# Impacts of Air Pollution Control Strategies in Kentucky

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**ABSTRACT** The purpose of this paper is to estimate the impacts of air pollution control strategies for one state, Kentucky, on its own economy. Effects of the Clean Air Act are estimated, but the emphasis is on scenarios for compliance with pending acid rain legislation. The most restrictive scenario involves a 478.000 ton per year reduction in $SO_2$. Based on elasticity and engineering estimates, we project shifts from high-sulfur Western Kentucky coal to low-sulfur Eastern Kentucky coal, higher electric utility rates and manufacturing costs, and lower manufacturing employment. Impacts are always less than 6 percent of 1985 levels.

THE CLEAN AIR ACT OF 1970 contained two major provisions designed to control pollution from stationary sources such as electric power plants. The Act established National Ambient Air Quality Standards (NAAQS) and New Source Performance Standards (NSPS). Both were aimed at the principal emission from coal-fired power plants—sulfur dioxide.

Under the NAAQS the United States was divided into 236 air-quality regions, and each region was designated an "attainment" or a "non-attainment" area, depending on whether ambient air quality standards were being met. The states had to develop plans, under EPA supervision, to improve air quality in non-attainment areas. The result was that electric

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utilities with power plants located in non-attainment areas had to take steps to reduce $SO_2$ emissions. The method for meeting the air pollution standards was left to the individual utilities.

The NSPS established emission limits for newly constructed power plants. The $SO_2$ limit was set at 1.2 pounds per million British thermal units (Btu) of coal burned, a fairly stringent requirement compared to prestandard experience. Utilities were allowed to decide whether to install scrubbers or to use low-sulfur fuels in order to meet the standard.

According to Navarro (1981), concern over the relocation of U.S. coal production led to the passage in 1977 of the Clean Air Act Amendments. These amendments were designed to make high-sulfur coal as economically attractive to utilities as low-sulfur coal. The NSPSs were revised to require a "technological system of continuous emission reduction" and a "percentage reduction" in $SO_2$ emissions. The essential effect of this rewording was to require that scrubbers be installed on all new generating units for which construction began after September 1978. As a result fuel-switching became impracticable. A "local coal amendment" was also included, and was designed to curtail the use of nonlocal coal in existing power plants. The 1977 Clean Air Act Amendments remain in force today.

In 1986 Representatives Waxman, Sikorski, and 160 of their colleagues introduced legislation which called for a 44 percent reduction in $SO_2$ emissions by the mid-1990s. The same year Senator Stafford submitted an even tougher bill which called for a 66 percent cut in $SO_2$ emissions. More recently, Representative Solomon introduced a bill in 1987 that calls for a 10-million-ton reduction in $SO_2$ emissions, half by 1991 and the rest by 1996. The impact of any such legislation would be to require states to develop strategies to reduce further emissions of sulfur dioxide and oxides of nitrogen. The federal legislation could have a noticeable impact on energy markets and especially on local coal-producing economies. Individual states are to be given some flexibility to tailor state plans to various situations as long as the federally required reduction is achieved.

The purpose of this paper is to estimate the impacts of compliance strategies for one state, Kentucky, on its own economy. We estimate the impacts of the Clean Air Act and its 1977 amendments and also of several strategies for compliance with possible acid rain legislation. Information on these impacts indicates the extent to which individual states can control their own situation and the extent to which impacts are beyond their control. The paper proceeds as follows. First, changes in utility rates in Kentucky directly attributable to the adoption of $SO_2$ and $NO_x$ emission reduction techniques by Kentucky utilities are documented for the 1980-84 period. The impacts of these rate changes upon costs and employment in selected Kentucky industries are analyzed. Second, the range of probable impacts of future $SO_2$ and $NO_x$ reduction requirements from possible acid rain legislation on the sale of coal from Kentucky's eastern and western coal fields and on employment is projected. Third, probable increases in utility rates resulting from these different abatement scenarios are estimated, and the impacts on production costs and employment are estimated.

