PRIVATE AND PUBLIC SECTOR ECONOMIES OF LIGNITE-ENERGY RESOURCE DEVELOPMENT IN RURAL CENTRAL TEXAS

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Demand for lignite-energy resources for the production of fuel for generating electrical power in Texas has increased significantly as a result of dramatic real price increases in the more traditional fuels, such as natural gas and crude petroleum (Kaiser). Rapid energy resource development has been shown to cause problems for the public sector in providing local services during the development stage as well as to place increased pressures on the private sector (Leholm, Leistriz, and Hertsgaard). Coal developments in the western states have had a profound impact on the abilities of both private and public decision-makers to plan for this type of development (Krutilla, Fisher, and Rice). The impacts of these developments are expected to occur primarily in rural areas and to have significant effects on many relatively small Texas communities. For many communities, such developments are likely to lead to significant economic and demographic growth and, therefore, the need for increases in public and private sector services.

One problem associated with public sector impacts has been the manner in which revenues and costs have been distributed in both spatial and temporal dimensions. Additions to the tax base in terms of plant, equipment, and associated facilities takes place in the more sparsely populated rural areas, while additional public sector services are placed on nearby populated centers. This situation has led to budgetary deficits in the populated centers and surpluses in the sparsely populated rural areas. Expenditure functions for power plants and associated mines during the construction period are highly skewed. This variation in expenditures during the construction period places increased risk on both private and public decision-makers in allocating resources in an efficient manner because of insufficient information concerning the short-run and long-run implications of lignite-energy resource development.

This paper presents estimates of the economic and fiscal impacts associated with the construction and operation of five lignite-energy generating stations and associated mines for the Brazos Valley Economy of central Texas. The Brazos Valley Economy is composed of seven counties (Brazos, Burleson, Grimes, Leon, Madison, Robertson, and Washington) located within a major near-surface lignite belt. Economic and fiscal impact projections are provided for a 23-year planning period (1977–99). The objectives of this paper are to (1) present the model used in estimating development impacts, (2) provide estimates of business activity (sales), income, and employment for the private sector, and (3) analyze net present values for costs and benefits accruing to the public sector as a result of development. Both temporal and spatial estimates are provided in that the model provides estimates at the regional, county, municipal, and school district levels for the forecast period.

REGIONAL ECONOMIC AND DEMOGRAPHIC MODEL

The traditional approach to regional impact analysis has been one in which estimates from input-output models have been used in a separate analysis to derive economic and population projections. Developmental impacts, however, should not be based solely on the economic structure of a region, but should also incorporate demographic characteristics as well as the economic-demographic interface. This model incorporates the economic demands associated with development with demographic factors to achieve an economic-demographic equilibrium in both spatial and temporal dimensions. The general model is composed of five components: (1) an input-output module, (2) a demographic module, (3) an economic-demographic interface module, (4) a gravity module, and (5) a fiscal-impact module.

Input-Output Module

The regional input-output module estimates base-line economic activity and projects economic activity over the forecast period. Input-output analysis requires the estimation of the transactions, technical coefficients, and interdependence coefficients matrices. The transactions matrix can be represented as:

$$(1)\quad X_i = X_{i1} + X_{i2} + X_{i3} + \ldots + X_{i26} + Y_i; \quad i = 1,2 \ldots 26.$$

This matrix exhibits the interstructure of the regional economy in terms of sales and purchases. The transactions matrix is read row-by-row to obtain total sales by the processing sectors, and the columns represent purchases. The X_{ij}'s represent purchases and sales by

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the processing sectors, and Y_i represents sales to final demand.

Technical coefficients are derived from the transactions matrix by assuming a linear relationship between the level of inputs purchased and gross sector output. This relationship is expressed as:

$$(2) \qquad X_{ij} = A_{ij}X_j$$

or

$$(3) \qquad A_{ij} = \frac{X_{ij}}{X_j} \qquad \begin{matrix} i = 1,2,\ldots 26 \\ j = 1,2,\ldots 26 \\ i \neq j \end{matrix}$$

The interdependence coefficients matrix can be derived by substituting (2) into (1).

$$(4) \qquad X_i = A_{i1}X_1 + A_{i2}X_2 + \ldots + A_{i26}X_{26} + Y_i \qquad i = 1,2,\ldots 26$$

This system of equations can be solved for Y_i where Y is the final demand vector and X is the total output vector. Solving for Y results in the system being expressed as $Y=(I-A)X$, where A is the technical coefficients matrix. Solving this system for total output results in $X=(I-A)^{-1}$. This specification provides the means for determining the level of individual sector outputs (x_i) for a given level of final demand (Y_i). The $(I-A)^{-1}$ matrix contains the coefficients that relate one sector to another and is referred to as the interdependence coefficients matrix.

