REGIONAL DEVELOPMENT IMPLICATIONS OF ALTERNATIVE FUTURE COAL PRODUCTION PATTERNS

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The prospect of a larger role for coal in meeting our nation's energy needs has stimulated interest in when, where, and at what cost coal can be produced. A growing literature has addressed the nature of changing coal demands, the economics of the production process, and the characteristics of input requirements that may constrain coal development.[1] A closely-related issue centers on how increased coal production may affect regional economic development. This is of particular interest since many coal deposits are located in areas that have experienced developmental difficulties. The Appalachia economy, for example, appears to be on the upswing due to the resurgence of coal mining.[2] Still, economic development in mining areas takes many shapes and is dependent on the ability of regional economies to respond to new economic influences triggered by coal development. Schlottman argues "the most important question of all . . . is the impact of the mining economy on the lives of past, future, and current residents of the coal mining districts."[3] Analysis of such effects may be focused at several levels. Local mining areas may, in the short term, experience undesirable rates of development, such as those associated with the "boom town" phenomenon. More generally, however, one might question whether, in the longer term, broad regional areas will find economic circumstances altered as coal development expands. Of particular interest is the degree to which supply-side constraints will be relaxed as coal production provides developmental impetus through increased demand for local input factors.[4] If these constraints do not relax, much of the development impetus may be exported to nearby regions.

This study seeks to examine how long-term changes in regional economic patterns may be influenced by changes in concentrations of coal mining activity.

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[1] A growing number of sources provide reference to this body of literature. See for example *Growth and Change,* Volume 10, No. 1, January 1979, "Proceedings of a Conference on Energy Problems and National Energy Policies," various articles; U.S. Department of Energy, "As Assessment of National consequences of Increased Coal Utilization" Executive Summary, TID-2945, Volume 2, February 1979; and Electric Power Research Institute "Economic Analysis of Coal Supply: An Assessment of Existing Studies," Volumes 1 and 2, EPRI EA-496, August 1977.

[2] William H. Miernyk, "Rising Energy Prices and Regional Economic Development," p. 54 in William H. Miernyk et al., *Regional Impacts of Rising Energy Prices,* August 1977, (Report to the Economic Development Administration).

[3] Alan Schlottman, "Modeling Growth and Change in the American Coal Industry—Comment," *Growth and Change,* Volume 10, No. 1, January 1979, p. 128.

[4] This issue is taken up in F. J. Anderson's "Demand Conditions and Supply constraints in Regional Economic Growth," *Journal of Regional Science,* Volume 16, No. 2, 1976.

Bureau of Economic Analysis functional economic (BEA) areas are used as units of spatial analysis. These areas are defined using the concept of regional labor markets, i.e., areas whose boundaries encompass both place of work and place of residence. They are natural units of analysis for the current task which is to measure the degree to which increased levels of coal activity stimulate new jobs in other sectors, subject to labor supply constraints and historical regional linkages. To conduct this analysis, two alternative growth paths for regional coal employment, one assuming high growth in eastern coal production and the other assuming high growth in western coal production, are evaluated using a multiregional economic systems model. This model, discussed below, can examine these topics because it combines economic and demographic behavior in its projections and considers regional interactions by using "gravity variables" as determinants of regional behavior. For each coal employment growth path, the same level of total national coal production and total national employment in other sectors is assumed. From these inputs, two sets of regional population and employment projections are prepared with data projected for each BEA region over the period 1975 to 2020.

The model's results indicate that individual regions respond quite differently to changes in coal employment. In particular, a range of multiplier effects is evident, with distinct patterns characterizing eastern and western portions of the nation. Multiplier impacts in the East appear to "spill out" to neighboring areas, whereas regions in the West give the appearance of "competing" with one another. For example, in the West some non-coal-producing regions grow more rapidly when mining expands in the East than when it expands in the West. This is because in the latter case, coal-producing regions capture economic activities they would not have enjoyed had growth in mining not occurred.

To understand the reasons these finding occur, it is necessary first to review the model, its input assumptions and data, and the regional characteristics against which the analysis is conducted. Attention now turns to a sequential discussion of these topics before examining the model outputs. In the final section, the relevance of these findings is discussed from a policy perspective.

The Model

Because the nature and performance of the model used in this analysis has been reported elsewhere, this section will highlight, rather than detail, its characteristics. This model, termed MULTIREGION,[5] is a multiregional systems model that projects population and employment in five-year increments for BEA areas. Its primary exogenous inputs are national population and employment projections, and, as such, the model falls into the class of "top-down" regional models. Some exogenous regional information is also required, in this case, projections of coal employment. The model is recursive in its five-year time steps, and lagged regional endogenous variables (either local or gravity variables formed from neighboring BEA areas) are the primary determinants of behavior.

The model's computational sequence for each time period is divided into two parts. In the first, projections of population and employment are estimated separately of subcategory. In the second, subcategories are aggregated and population and employment totals are forced to "equilibrate" for each individual region. The method of equilibration is a proportional adjustment mechanism that

[5] R. J. Olsen, et al., "MULTIREGION: A Simulation-Forecasting Model of REA Area Population and Employment," (Oak Ridge National Laboratory), ORNL/RUS-25, October 1977.

constrains the final population/employment relationship to a projected "employment pressure index," formed as the ratio of employment to population of work-force age.

Thirty-seven employment subcategories are projected, though for this study only total employment is reported. These categories are subdivided into three types: natural resource-based, manufacturing, and service. Natural resource employment, including coal, is estimated exogenously by region. Manufacturing employment is projected using equations specified to link manufacturing activity in each region to lagged activity in own and neighboring regions, including access to input and output markets using gravity variables. Service sector equations exclude access to input markets, but measure access to output markets by a personal income gravity variable.