## Impacts on Utility Rates, Manufacturing Costs, and Employment, 1976-1985

We consider changes in Kentucky utility rates over time, look at the changes in rates attributable to air pollution reduction techniques, and evaluate the impact of those rate increases on the manufacturing sector of the Kentucky economy.[1] In particular, we consider the impact of the rate increases on costs and employment by two-digit industry within manufacturing. The manufacturing sector of the economy contains most of the electricity-intensive industries, those most likely to be affected by changes in electricity rates. For example, primary aluminum and gaseous diffusion are contained respectively in SIC33, Primary Metal Industries, and SIC28, Chemicals and Allied Products. We estimate the impacts separately for these industries along with other 2-digit industries within manufacturing.

Unfortunately, direct data on the costs of adoption of $SO_2$ and $NO_x$ emission reduction techniques are not available. However, each utility annually reports Environmental Protection Expenses on Page 429 of Federal Energy Regulatory Commission (FERC) Form No. 1. These expenses refer to all environmental protection, not just $SO_2$ and $NO_x$ reduction techniques. We are able to estimate air pollution reduction expenses which then represent an upper bound on $SO_2$ and $NO_x$ reduction expenses.[2]

On the FERC form, environmental protection expenses are divided into the following categories: depreciation; labor, maintenance, and supplies that are cost-related to environmental facilities and programs; fuel-related costs (operation of facilities, fly ash and sulfur sludge removal, difference in cost of environmentally clean fuels); replacement power costs; taxes and fees; administrative and general; and other. All of the fuel-related costs except operation of facilities are attributed to air pollution reduction expenses. The other expenses are prorated to reflect air pollution reduction expenses in the following way. Book value of various categories of environmental protection facilities is reported on Page 428 of FERC Form No. 1. The proportion of the total book value taken up by air pollution control facilities is used to obtain an estimate of the amount of other expenses due to air pollution control.

Table 1 contains estimates of the cost per KWH of air pollution control, the average cost of electricity per KWH across all customers, and the percent of the total cost accounted for by air pollution reduction costs in Kentucky from 1976 to 1985. Not surprisingly, the cost of air pollution abatement rose faster than the overall cost of electricity. Its share increased from 1.06 percent in 1976 to 4.83 percent in 1980 and further up to 6.24 percent in 1985. Using the GNP implicit deflator we calculate that the real cost of abatement increased eightfold from 1976 to 1985: from .03¢/KWH to .24¢/KWH in 1982 dollars. From 1980 to 1984, the increase was .17¢/KWH to .23¢/KWH, or 32.4 percent.

The largest adjustments to these higher costs takes place in the firms that use electricity most intensively, i.e., those for whom electricity makes up the largest share of total costs. These electricity-intensive firms are located mainly in the manufacturing sector. In order to assess the magnitude of these impacts, we estimate the cost and employment impacts of the increases in electricity rates from 1980 to 1984 by 2-digit manufacturing industry in Kentucky. Data constraints prevented disaggregation to 3- and 4-digit industries within Kentucky. These estimates are obtained using data gathered from 1980 and 1984 *County Business Patterns*, the 1982 *Census of Manufactures*, 1983 *Annual Survey of Manufacturers*, cost function parameter estimates by 2-digit manufacturing industry from Berger (1984), and price elasticities of demand from Hamermesh (1976).

In order to determine which specific 2-digit industries are the most electricity-intensive, we have calculated the percentage of total cost (defined as value of shipments) taken up by expenditures on electricity within each industry in Kentucky. We do this using data from the 1982 *Census of Manufactures*, the most recent available which was gathered for the midpoint of our 1980-84 examination period. The state-specific electricity expenditure data are given for 1981. In order to convert them to 1982 expenditures we apply the rate of change in electricity expenditures between 1981 and 1982 by 2-digit industry at the national level.