The regional input-output module was developed from the Texas Input-Output model for 1972 (Grubb) using a location-quotient approach (Mustafa and Jones) and is composed of 26 endogenous sectors. The location-quotient approach is a procedure for comparing the relative importance of an industry (sector) in a given area to its relative importance within a subregion of this same area. This procedure regionalizes the technical coefficients matrix of the Texas model to account for the unique regional production characteristics of the Brazos Valley Economy. The definition of the location quotient is as follows:

$$(5) \qquad LQ_1 = \frac{Z_i/Z}{X_i/X}$$

where Z_i represents Brazos output for industry i, Z is total Brazos output for all industries, X_i is Texas output for industry i, and X represents total Texas output for all industries. Estimated location-quotient values for each of the economic sectors used in analyzing the Brazos Valley Economy are given in Table 1. Economic activity in the input-output analysis is induced by the magnitude of final demand under either base-line (without development) or impact (with development) conditions. That is, base-line economic activity is based on historical observations and provides the expected trend in final demand for the economy without lignite development, whereas the lignite project activities are considered in a comparative analysis of final demand. Final demand in this model is composed of government purchases (federal, state, and local), capital formation, inventory change, and exports. Trend analysis (with time as the independent variable) based on data for 1958–77 was used to project expected base-line final demand (Andrews et al.) for the 26 economic sectors.

Table 1. Economic Structure of Brazos Valley Economy

Sector	Location Quotient
1. Agricultural Crops	1.06
2. Livestock	4.05
3. Agricultural Services	0.40
4. Crude Petroleum	0.15
5. Oil and Gas Services	0.66
6. Mining and Quarrying	0.58
7. Residential Construction	1.13
8. Industrial Construction	1.19
9. Other Construction	0.80
10. Food and Fiber Processing	0.92
11. Forestry, Wood and Paper	1.74
12. Chemicals	0.12
13. Petroleum Products	0.61
14. Metal and Equipment Manufacturing	0.82
15. Mining and Machinery Manufacturing	0.22
16. Transportation Equipment	0.27
17. Other Manufacturing	0.90
18. Transportation	0.53
19. Communications	1.11
20. Utilities	0.60
21. Wholesale Trade	0.59
22. Retail Trade	1.39
23. Finance	0.62
24. Services	2.18
25. Households	1.02
26. Lignite-Fired Utilities	2.32

The traditional utilities sector within the Texas model was found to be inadequate in modeling the impact of development during the operational phase since the major source of fuel historically has been petroleum. To measure the economic impacts of electrical production from lignite-fired utilities, a separate lignite-based mine-mouth-located utilities sector was developed (Andrews et al. p. 53). Annual expenditures for the contract construction, retail trade, and household (labor) sectors were inputed into final demand vectors. Thus, the construction-phase final demand vectors contain the injection of new expenditures into the regional economy. These estimated increases in final demand over the forecast period are the basis for estimating the direct, indirect, and induced project impacts.

The regional input-output module developed suffers from the same limitations as traditional modules of this type: (1) no joint output, (2) linear production functions, and (3) temporally fixed coefficients. A shortcoming of this module is that static coefficients are used in analyzing the impact of a new industry. However, efforts were made to obtain representative coefficients for the lignite power industry.

Demographic Module

The demographic module used in this analysis was developed specifically for lignite-energy impact assessment (Murdock et al.) in that the skill levels required for employment in power plant construction, operation, and lignite mining are evaluated for the base-line (indigenous) population. This module uses the cohort-survival method of population projection, which consists of applying a set of historically averaged birth, migration, and survival rates to a set of base-line population data for a forecast period to estimate population levels throughout the period. The module determines the mechanisms available to increase or decrease the initial population level. This logic is shown by use of the basis population equation:

$$(6) \quad P_{t+1} = P_t + B - D + M$$

where P_{t+1} is population stock one period in the future for a given geographic area, P_t is population stock in the initial period, B represents births between time points t and t+1, D represents deaths between time points t and t+1, and M is net flow of migrants (plus or minus) between time points t and t+1.