Population is subdivided into thirty-two age/sex cohorts and projected using a cohort-component method. Again, only population total are reported below. Closed population change is projected using age/sex/region-specific birth and survival rates. In- and out-migration rates are projected separately for each age/sex cohort using equations specified to include the influence of neighboring regions using gravity variables and local conditions using the above-mentioned employment pressure index.

Input Data and Assumptions

The level of national coal production assumed for this study basically follows that of former President Carter's National Energy Plan through the year 2000.[6] From a production level of 16.2 quadrillion Btu (quads) in 1975, production increases to 31.1 quads in 1985 and 44.9 quads in 2000. Production in the year 2020 is extrapolated to grow to 67.6 quads (see Table 1).

Regional estimates of where this coal will be produced are available from an Oak Ridge National Laboratory (ORNL) study that serves as a base case for the present study.[7] Production in the base case is then redistributed such that an additional 20 percent of the nation's coal output is alternately produced in the West and in the East. West and East are separated by an imaginary dividing line that roughly falls perpendicular to the Canadian border in Western Minnesota such that North Dakota lies in the West and Iowa in the East. Under the high West assumption, the share of national production in the West increases from 13.1% in 1975 to 60.6% in 2020. Eastern production falls from 86.9% to 39.4% over this same period. In the high East case the West's share of national production also increases but much less dramatically than in the high West case. In this instance western production comprises 20.6% in 2020, relative to 79.4% for the East. For both cases or "scenarios," national coal production measured in energy content is the same.

Once the production levels for the East and West are derived, estimates of production by county are prepared and county-level data are aggregated to BEA functional economic areas. The method used to estimate county coal production is to allocate the assumed western and eastern totals on the basis of past

[6] *The National Energy Plan*, Executive Office of the President, Energy Policy and Planning, April 29, 1977.

[7] These projections are reported in D. J. Bjornstad, et al., "Long-Term Projections of Population and Employment for Regions of the United States (Series TOPS. R2. OBERS)," (Oak Ridge National Laboratory) ORNL/TM-6557, December 1978.

Table 1. Input Assumptions For Coal and Coal Employment

	1975	1985	2000	2020
Total coal production (in quads)	16.2	31.1	44.9	67.6
High west				
% in west	13.1	38.4	53.7	60.6
% in east	86.9	61.6	46.3	39.4
High east				
% in west	13.1	18.4	13.7	20.6
% in east	86.9	81.6	86.3	79.4
Total coal employment high west	131,154	183,709	217,861	325,154
% in west	7.0	21.2	34.6	43.7
% in east	93.0	78.8	65.4	56.3
Total coal employment high east	131,154	250,042	409,569	613,183
% in west	7.0	11.3	11.0	15.7
% in east	93.0	88.7	89.0	84.3

production and available reserves.[8] To conduct this allocation, production is divided into output from strip mines and output from deep mines. This division is necessary because of the quite different levels of output per worker that characterize the two techniques. Output per worker also differs because the characteristics of coal reserves require varying amounts of effort per unit of production. To convert the BEA coal production levels to employment levels, it is assumed that producing one quad of coal through deep mining techniques would require 14,000 workers in the Appalachian portion of the nation, 109,000 workers in the central portion, and 12,000 workers in the western portion. To produce one quad of coal through strip mining techniques the respective worker requirements are 4,000, 3,000, and 1,700[9].

When the production estimates are divided by these coefficients, an estimate of coal employment is obtained. Note in Table 1 that these input assumptions produce a level of coal employment that is greater for the high East case than the high West case. Under the high West assumptions, coal employment of the U.S. grows from 131 thousand in 1975 to 325 thousand in 2020, while in the high East case, coal employment grows to 613 thousand by 2020. Thus, the West experiences a smaller rate of growth in its share of coal employment than in its share of coal production.

Because the intent of the study is to observe the impacts on regional development of alternative rates of growth in coal production, other input assumptions are held constant. These include the Series II fertility rates, which generate a population of 294 million by 2020 and an OBERS-based rate of total employment

[8] For further details on this procedure see D. J. Bjornstad and D. N. Stuckwish "County Coal Projections 1975-2000: Prepared for the National Coal Utilization Assessment," (Oak Ridge National Laboratory), ORNL/TM-6752, January 1980.

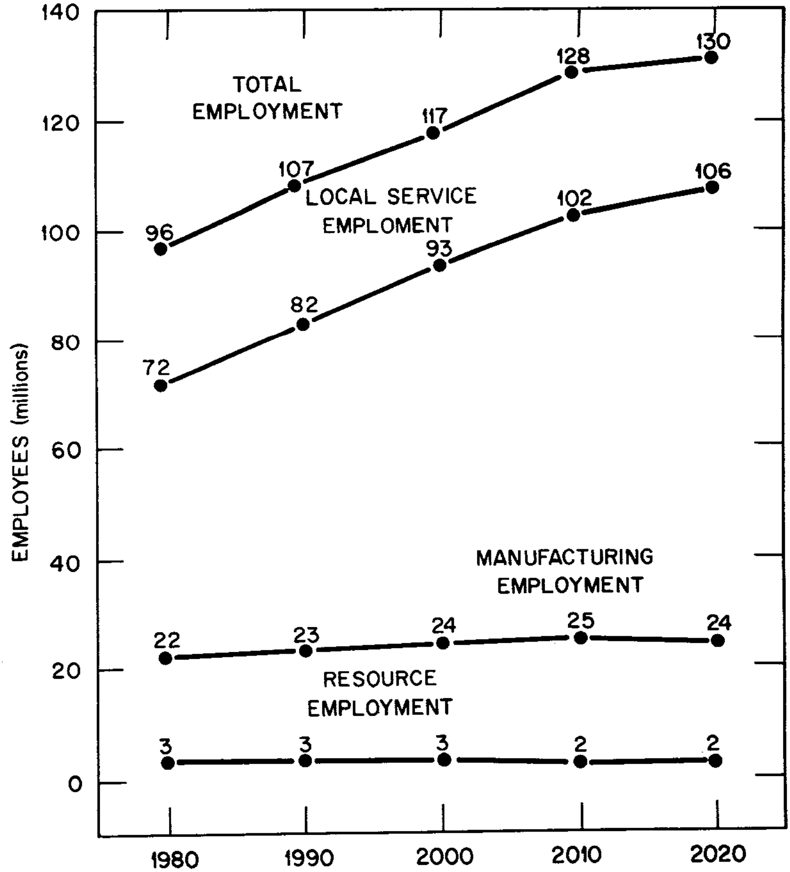
[9] *Ibid.*, p. 8.

growth of slightly less than 1 percent.[10] This generates a total employment level of 130 million by 2020, as is illustrated in Fig. 1.