TABLE 1. AIR POLLUTION ABATEMENT COSTS AND ELECTRICITY PRICES IN KENTUCKY, 1976-1985

| Year | Abatement Costs (¢/KWH) | Price of Electricity Average for All Customers (¢/KWH) | Abatement Cost Share (Percent) |
|---|---|---|---|
| 1976 | .02 | 1.89 | 1.06 |
| 1977 | .07 | 1.90 | 3.68 |
| 1978 | .09 | 2.61 | 3.45 |
| 1979 | .11 | 2.77 | 3.97 |
| 1980 | .15 | 3.10 | 4.83 |
| 1981 | .21 | 3.59 | 5.85 |
| 1982 | .27 | 4.09 | 6.60 |
| 1983 | .28 | 4.50 | 6.22 |
| 1984 | .25 | 4.17 | 6.00 |
| 1985 | .27 | 4.33 | 6.24 |

Source: Calculated from data supplied by Public Service Commission on Kentucky and FERC Form No. 1, pp. 428-29.

The estimates of the percent of total costs made up by electricity expenditures are given in Table 2. In 18 of the 20 2-digit industries, the electricity cost percentage is fairly small, not exceeding 3 percent. But in SIC28, Chemicals and Allied Products, and SIC33, Primary Metal Industries, electricity costs make up more than 10 percent of total costs. It is in these industries that the initial cost impacts of any increase in the price of electricity are the greatest, as is shown also in Table 2. Higher utility rates cause

TABLE 2. COST AND EMPLOYMENT IMPACTS OF AIR POLLUTION ABATEMENT, MANUFACTURING SECTOR IN KENTUCKY, 1980-1984

| SIC | Industry | Electricity Cost Percent[a] | Percent Cost Impact[b] | 1980 Employment[c] | 1984 Employment[d] | 1980-84 Employment Change | Short-Run Employment Impact[e] | Long-Run Employment Impact[f] |
|---|---|---|---|---|---|---|---|---|
| 20 | Food and Kindred | .56 | .0098 | 19,370 | 17,261 | – 2,109 | – 4 | 2 |
| 21 | Tobacco | .35 | .0061 | 9,702 | 7,666 | – 2,036 | – 1 | – 79 |
| 22 | Textile Mill | 1.68 | .0295 | 7,150 | 6,569 | – 581 | – 3 | 5 |
| 23 | Apparel, Other Textiles | .88 | .0154 | 26,861 | 25,581 | – 1,280 | – 5 | – 428 |
| 24 | Lumber and Wood | 1.42 | .0250 | 9,330 | 8,037 | – 1,293 | – 4 | 9 |
| 25 | Furniture and Fixtures | 1.31 | .0231 | 3,917 | 3,273 | – 644 | – 1 | 14 |
| 26 | Paper and Allied Products | 2.30 | .0404 | 5,769 | 5,659 | – 110 | – 4 | – 22 |
| 27 | Printing and Publishing | .66 | .0116 | 15,583 | 16,031 | 448 | – 2 | – 3 |
| 28 | Chemicals and Allied Products | 13.55 | .2384 | 15,012 | 12,198 | – 2,814 | – 56 | 66 |
| 29 | Petroleum Refining | .77 | .0136 | 1,575 | 1,556 | – 19 | – 1 | – 7 |
| 30 | Rubber, Miscellaneous Plastics | 1.94 | .0342 | 9,280 | 10,005 | 725 | – 5 | 4 |
| 31 | Leather | .78 | .0137 | 3,628 | 2,074 | – 1,554 | – 1 | 6 |
| 32 | Stone, Clay, Glass | 1.98 | .0348 | 7,710 | 6,752 | – 958 | – 3 | – 11 |
| 33 | Primary Metal Industry | 10.03 | .1765 | 18,498 | 15,815 | – 2,683 | – 66 | – 41 |
| 34 | Fabricated Metal | .94 | .0165 | 23,971 | 19,278 | – 4,693 | – 7 | – 57 |
| 35 | Machinery, except Electrical | .84 | .0147 | 40,063 | 33,550 | – 6,513 | – 9 | 47 |
| 36 | Electric/Electronic Equipment | 1.21 | .0213 | 32,292 | 26,586 | – 5,706 | – 11 | 38 |
| 37 | Transportation Equipment | .42 | .0074 | 14,161 | 14,689 | 528 | – 2 | 32 |
| 38 | Instruments | .67 | .0118 | 3,407 | 2,334 | – 1,073 | – 1 | – 36 |
| 39 | Miscellaneous Manufacturing | .82 | .0144 | 3,791 | 3,545 | – 246 | – 1 | 17 |
| | TOTAL | 2.95 | .0519 | 283,876 | 253,005 | – 30,871 | – 187 | – 444 |