Rather than utilizing total population figures, this method employs a set of age-sex cohorts, with mortality, migration, and fertility rates specific to each cohort. These cohort rates for the projected period are applied to the population in each cohort to determine the future population for any geographical area and projection period. The procedure is estimated in the following manner:

$$(7) \quad P_{ci,t+1} = P_{ci,t} - P_{ci}B - P_{ci}D_1 + P_{ci}M_1$$

where the subscript C_i represents cohort i, with other variables being defined as in (6). The total population is obtained by summing for all cohorts:

$$(8) \quad P_{t+1} = \sum_{i=1}^{N} P_{ci,t+1}$$

In deriving factors for this module, adjustments for the geographical unit, data limitations, and other features unique to the estimation process were implemented. Seventy-five single-year-age cohorts were used for each sex. The initial population in each cohort for each county was based on 5-year age-sex cohorts derived from U.S. Census estimates (Irwin). Each 5-year age-sex cohort was disaggregated into five 1-year cohorts of equal size. This disaggregation procedure was necessary because 1-year cohort projections were not available.

County age-specific fertility rates were derived from birth data by age of mother for counties included in the study area. To compensate for probable changes in fertility trends, county fertility rates were adjusted (projected national trends) by a ratio of the 1970 county age-specific fertility rates to equivalent national rates. The application of this ratio to projected rates for subsequent periods (1979–2000) for the nation yielded estimated county rates (U.S. Bureau of the Census).

The measure of mortality used for the age-sex cohorts consists of 75 statewide survival rates for each sex derived from the life table functions for 1969–71 for Texas (National Center for Health Statistics). Because of data limitations and the minor change in state mortality rates over time, state rates were assumed representative for counties across all projection periods.

Migration rates for the working-age population (65 or less) are determined through the economic-demographic interface. The interface procedure determines migration through a comparison of employment requirements based on the input-output module with the available workers and skill types from the demographic module. If this comparison indicates that available workers exceed required workers by a specified parameter (13 percent), out-migration will occur. If the number required exceeds the number available, in-migration takes place.

Economic-Demographic Interface Module

An economic-demographic interface module provides the connective link between the input-output and demographic modules. The input-output module provides projections of the required work force, and the demographic module provides projections of the available labor force by skill type. The interface module provides the computational mechanism for synchronizing these projections through time to determine employment equilibrium based on quantity adjustment rather than price adjustment. Therefore, the supply of labor is assumed infinitely elastic at the market wage rate. This is more likely to be the case in rural economies that have been experiencing out-migration on a historical basis.

Computations are provided for (1) projections of the number of persons available for each of several distinct types of base-line and project-related employment and (2) projections of the number of workers by age and sex that must in-migrate to or out-migrate from the Brazos Economy to achieve employment equilibrium. The interface model is applied at the county level and is operational for both base-line and project-development sequences.

Gravity Module

Residential settlement patterns for project-related in-migrants and their dependents are determined by use of a gravity module (Richardson). This module assumes that in-migrants are attracted to population centers in direct proportion to population size, but inversely to the distance of the population center relative to the project employment site. Employment was substituted in the module because employment by specific category type (base-line construction, operational and indirect) is more appropriate than total population values. The various types of workers are assumed to be attracted to those areas that contain a greater number of their occupational type.

In-migrants are distributed to municipalities whenever required employment in a given skill classification for the region is greater than the available labor force within the classification. The form of the module is:

$$(9) \quad M_i = \frac{\dfrac{E_{it}^{\;a}}{D_{ij}}}{\sum_{i=1}^{N} \dfrac{E_{it}^{\;a}}{D_{ij}}}$$

where M_i is the fraction of total in-migrants locating in city i, E_{it} is the employment of city i by employment type t, D_{ij} represents distance between city i and the project site raised to the gravity power (a).

Separate gravity model allocations are made for each type of worker. Gravity powers were obtained from a study of energy-worker settlement patterns in the Northern Great Plains (Wieland et al.). Gravity powers are 1.5 for construction workers, 2.0 for operations workers, and 1.6 for project-related indirect workers. This procedure results in a smaller proportion of construction workers than of operating workers being allocated to municipalities near the plant site. Indirect workers are assumed to reside and work in the community to which they have been allocated. The set of municipalities to which workers could migrate was limited to within a 100-mile radius of a given project site. Variations in the cost of living between municipalities were not incorporated into the gravity module. Therefore, an infinite elasticity with respect to the ability of these municipalities to absorb in-migrants at prevailing housing prices is assumed. In-migrants are not allowed to settle in other than incorporated areas.