Analysis Framework

As a preface to examining the model results from this analysis, it is useful first to place in persective the current spatial distribution of coal production activities and their relative importance within their respective regions. Figure 2 displays the spatial distribution of coal mining employment in 1975 by BEA area. Recalling from Table 1 that more than 90 percent of coal-related employment lay in the eastern portion of the U.S. at that time, it is interesting to note that in only four regions did coal employment exceed 1,000 workers (but less than 10,000) in 1975.

Figure 1: National Employment Projections, By Type.



Source: U.S. Water Resources Council, "1972 OBERS Projections (Series E Population)" April 1974

[10] For further discussion of the input assumptions, see D. J. Bjornstad et al., op. cit. p. 7-9. These data are derived from U.S. Bureau of the Census, "Population Projections of the U.S. 1977 to 2010," *Current Population Reports*, Series p-25, No. 704, July 1977; and *U.S. Water Resource Council*, "1972 OBERS Projections (Series E Population), April 1974.

Figure 2: Coal Employment — 1975.

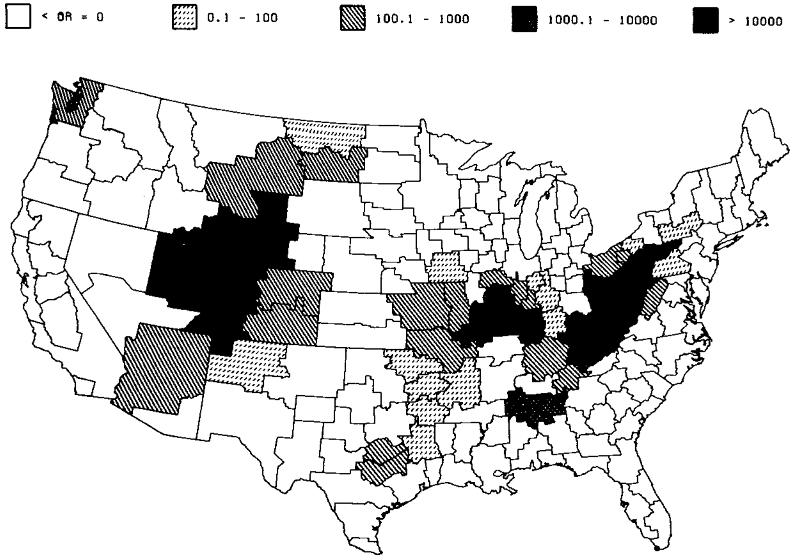
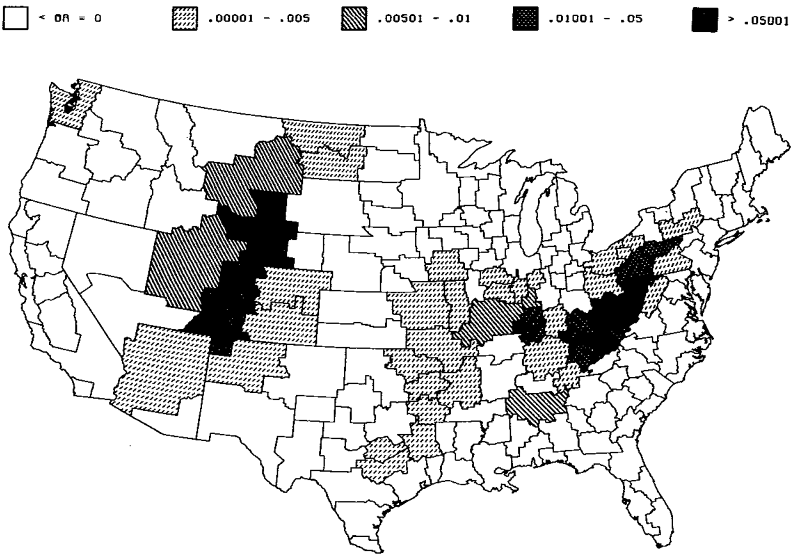


Figure 3: Coal Employment as a Share of Total Employment — 1975

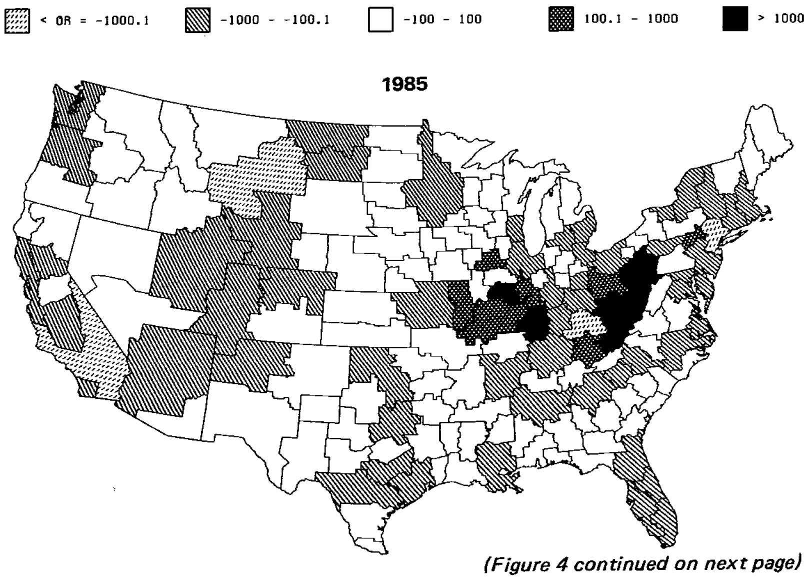


Moreover, as viewed in Fig. 3 for all but two regions, coal employment made up less than 5 percent of total employment in 1975. In many Appalachian regions, coal employment constituted between 1 percent and 5 percent of total employment, whereas in the West, only two regions fell into this category.