[a] Estimated by industry as (1982 Electricity Costs/1982 Value of Shipments) × 100 (Source: *1982 Census of Manufactures*). Only 1981 Electricity costs by industry for Kentucky are reported in the *1982 Census of Manufactures*. Therefore, to obtain 1982 estimates, the 1981 were adjusted by the percentage changes in electricity costs between 1981 and 1982 at the national level using data from the 1983 Annual Survey of Manufacturers.

[b] Estimates by industry as (1982 Electricity Costs/1982 Value of Shipments) × (1980-84 percent change in real statewide average price of electricity per KWH for industrial customers). The 1984 statewide average portion of electricity rates due to air pollution abatement was converted to 1980 dollars using the GNP deflator.

[c] Source: *1980 County Business Patterns*.

[d] Source: *1984 County Business Patterns*.

[e] Estimated as $-S_EN$ ($\%\Delta P_E$) × $EMP_{80}$ where $S_E$ is the share of electricity in total costs (defined as value added plus energy costs) by industry in Kentucky for 1982 (source: *1982 Census of Manufactures, 1983 Annual Survey of Manufacturers*), N = .76 (source: Hamermesh [1976]), $\%\Delta P_E$ = 1.76 (source: estimated from data supplied by Public Service Commission of Kentucky for industrial customers and from FERC Form No. 1, pages 428-29), and $EMP_{80}$ is 1980 employment levels for Kentucky 2-digit industries (source: 1980 County Business Patterns).

[f] Estimated as ($S_EN_{LE}$ = $S_EN$) × $\%\Delta P_E$ × $EMP_{80}$, where $S_E$, N, $\%\Delta P_E$ and $EMP_{80}$ are defined in note e, and $N_{LE}$ is the cross elasticity of labor demand with respect to electricity prices (source: derived from production labor-energy and nonproduction labor-energy cross elasticities reported in Berger [1984] by 2-digit industry).

firms to alter output and perhaps technology, both of which cause changes in employment levels. Employment changed between 1980 and 1984 in Kentucky for a number of reasons besides changes in electricity rates. Employment decreased between 1980 and 1984 in 17 of the 20 two-digit manufacturing sectors. The biggest declines in employment occurred in the machinery, electric, and fabricated metal industries. The largest gain occurred in the rubber and miscellaneous plastics industry. Overall, employment declined by almost 31,000 workers in manufacturing between 1980 and 1984.

Estimates of the amount of the actual change in employment due to increases in air pollution abatement expenditures are given in the last two columns of Table 2. These estimates are based on short-run and long-run cross-elasticities of employment with respect to changes in the price of electricity. The short-run elasticities incorporate employment changes due to changes in output but not changes in the combination of inputs used to produce output, while the long-run elasticities incorporate both. Whether the estimated short-run or long-run impacts are more accurate depends on how quickly long-run adjustments are made. The two estimates represent bounds between which the true effect of increased abatement expenditures fall.

The formula for calculating the employment impacts is discussed in detail in Hamermesh (1986). The exact expression is:

$$\Delta EMP = (S_E N_{LE} - S_E N) \cdot \% \Delta P_E \cdot EMP_{80}$$

where $\Delta EMP$ is the estimated change in employment between 1980 and 1984, $S_E$ is the share of electricity in total costs by 2-digit industry in Kentucky (defined as value added plus energy costs for consistency with the elasticity estimates used), $N_{LE}$ is the cross elasticity of labor demand with respect to electricity calcuated by 2-digit industry from Berger (1984), N is the price elasticity of output demand, $\% \Delta P_E$ is the percentage change in real electricity prices on a statewide basis from 1980 to 1984 using the air pollution cost data from Table 1 and the state average price of electricity in 1980 for industrial customers, and $EMP_{80}$ is the employment level by 2-digit industry in Kentucky taken from Table 2.