Fiscal Impact Module

The impact of energy project development on the financial position of the public sector is estimated by accounting for development impacts on public sector revenues and costs (Leholm, Leistritz, and Hertsgaard). The net fiscal balance for the public sector resulting from energy project development is defined as additional public revenues minus additional public costs for a given accounting period.

Public sector revenues and costs as a result of in-migrations of project-associated workers are estimated for counties, municipalities, and school districts, assuming a constant per capita cost function (Table 2). Positive net fiscal balances indicate that additional revenues are greater than additional costs, and a negative net fiscal balance indicates the reverse. Local revenue items included in the model are (1) ad valorem property taxes, (2) user fees, (3) special assessments, and (4) transfer payments (including educational, federal revenue sharing, and local share of sales tax collections based on program levels as of 1980. Capital costs for new local government facilities were estimated primarily from engineering data obtained from state and local agencies. The capital costs of streets, water, and sewer facilities were amortized over a 20-year period at 7 percent.

RESULTS OF ECONOMIC AND FISCAL IMPACT ANALYSIS

The regional economic-demographic model was used to simulate the economic and fiscal impacts of five lignite-fired, mine-mouth-located electrical generation facilities on the Brazos Valley Economy. One project is a 400-megawatt station, and the remaining four are 750 megawatts. The construction period for

Table 2. Public Service Cost Parameters for Fiscal Impact Module

Cost Item	Annual Costs (1975 Dollars)
City and County	
City Fire Protection	15.87 per capita
City Police Protection	24.10 per capita
City Operating Costs	16.39 per capita
County Social Services	29.32 per capita
County Law Enforcement	3.64 per capita
County Operating Services	101.63 per capita
County Highways	12.39 per capita
Distribution and Treatment of Water	1,574.00 per capita
Waste-Water Systems and Treatment	168.00 per capita
Solid Waste Disposal	3.60 per capita
Schools	
Operation Expenditures	1,228 per pupil
Capital Investments	39 per square foot
Streets	
Operating and Maintenance Expenditures	2,597 per mile
Capital Investments	190,080 per mile

all stations was set at five years. One facility began their operation in 1982, another in 1984, another in 1986, and two in 1985.

Results of Economic Impact Analysis

Economic impacts were investigated for regional, county, and municipal jurisdictions. The regional analysis presents projections of business activity and personal income for base-line and project development, and the county and municipal analyses present estimates of employment resulting from project development.

Regional Analysis. The economic analysis for the regional economy provides projections of base-line and project business activity and personal income in 1972 dollars for the entire seven-county region. Total business activity resulting from project development increases from $987,000 in 1977 to $197 million in 1999. Business activity in constant dollars for the entire projection period totals $2.98 billion, or an annual average of $130 million. Project-related income increases from $1.39 million in 1977 to approximately $45 million in 1999. Project-related personal income totals $782 million for the entire project period or an annual average of $34 million. Project-related business activity and personal income represent the direct, indirect, and induced impacts of lignite development on the private sector of the Brazos Valley Economy for both construction and operational phases of development. Initially, these projects have limited impacts; however, once the operational phase begins, the level of impact increases significantly. Business activity for base-line and project development is presented in Figure 1.

County and Municipal Analysis. Employment impacts for four counties (Brazos, Grimes, Leon, and Robertson) and nine municipalities located within these counties (Bryan, College Station, Navasota, Buffalo,

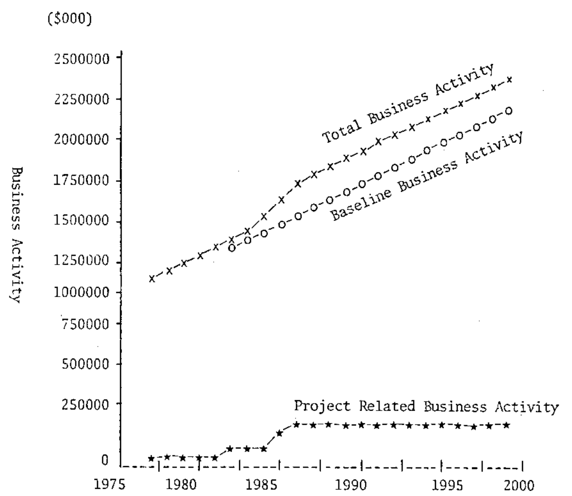

Figure 1. Business Activity Projections for Brazos Valley Economy

Jewett, Marquez, Bremond, Franklin, and Hearne) were included in the analysis. Employment impacts were minimal for Burleson, Madison, and Washington counties since the lignite power plants and associated mines simulated were located in other counties. These counties also contained no major population centers and therefore attracted few project-related workers. Brazos County receives the greatest employment impact, while Grimes County receives the least of those counties presented.