Figure 4 illustrates the spatial distribution of the coal employment assumptions discussed in the previous section. The data for this figure were obtained by subtracting the coal employment assumption of the high West scenario from that of the high East scenario. Hence, in the western portion of the U.S. these differences appear as negative entries, while in the East they are positive. These figures illustrate the cumulative effect of the scenario assumptions on regional coal activity. For 1985, only three western regions experience a coal employment difference greater than 1,000 workers. By 2000, two additional regions are added to this group and by 2020, the final year of the analysis, an additional region is added, while four regions experience loss of between 100 and 1,000 workers. In the eastern portion of the nation, due primarily to lower rates of worker productivity, direct employment impacts due to the input assumptions tend to be extended over a larger group of regions. By the year 2020, the majority of coal-producing regions receive direct employment impacts that exceed 1,000 workers.

Once entered into the model, these direct employment impacts trigger a range of initial effects on both the employment and population sectors. In general, these initial impacts occur for two reasons. First, the addition of exogenous employment causes a tightening of labor markets such that the level of employment relative to potential employees of work-force age increases. This impact tends to increase the rate of in-migration in succeeding periods and tends to decrease the rate of out-migration, with the net effect of additional in-migration to areas receiving a stimulus. This effect also influences the level of employment in service and manufacturing industries, with the result that certain industries receive positive stimuli and other industries receive negative stimuli. The second initial impact is present only in the service sector and occurs because the exogenous impact tends to increase the overall level of activity in the region, *ceteris paribus.* This increase adds to the demand for local services and increases employment in these sectors as a result. Among the largest secondary service

Figure 4: Total Population Difference in High East vs. High West.



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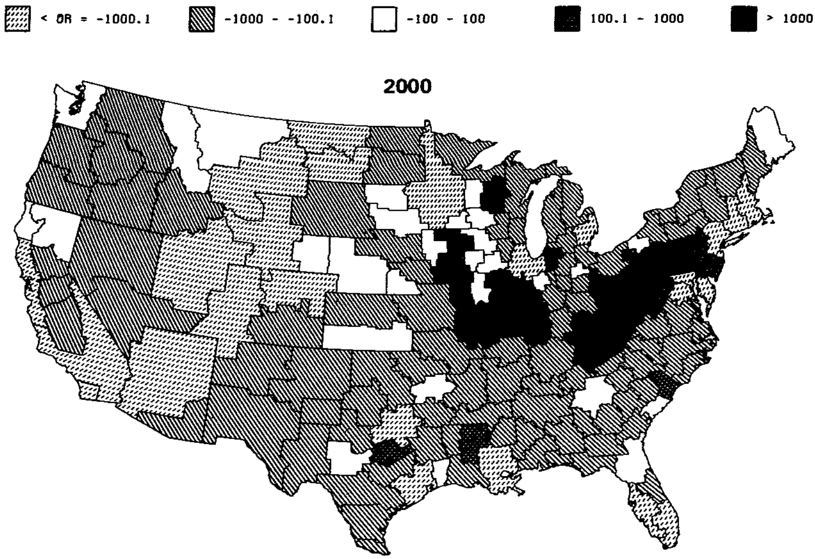
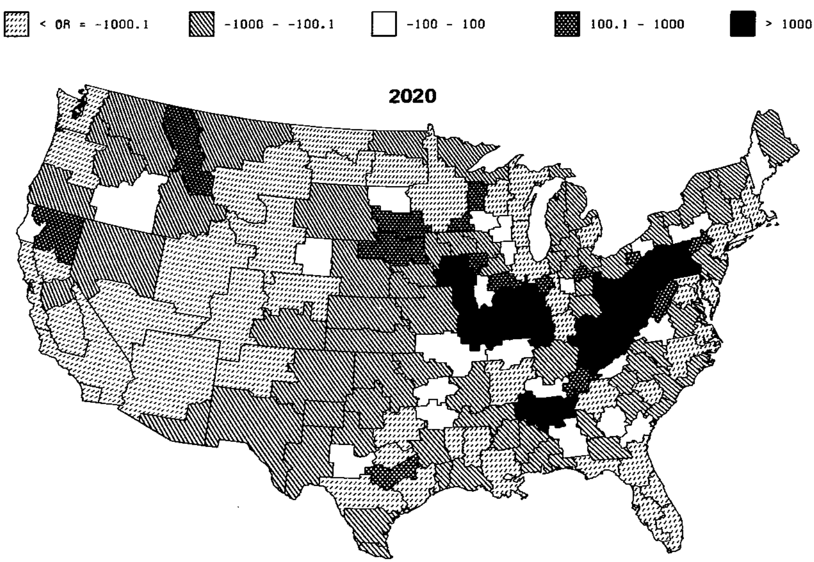