Estimates of N by industry are difficult to obtain, so we use an economy-wide value reported by Hamermesh (1976). This economy-wide value is likely to be lower than industry-specific estimates, so our estimates of employment changes due to output changes may understate the true changes. These employment impact estimates assume the only changes are in the price of electricity and output. They allow for no changes in the price of labor, capital, or other forms of energy, and therefore focus on the partial effect of the change in electricity prices. The elasticity estimates on which the employment changes are based are strictly valid only for small changes.

The difference between the short-run and long-run estimates is that in the short-run $N_{LE}$ is assumed to be equal to zero. In other words, it is assumed that no changes in the combinations of inputs used occur which would raise or lower the amount of labor used. The only change in employment comes from changes in output due to a higher price of output.

$N_{LE}$ can either be positive or negative. If $N_{LE}$ is positive, then labor and electricity are substitutes in production. A rise in the price of electricity increases labor use. Production is realigned in a less electricity-intensive and a more labor-intensive manner. The opposite is true if $N_{LE}$ is negative, or labor and electricity are complements in production. For twelve of the 2-digit industries, the estimated $N_{LE}$'s for Kentucky are positive, indicating electricity and labor are substitutes, and in eight they are negative, indicating complements.

The most electricity-intensive industries, SIC28 and SIC33, have the largest short-run employment losses as expected: 56 and 66 jobs. However, these losses are very small when compared to the actual employment change from 1980 to 1984. The same is true for the entire manufacturing sector. The estimated short-run impact is 187 jobs, .6 percent of the 30,781 actual decline in employment. The estimated long-run employment impact for the manufacturing sector is 444 jobs, or 1.4 percent of the actual change. Notably, even the long-run estimate suggests a relatively minor employment reduction due to air pollution abatement expenditures.[3]

Estimates are given for the manufacturing sector only because it is the most electricity-intensive, and the biggest impact occurs there. The impacts in other sectors are proportionately smaller. In 1980, 29.5 percent of all jobs in Kentucky were in manufacturing. Using this and the fact that manufacturing is more electricity-intensive than other sectors, we can produce an upper-bound employment impact of air pollution abatement from 1980 to 1984; 444/.295 = 1504. The overall employment reduction in Kentucky over the same period was 14,352. Thus, at the very most, air pollution abatement accounted for 10.5 percent of the reduction. But this estimate probably vastly overstates the true impact because nonmanufacturing sectors are not as electricity-intensive.

The long-run employment impacts in the last column of Table 2 are actually positive in 11 of 20 industries. This occurs because the effect of substituting into more labor-intensive technologies outweighs the loss in production due to higher electricity rates. SIC28 actually experiences an employment gain although its costs of production have risen. In SIC33, the long-run employment change is negative, but it is less than the short-run change. This indicates a movement toward greater labor intensity, but not enough to offset the loss of jobs due to lower production levels. In some industries, the long-run employment loss is relatively large. For example, in SIC23, Apparel and Other Textiles, the estimated long-run impact is 428 jobs. In contrast, the short-run employment change is quite small. The long-run adjustments to higher electricity rates are what cause the noticeable employment losses for this footloose industry. These adjustments could take the form of altering the production technology away from labor and energy, but also the movement of part of the industry to locations outside Kentucky.

Overall, the impact of increases in utility rates from 1980 to 1984 due to air pollution expenditures has not been large. Even the most electricity-intensive industries suffered only a small increase in costs, at most 0.24 percent. Estimated employment losses in Kentucky manufacturing were at most

444, compared to actual total employment losses of 30,871 in Kentucky manufacturing.

