughly speaking, one of these persons is the construction employee (although not all construction employees lived in Page, since some were Navajo commuters). That leaves 1.82 other persons associated with each construction employee, and 0.54 of these are school children. The remaining 1.28 persons include spouses, non-school-age dependents, unemployed persons, and indirect population effects. Contrast this plausible result with that for permanent employees. There, a 3.72 population is estimated to be associated with each permanent employee at the Project. Approximately one of these is the employee and, from the equations, 2.28 are school children. This leaves only 0.44 person per employee, including spouses, non-school-age dependents, and indirect population effects. If three-fourths of these are spouses, then there are 6.9 school-age children per spouse, an outlandish expectation. This may most easily be explained by way of the t-statistics under the coefficients. For example, the school membership coefficient for permanent employment is 2.28, but this parameter could be as low as 1.12 and still be within two standard errors of the estimated value. This result would bring the ratio of school-age children per spouse to well within the range of reason. Another factor to consider is the likelihood of autonomous increases in school membership, associated perhaps with the school's enlarged capacity and more students coming in from outside Page. Some colinearity between these increases and permanent Project employment may be present.

While the accuracy of the school membership results is thus discounted, it remains true that there are several reasons to expect construction workers to be associated with significantly fewer school-age children.

These include possibly substantial factors such as (1) younger and smaller families among construction workers; (2) the fraction of Navajos among construction workers as compared to permanent employees (Navajo families tend to be larger, but many Navajo construction workers may commute); (3) construction workers who leave their families at permanent homes elsewhere while they pursue temporary employment; and (4) the fraction of construction workers who are unmarried as compared to the fraction of permanent employees who are unmarried.

The payroll equation indicates that project employees are paid high wages, with construction employees receiving somewhat higher compensation (although the difference is not significant when tested, considering the variation of the coefficients in our equations). These results are consistent with our expectations.

The equation for dwelling units indicates that there is 0.933 unit for each permanent employee, as against 0.779 unit for each construction employee. (Again, the difference is not statistically significant.) These coefficients are less than one, indicating that (1) some employees do not live in Page, e.g., Navajos living nearby; and (2) there may be more than one employee per household in some cases. If this were not the case, one would expect that these coefficients, at least the coefficient on permanent employment, would be greater than 1.0, to account for some new households which are only indirectly associated with the Project, perhaps in support services.

The analysis presented here does not purport to be an intensive demographic study. Instead, a brief overview of the relationships among gross parameters such as population and employment is achieved.

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