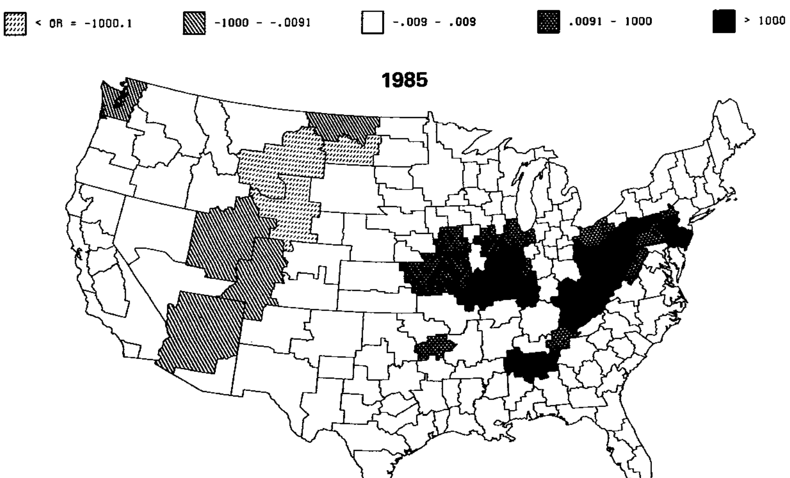


impacts are those occurring in the construction sector, where the model adds workers to construct the operating mine facilities and housing and related facilities for mine workers. Other service sectors receiving relatively large impact are the lodging, business and repair services, and amusement and recreation sectors. For regions receiving negative direct impacts due to the input assumption, symmetric, but negative initial impacts are generated by the model. It should be noted that there are no direct linkages within the MULTIREGION model between the coal sector and such related sectors as railroad transportation or equipment manufacture. Hence, the initial effect of the exogenous employment change is a general one, which considers the aggregated character of regional change.

Following the initial impacts of the coal employment change, a secondary set of impacts are measured by the model. These impacts occur due to the interrelatedness of regional growth and due to the fact that the model's specification captures the influence of change in each particular region on neighboring regions. The strength of this influence diminshes over distance. Because the model solves for population and employment change using an algorithm that approximates a simultaneous solution, and because the regional connectiveness variables consider relevant input and output markets, the sequence of the secondary impacts cannot be described simply. However, an example should aid in understanding the growth process which the model attempts to capture.

For any given pair of proximate regions there exists a potential for economic change which is described by the model's employment and migration equations and by initial regional conditions. The degree to which this potential is realized is governed by a number of exogenous variables, including the performance of the national economy and exogenous change at the regional level. If an exogenous increase occurs in one of the pair of regions, the region receiving the stimulus will receive additional employment and population through the process described above. For the proximate region, two (admittedly polar) results are possible. Growth in the impacted region may trigger growth in the proximate region by stimulating linked manufacturing and service sectors. This may be described as an example where growth "spills out" of the impact region and may, in general, be though of as a multiplier effect. However, such growth need not occur since the two proximate regions are also "competing" for new economic growth and in-migrants. Thus, there exists the possibility that the proximate region may grow less rapidly than it would have had the exogenous impact not occurred. Total national economic activity, net of the exogenous impact, will remain unchanged, since the model, as specified, does not recognize factors that would feed back to the national economy. For some regions to grow more rapidly, others must grow

Figure 5: Coal Employment Difference in High East vs. High West



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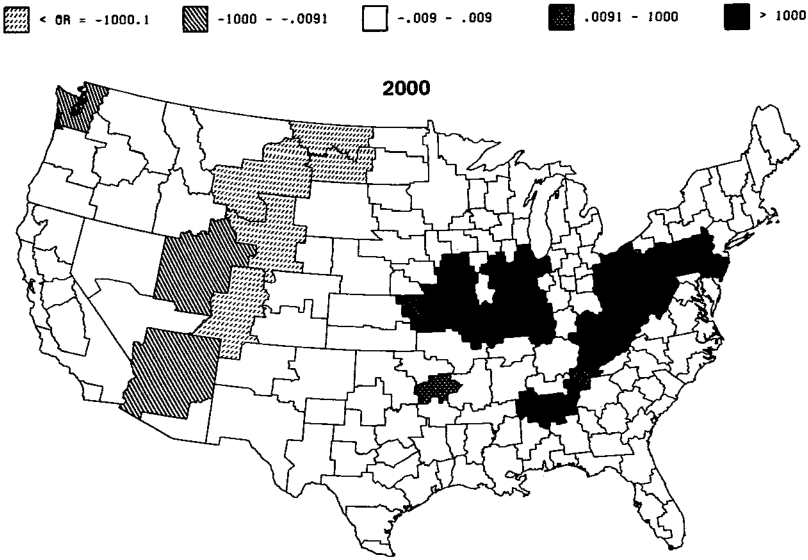
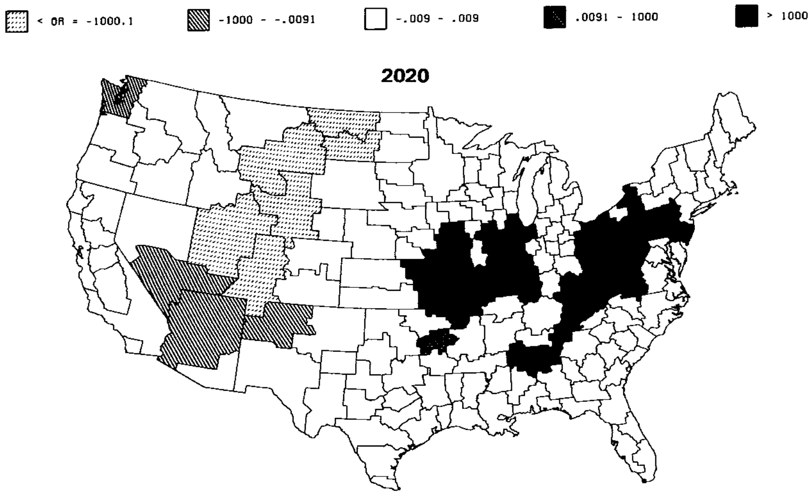