## Potential Impact of Acid Rain Control on Kentucky Coal Use

While existing abatement in Kentucky appears to have had only a small impact, considerable concern exists over potentially large impacts of future efforts associated with acid rain control. Techniques for controlling $SO_2$ and $NO_x$ emissions from existing stationary sources in Kentucky include: flue gas desulfurization, duct sorbent injection, limestone injection, multistage burners, physical coal cleaning, selective catalytic reduction, low $NO_x$ combustion, fluidized bed combustion, fuel switching and blending, and least-emissions load dispatching and production distribution.[4] Most available techniques would not alter noticeably coal purchases in Kentucky because utilities will continue to try to burn local coal which is cheapest. Fuel switching could result, however, in a large shift from high-sulfur Western Kentucky coal to low-sulfur Eastern Kentucky coal.

Twelve different scenarios are considered for abatement of acid rain based on an engineering analysis by PEI Associates (1986). The scenarios are combinations of: amount of emission reduction required, whether or not $NO_x$ reduction is counted along with $SO_2$ reduction in achieving a required amount of emission reduction, and whether or not fuel switching is permitted. To simplify, we focus on results for only the scenarios with the largest and smallest impacts. The least disruptive scenario involves a 360,000 ton-per-year reduction in the combined emissions of $SO_2$ and $NO_x$ and allows fuel switching. This reduction corresponds to an emission limit of 1.2 pounds per million Btu of coal burned. The two most disruptive scenarios involve a 478,000 ton-per-year reduction in $SO_2$. One permits and the other prohibits fuel switching. This reduction corresponds to an emission limit of 0.9 pounds per million Btu. PEI Associates have evaluated the major sources of $SO_2$ and $NO_x$ in Kentucky and estimated the cost of emission abatement using the different techniques described above. They have developed also an algorithm which identifies the least costly way to attain a given level of emission reduction and calculates the cost for each scenario.

Scenarios which preclude fuel switching are expected to have little impact on coal production in Kentucky. Accordingly, we consider only the $360 - SO_2 + NO_x$ – switch scenario and the $478 - SO_2$ – switch scenario for shifts in coal use. The projected impacts on the Kentucky coal market are constructed as follows. Data on the total amount of coal burned in 1985 are obtained for each production unit in the PEI report. The percentages of coal coming from Eastern Kentucky, Western Kentucky, and outside Kentucky are determined for utilities by evaluating the sources of the coal shipped to each plant in 1985. Coal used by industrial sources is assumed to come from either Western or Eastern Kentucky, depending on the location of the plant and the sulfur content of the coal. Whenever the PEI cost minimization algorithm indicates that a source will switch fuels and that source is using Western Kentucky coal, it is assumed that Eastern Kentucky and out-of-state coal will make up the difference keeping the same proportions as before the fuel switching.

Table 3 indicates that for a total reduction of both $SO_2$ and $NO_x$ of 360,000 tons, purchases of Western Kentucky high-sulphur coal will drop by over 984,000 tons. Production in Eastern Kentucky low-sulfur mines is projected to increase by almost 250,000 tons. For a 478,000-ton reduction in $SO_2$ emissions, purchases of Western Kentucky coal will drop by over 2,286,000 tons while production in Eastern Kentucky is projected to increase by almost 1,228,000 tons. Again, production within Eastern Kentucky shifts to low-sulfur mines. The extent of the shift from western to eastern coal in Kentucky depends greatly on the stringency of the acid rain control strategy. Compared to the less stringent scenario, the decline in Western Kentucky coal is more than double under the 478,000 ton scenario and the increase in Eastern Kentucky coal is almost quintupled. Nevertheless, the shifts are extremely small compared to total coal production. Even in Western Kentucky under the stringent strategy the projected loss is less than 6 percent of coal production in Western Kentucky. A falling price of high-sulfur coal will lead to a shift even smaller than 6 percent.[5]

These projections consider only Kentucky users of Kentucky coal, because Kentucky authorities have little control over strategies adopted by other states. The relatively small projected shifts in large part can be attributed to the fact that over 75 percent of Kentucky coal is shipped to other states. If other states permit fuel switching, then the demand for low-sulfur coal will increase sharply. The shifts in coal production are not particularly sensitive to alternative Kentucky control strategies alone.