Project employments for Brazos, Grimes, Leon, and Robertson counties increase rapidly from 1977 to the mid-1980s. Employment impacts for Brazos County and its municipalities (Figure 2) increases from less than 100 workers in 1977 to 1,650 workers in 1987, at which point employment stabilizes for the remainder of the projection period. The employment pattern for Brazos County is typical of other counties in this analysis. Impact employment for Grimes County reaches a peak of 115 workers in the mid-1980s. Project employment for

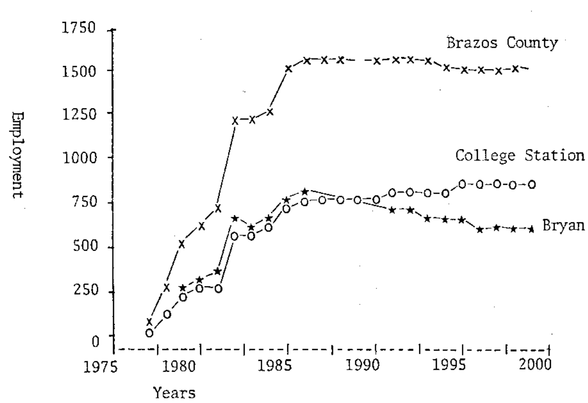

Figure 2. Project Related Employment for Brazos County and Associated Municipalities

Leon County peaks at 950 workers in 1989; following this peak, impact employment decreases to 775 workers by the end of the forecast period. Robertson County is third in total project employment with a peak of approximately 350 workers in 1986, after which employment gradually declines.

Results of Fiscal Impact Analysis

Fiscal impacts are estimated at district levels. The fiscal impact analysis provides yearly estimates in current (1980) dollars of revenues and expenditures for each governmental entity. Current dollars are used in this part of the analysis, because public decision-makers are more concerned with balances in current than in constant dollars. The long-run inflation rate was assumed at 7 percent. Summation of revenue and expenditure items for each governmental input produces a net fiscal balance for the forecast period. Property tax rates used in assessing income from project-induced development are based on regional averages. These regional ad valorem tax rates for counties, municipalities, and school districts were 2.5, 2.9, and 3.1 mills, respectively.

The financial impacts of lignite development over the 23-year planning horizon were estimated using net present value analysis. Net cash flows relevant for this analysis are the annual net fiscal balances for each governmental jurisdiction obtained from the fiscal impact module. Just as the private investor considers an investment criteria when reviewing alternatives available for his financial resources, so should decision-makers in the public sector. The method for discounting future cash flows is:

$$(10) \qquad V_o = P_n (1+i)^{-n}$$

Where V_o is the present value of the series of returns, P_n is the return for each conversion period ($n = 0,1,2,3, . . N$), and i is the discount rate. After careful consideration, a discount rate of 10 percent was specified. While municipalities can usually borrow funds at rates lower than the private sector due to tax considerations, it was deemed appropriate to specify a discount rate that equalled the return required in the private sector. The net present value for the sum of all governmental entities was 16.29 million dollars (Table 3). While these projects are, in general, favorable public investments, the impacts were highly unfavorable for certain governmental units.

County Analysis. Present values for net fiscal balances at the county level are positive for all counties with the exception of Brazos County (Table 3). The aggregate present value for all counties is 9.74 million dollars. The additions to the tax base as a result of development are more than adequate in providing revenue for covering the demands for public services at the county level resulting from project development. The major factors accounting for these highly favorable impacts are the addition of lignite mines and generating facilities to the county tax rolls.

Present values range from a low of negative

Table 3. Present Values for Net Fiscal Balance Using a 10 Percent Discount Factor

Governmental Entity	Present Values (1980 Dollars)
Counties:	
Brazos	-598,000
Grimes	3,516,000
Leon	647,000
Robertson	6,184,000
Total for Counties	9,749,000
Municipalities:	
Bryan	-253,000
College Station	-535,000
Navasota	1,936,000
Buffalo	-187,000
Jewett	-243,000
Marquez	-99,000
Bremond	-50,000
Franklin	-49,000
Hearne	-122,000
Total for Municipalities	408,000
School Districts:	
Bryan	-923,000
College Station	-1,191,000
Navasota	-213,000
Buffalo	-255,000
Jewett	840,000
Marquez	117,000
Bremond	60,000
Franklin	7,722,000
Hearne	-164,000
Total for School Districts	6,139,000
Total All Government Entities	16,246,000

$598,000 for Brazos County to a high of $6.18 million for Robertson County. Brazos County received a negative present value because it receives the major portion of project-related in-migrants, therefore incurring costs associated with providing public services for this added population. Brazos County, however, has no lignite projects located within its boundaries; thus, it receives minimal additions to its tax base.