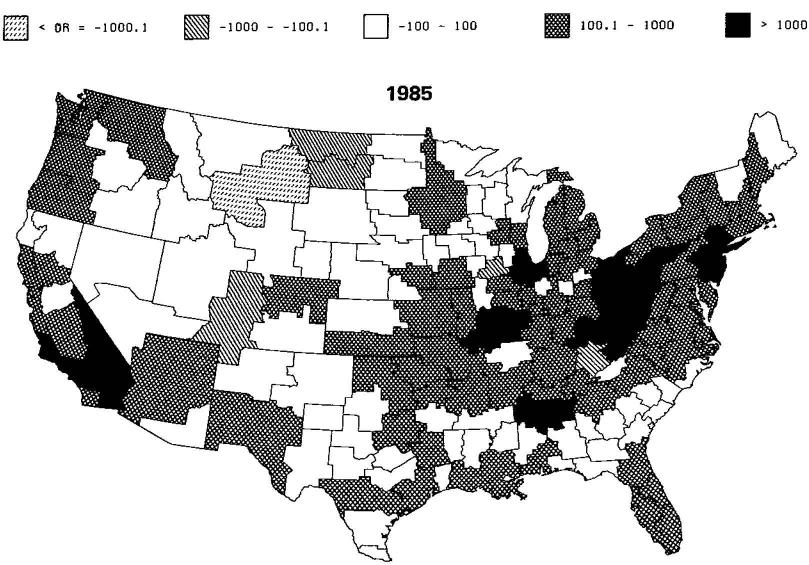
less rapidly. Whether the competitive effect or the spillout effect dominates is dependent upon the initial industrial makeup of each region and its demographic composition working through the model's behavioral equations. It is also influenced by these conditions in neighboring regions, because of the use of gravity variables in the specification. An important aspect of the regional adjustment process as currently modeled is the interaction between population and employment in the second stage of the computational sequence (described above). Because of the employment pressure index contraint, a region receiving an employment stimulus will receive a larger impact if its demographic composition is "receptive" to net in-migration, i.e., if there are concentrations of population in younger age groups, unemployment rates are low, etc. Regions of this type are referred to as possessing "latent development potential" since they respond to an employment stimulus more than regions having demographic characteristics less favorable to net in-migration.[11]

Empirical Results

The total employment changes at the regional level that result from entering the exogenous coal employment impacts into the MULTIREGION model are illustrated in Fig. 5. Of interest is the fact that both the competitive effects and the spillout effects described in the previous section are quite evident. As in the previous figures, the data illustrated result from subtracting the high West scenario from the East scenario.

Beginning with 1985, the primary changes apparent are those that fall into the category of direct impacts. In the West the primary change occurs in Billings, Montana, where the largest exogenous coal employment impacts occurred. Similarly, in the East, the pattern of exogenous coal employment impacts is traced onto Appalachia and the Central coal-producing regions. Yet even in this early period (i.e., ten years into the model's time horizon) a range of secondary effects is evident. In the East, spillout effects are visible in a broad range of regions and only isolated instances of competitive effects are visible. Much of the South is unaffected. Similarly, many western regions are unaffected, but the presence of the competitive effect is much more pronounced. Along the western seaboard and throughout Arizona and New Mexico, positive growth occurs in response to the decline in western coal activities.

Figure 6: Total Employment Difference in High East vs. High West



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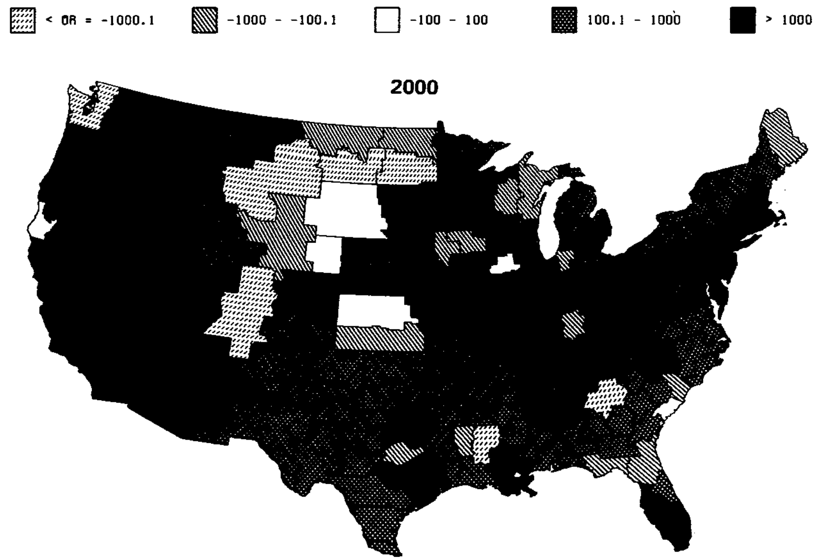
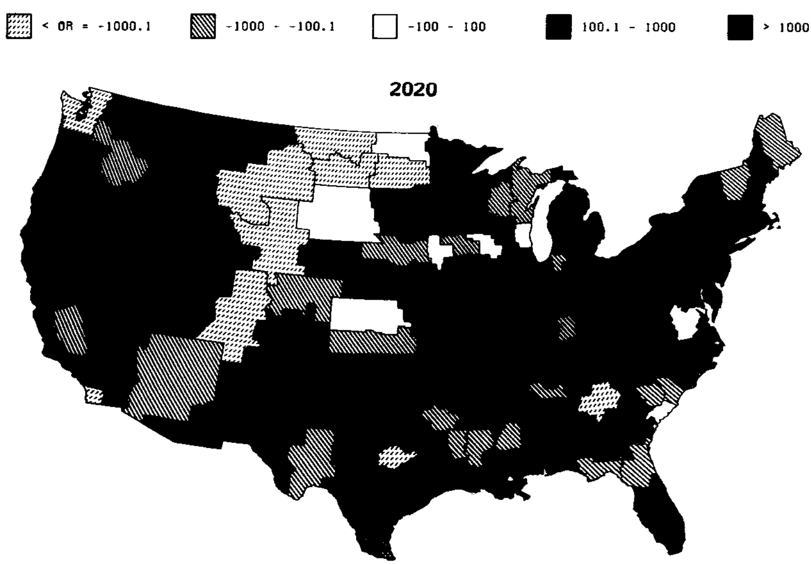
[11] For a detailed description of the model's migratory behavior see Henry W. Herzog, Jr. and David J. Bjornstad, "Urbanization, Interregional Accessibility, and the Decision to Migrate," forthcoming in *Growth and Change.*