TABLE 3. SHIFTS IN KENTUCKY COAL PRODUCTION DUE TO FUTURE ACID RAIN ABATEMENT IN KENTUCKY

| Shift/Scenario | 360,000-ton reduction in $SO_2 + NO_x$, fuel switching permitted | 480,000-ton reduction in $SO_2$, fuel switching permitted |
|---|---|---|
| Western Kentucky Change | —984,128 tons | − 2,286,001 tons |
| Percentage of Regional Coal Production[a] | − 2.5 | − 5.9 |
| Eastern Kentucky Change | + 249,650 tons | + 1,227,651 tons |
| Percentage of Regional Coal Production[a] | + 0.2 | + 1.1 |
| Change from High-Sulfur to Low-Sulfur Coal within Eastern Kentucky | + 822,318 tons | + 4,610,254 tons |
| Percentage of regional Coal Production[a] | + 0.7 | + 4.1 |

[a] Percentages are calculated based on 1985 output: 39,020 millions tons for Western Kentucky and 113,251 million tons for Eastern Kentucky.

## Potential Impact of Acid Rain Control on Kentucky Utility Rates, Manufacturing Costs, and Employment

Control strategies imply changes in the price of electricity, costs of manufacturing, and employment in addition to the shifts in coal usage. Again we focus on the control scenarios which yield the extreme impact values; in this section the $360 - SO_2 + NO_x$ – switch scenario and the $478 - SO_2$ – no switch scenario.

To estimate the impact on utility rates, the PEI Associates cost estimates were aggregated to the utility level. Costs were combined with 1985 KWH sold and the average price per KWH sold as calculated from data supplied primarily by the Public Service Commission of Kentucky. The change is an increase of 6.5 percent over the 1985 average rate of 4.3 ¢/KWH. For the less restrictive scenario, the average rate is projected to increase by 0.28¢/KWH. For the more restrictive control scenario, the increase is projected to be 0.79¢/KWH, an 18.2 percent increase. The rate increase would affect all electricity users, but especially commercial and industrial users.

Table 4 reports the estimated increases in costs of production under each scenario by 2-digit industry in the manufacturing sector, the most electricity-intensive sector of the economy. The first column shows the percentage of total costs (defined as value of shipments) made up of electricity costs as taken from Table 2. These percentages are estimated using data from the 1982 *Census of Manufactures*. Then the statewide average percentage increases in electricity rates under each scenario are applied to the electricity cost shares to obtain the percentage increase in costs of production, assuming that output and the prices and quantities of other inputs stay the same. This can be thought of as the initial impact on costs of the increase in utility rates. The biggest impacts on costs under each scenario occur in the two most electricity-intensive industries: SIC28, Chemicals and Allied Products, and SIC33, Primary Metal Industries. Under the highest cost scenario ($478{,}000 - SO_2$ – no switch) production costs in SIC28 increase by 2.48 percent and in SIC33 by 1.83 percent. The increases in costs are smaller for the lowest cost scenario, .88 percent for SIC28 and .65 percent for SIC33.

These cost increases will set off a number of responses, one being a change in the amount of electricity demanded. Estimated declines are obtained by multiplying the percentage statewide average rate increases by short-run and long-run, industry-specific, own-price elasticities of electricity demand obtained from Chang and Chern (1981). They report elasticities for a number of 3-digit SIC industries. We convert these into 2-digit estimates by taking a 1982 employment-weighted average of the 3-digit estimates. The resulting 2-digit estimates are: SIC28, SR: – .482, LR: – 1.33; SIC33, SR: – .629, LR: – 1.36. Even the short-run declines are sizable, from 3.12 percent to 8.79 percent for SIC28 and 4.07 percent to 11.47 percent for SIC33. In the long run, the estimated decreases in electricity use vary from 8.6 percent to 24.26 percent in SIC28 and from 8.8 percent to 24.81 percent in SIC33, depending on the scenario. These decreases in electricity use in response to increases in its price accompany a number of other changes,