Municipal Analysis. Present values at the municipal level indicate that the impacts of development are negative for all municipalities considered with one exception (Table 3). Present values range from a low of negative $525,000 for College Station to a high of $1.93 million for Navasota. The impact on Navasota is positive as a result of impact payments from the publicly owned project located within Grimes County; otherwise, this municipality would also experience a negative fiscal impact.

Negative present values result for municipalities due to a lack of tax revenue from lignite project development. The lignite facilities are located within the boundaries of counties and school districts, but outside municipal boundaries. Municipalities, however, receive the population impact as a result of development. Demands for greater public services are exerted at the municipal level. Negative present values at the municipal level are indicative of an unacceptable public investment. The aggregate present value for municipalities is $408,000, which indicates a marginal investment at this jurisdictional level.

School District Analysis

Present values for school districts range from a low of negative $1.19 million for College Station to a high of $7.72 million for Franklin (Table 3). The taxable lignite projects are located in Leon and Robertson Counties. Lignite mines are located in Leon County, which accounts for the positive present values for the Jewett and Marquez school districts. The greatest positive present value occurs in Franklin because two lignite-fired generating facilities and associated mines are located in this school district. The aggregate present value for all school districts is highly positive as a result of the Franklin district. However, only those districts that contained a taxable project experienced positive present values.

CONCLUSIONS AND LIMITATIONS

Economic and demographic impacts of lignite resource development on the public and private sectors of the Brazos Valley Economy are similar to the experience of other regions within the country. The employment analysis indicates that the number of jobs available to the indigenous population increases as a result of lignite development. Some municipalities experience short-run employment increases of 10 percent or more as a result of the development. However, while lignite development increases the number of jobs available in these communities initially, it does not provide for a continuing upward trend in long-run employment.

Lignite development proves to be a highly attractive regional investment, especially to the private sector. The present value of project-induced income to the private sector of the regional economy, assuming a 10 percent discount rate, was approximately $605 million (current dollars). The fiscal impact analysis for the public sector (counties, municipalities, and school districts) resulted in a present value of approximately $16 million (current dollars). Summation of the present values for the private and public sectors yields a net present value to the regional economy of approximately $621 million.

Fiscal impacts for the governmental components within the regional economy are more variable, being more favorable for counties and school districts than for municipalities. Specific fiscal impacts are of a complex nature, depending upon the project location, tax status, and expected population impacts as a result of in-migration. All public entities that receive revenue from taxable and nontaxable projects experience positive fiscal balance. However, governmental jurisdictions not receiving revenues from projects suffered negative fiscal impacts.

While the aggregate fiscal impact is positive for the region as a whole, the problem of negative fiscal impact for some components must be considered. The problem is not one of inadequate total revenue (efficiency), but rather a distributional (equity) problem. Use of the ad valorem tax mechanism to increase revenue to those governmental units adversely impacted would be inefficient and, therefore, inappropriate for this problem. The use of this mechanism is inefficient since the additional (marginal) tax revenue generated based on the present tax system is greater than the additional (marginal) public service cost. The problem is one of spatial distribution rather than insufficient funds generated to the public sector. Equity questions have always been a dilemma due to the value judgments that must be imposed. However, a redistribution of funds from governmental entities where the revenue-generating projects are located but which receive minor impacts to those areas that are adversely impacted should be considered. A regional economic impact assessment district that would evaluate impacts on a regional basis rather than the present system based on jurisdictional boundaries is one alternative.

Only private benefits and costs were considered in assessing the impact of lignite development for the Brazos Valley economy. Environmental impacts were not evaluated; therefore, these estimates are unadjusted for possible social costs, such as pollution. Additional problems and short comings in modeling and impacts of lignite development have already been discussed. Data problems usually exist in any modeling effort below the state level. The estimates in this study are based on a static open input-output model, which is a limitation because the study attempts to model the impacts of a new industry over time.

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