Over time, these effects become much more pronounced. The years 2000 and 2020 show that growth attributable to expanding coal employment successively triggers a good deal of economic expansion. Limited degrees of decline are evident in Maine and in parts of the South. In the West, however, a quite different picture is presented. Here, decline is limited primarily to producing regions, whereas proximate regions tend to grow more strongly in the absence of western coal development. It is of particular interest to note that most western regions that do not produce coal experience greater growth under the high East case than the high West case. This suggests that their competitive position is governed by their relative position in the expansion of western coal production, rather than the fact that in an absolute sense the expansion provides an exogenous impetus for growth. In the presence of the western coal expansion these regions found their competitive position altered by the relatively stronger growth incentive in proximate regions and were unable to maintain the level of relative attractiveness that would have existed had expansion not occurred.

From the context of the nation as a whole, there is no reason to believe that population aggregates will be significantly affected over the next several decades due to the location of coal activities. Moreover, since regional labor markets can, within limits adjust through changes in labor force participation rates and unemployment rates, one should not expect a one-to-one correspondence between employment change and population changes.

Figure 6 illustrates these points by describing the model's population outputs generated in response to the exogenous coal changes and accumulated total employment effects. As might be expected, the primary movement of population that results from increased eastern employment is a general West-to-East shift. In each case the primary recipients of population are those areas receiving the exogenous impacts. Eastern coal areas are the primary recipients of net inmigration, whereas western coal-mining areas tend to be characterized by net out-migration. Also visible are the effects of proximity to the impact regions on net migratory patterns. Regions farther from the impact areas tend to supply population to growth areas.

Finally, it is of interst to examine the sensitivity of individual impact regions to the exogenous changes postulated for this study. This is done by examining the ration of total employment change to change in the coal employment sector. For a number of reasons, however, these ratios should not be interpreted as "multipliers" in the traditional sense of economic base analysis, and these ratios, to a degree, indicate the possible difficulties in using such multipliers. First, since we are examining a system of regions, it is the impact of the set of input assumptions rather than of any single input, which is of interest. Indeed, in this context it is incorrect to suggest that the change in coal employment "caused" a local response. Second, the model operates on a long-term time horizon rather than a short-term one, and relating current coal activity to current total employment neglects the importance of lags in the system. Instead, these ratios provide a useful summary measure for illustrating how groups of regions undergo systematic changes as the set of exogenous variable is changed.

Figure 7 shows the spatial distribution of the total employment/coal employment ratio over time. Over time, a distinct pattern is present in the East. Core coal areas, generally those with largest levels of coal employment at the starting point of this analysis and the largest concentrations of coal employment relative to total employment, tend to exhibit lower ratios of total employment change to coal employment than the regions on the perimeter of the core, where major growth in coal employment occurs over the projection period. This implies that the economies in the latter group exhibit a larger growth potential than those of the former group, based on the behavior captured by the MULTIREGION model structure. Stated differently, unless significant structural change occurs, the model outputs suggest that many older coal-producing regions will be unable to capture the full potential economic benefit of increased coal extraction activity, when this benefit is measured by total employment growth.

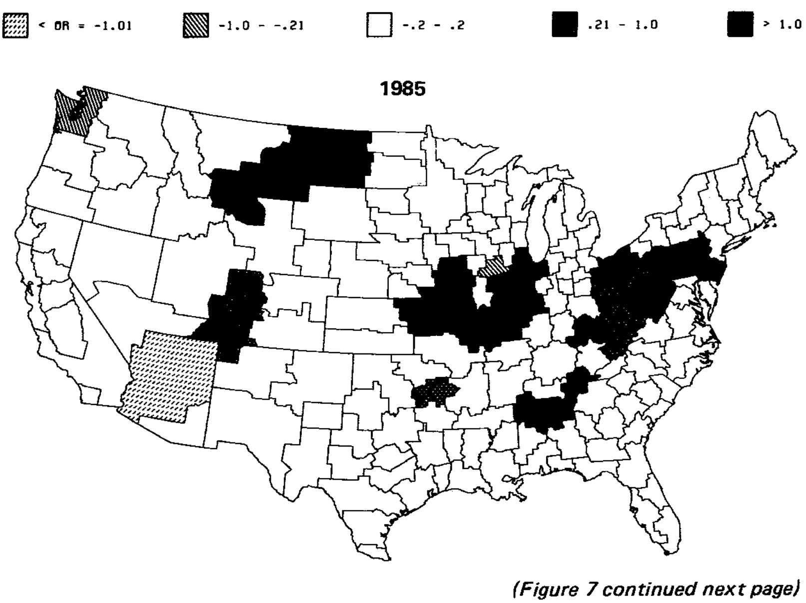
Coal-producing regions of the western United States display somewhat different behavior from those of the East, as was discussed above. Whereas by 1985, no region shows a significant reponse to the lower level of coal employment measured in the high East relative to the high West case, by 2000 and particularly by 2020 several regions show rather large ratios. However, for parts of Nevada, Utah, and New Mexico, declines in coal activity were accompanied by increases in total employment. This indicates the interconnectedness of the regional systems of the West and also suggests the potential pitfalls of analyzing portions of a larger area separately in the face of differential changes within the overall region.

Concluding Remarks

The model outputs just reviewed have highlighted a range of possible impacts that could accompany alternative patterns of regional coal development. Among the most important findings are the tendencies for development to "spill out" of producing areas in the East and for development to exacerbate competitive relationships in the West. Of note is the observation that the older core areas of coal development in Appalachia and the Midwest may be less able to capture the economic fruits of employment growth than proximate regions at their peripheries. Of similar note in the West is the tendency for certain coal development regions to lose relative advantage in the face of expanded development in proximate regions and thereby to experience less absolute employment growth in the presence of expanded coal activities than in their absence.

It would have been possible to review the countless regional data that underlie these broad effects. To do this would, however, elicit an impression of implied precision that is perhaps inappropriate for a long-term multiregional model of the

Figure 7: Ratio of Total Employment Change to Coal Employment Change in High East vs. High West.



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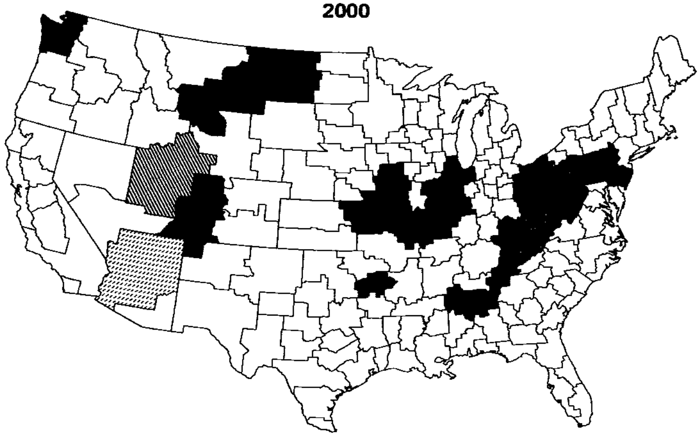

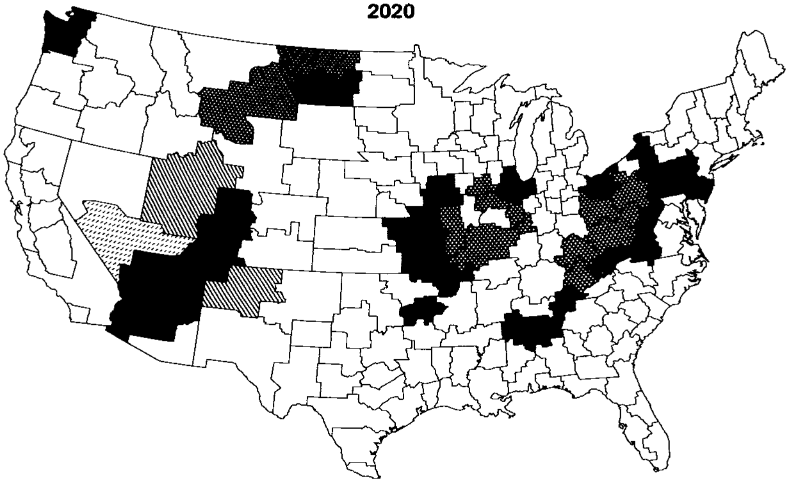

type used in this analysis. It would, moreover, not serve the interests of long-term secondary effect analysis. To illustrate this, it is useful to review briefly the range of issues and model horizons that may be fruitfully matched.

Despite the considerable overlap, the time frames in which issues are addressed by policy makers can be described as short-, mid-, or long-term. Short-term issues such as the rapid in-migration of construction workers accompanying the opening of a major coal field elicit management responses and are best addressed through analysis of current data for the individual area under concern, juxtaposed with the direct impacts brought about by the construction activity. A first-cut indication of potential "management" problems may be generated by a simple screening of counties according to "assimilative capacity," as is done by Stenehjem in the first steps of a county-level impact assessment of coal development.[12]

Mid-term issues elicit programmatic responses that are frequently aimed at institutionalizing and facilitating the range of management responses. Analysis for buttressing such responses should extend to the mid-term and should account for induced impacts as well as direct ones. The proposed Inland Energy Impacts Assistance Act illustrates such a programmatic response. Models for the study of mid-term regional economic effects often fall into the category of economic base analysis, such as the Social and Economic Assessment Model (SEAM) operated by Argonne National Laboratory.[13] Here the attempt is to account for a range of limited interactions which must be considered in creating programmatic guidelines.

Issues that are addressed over the long-term have been described by Andrei Rogers of the International Institute of Applied Systems Analysis as encompassing the process through which systems of human settlement patterns evolve.[14] These are factored not into management schemes or programs, but rather into the policymakers' planning horizon. Here the need is less for precision than for a broad accounting of socioeconomic interrelationships and possible outcomes. The current study has been designed to meet such planning needs.[15]

Moreover, because this planning process extends over a large number of years, it does not imply that current decisions could not be affected. Technologies are currently under development that could reduce our dependence on coal as a major fuel source during the next century. Although studies such as the present one cannot fully address the exigencies of the downtown in coal demand that may well occur, they do point to the range of regional response that will accompany coal development thereby implying the regional characteristics of the declines that might accompany the downside of our emerging coal boom.

[12] Eric J. Stenehjem, "An Assessment of the Relative Socioeconomic Effects of Increased Coal Development in the U.S.," (Argonne National Laboratory), draft, June 1979, p. 8.

[13] Eric J. Stenehjem, "Summary Description of SEAM: the Social and Economic Assessment Model" (Argonne National Laboratory) ANL/IAPE/TM/78-9, April 1978.

[14] Andrei Rogers "The Human Settlements and Services Area: The First Five Years," (International Institute for Applied Systems Analysis: Laxenburg, Austria) SR-79-1, January 1979, p. 21.

[15] The concept of describing modeling goals in terms of policy horizons is not a new one, nor has it been fully developed for regional analysis. The particular interpretation given them here has evolved through discussions with my colleague David Vogt, also of Oak Ridge National Laboratory. See his paper "Modeling Regional Economic Implications of Energy Systems: Problems and a Prospective," presented at the Southern Regional Economics Association Meeting, November 7-9, 1979, Atlanta, Georgia.