TABLE 4. INCREASES IN COSTS OF PRODUCTION AND CHANGES IN EMPLOYMENT DUE TO INCREASES IN UTILITY RATES UNDER ALTERNATIVE SCENARIOS, BY 2-DIGIT MANUFACTURING INDUSTRY IN KENTUCKY

| SIC | Description | Electricity Cost Percentage | 360,000 Ton Reduction – $SO_2 + NO_x$ – Switch | | | 478,000 Ton Reduction – $SO_2$ – No Switch | | |
|---|---|---|---|---|---|---|---|---|
| | | | Production Cost | Employment Change | | Production Cost | Employment Change | |
| | | | Increase | Short Run | Long Run | Increase | Short Run | Long Run |
| 20 | Food and Kindred Products | .56 | .04 | – 26 | 190 | .10 | – 73 | 535 |
| 21 | Tobacco Products | .35 | .02 | – 5 | 287 | .06 | – 14 | 810 |
| 22 | Textile Mill Products | 1.68 | .11 | – 21 | – 138 | .31 | – 60 | – 390 |
| 23 | Apparel, Other Textile Products | .88 | .06 | – 37 | – 2,897 | .16 | – 104 | – 8,177 |
| 24 | Lumber and Wood Products | 1.42 | .09 | – 27 | – 252 | .26 | – 77 | – 711 |
| 25 | Furniture and Fixtures | 1.31 | .08 | – 8 | 559 | .24 | – 22 | 1,577 |
| 26 | Paper and Allied Products | 2.30 | .15 | – 27 | 153 | .42 | – 77 | 432 |
| 27 | Printing and Publishing | .66 | .04 | – 16 | 2 | .12 | – 46 | 6 |
| 28 | Chemicals and Allied Products | 13.55 | .88 | – 338 | 496 | 2.48 | – 953 | 1,401 |
| 29 | Petroleum and Coal Products | .77 | .05 | – 9 | – 1 | .14 | – 26 | – 3 |
| 30 | Rubber, Miscellaneous Plastics | 1.94 | .12 | – 38 | 270 | .36 | – 109 | 763 |
| 31 | Leather, Leather Products | .78 | .05 | – 3 | – 185 | .14 | – 9 | – 522 |
| 32 | Stone, Clay, Glass Products | 1.98 | .13 | – 22 | – 107 | .36 | – 63 | – 302 |
| 33 | Primary Metal Industry | 10.03 | .65 | – 418 | – 218 | 1.83 | – 1,179 | – 617 |
| 34 | Fabricated Metal Products | .94 | .06 | – 40 | – 43 | .17 | – 113 | – 120 |
| 35 | Machinery, except Electric | .84 | .05 | – 57 | – 305 | .15 | – 160 | – 862 |
| 36 | Electric/Electronic Equipment | 1.21 | .08 | – 64 | – 768 | .22 | – 180 | – 2,168 |
| 37 | Transportation Equipment | .42 | .03 | – 18 | – 12 | .08 | – 50 | – 34 |
| 38 | Instruments, Related Products | .67 | .04 | – 6 | 429 | .12 | – 8 | 1,210 |
| 39 | Miscellaneous Manufacturing | .82 | .05 | – 6 | 132 | .15 | – 16 | 373 |
| | TOTAL | 2.95 | .19 | – 1,183 | – 2,410 | 0.54 | – 3,338 | – 6,803 |

among them production levels and the use of other forms of energy. Perhaps the most noticeable socioeconomic impact will be in the form of changes in employment levels. In the short run, employment will decrease in response to an increase in electricity rates because production levels decrease. In the long run, employment may decrease by a greater amount if electricity and labor are complementary in production or may decrease by a lesser amount or actually increase if electricity and labor are substitutes in the production process.

Table 4 also shows estimates of the short-run and long-run employment changes by 2-digit industry within manufacturing under each scenario. The method is the same as that used for the employment changes reported in Table 2. Elasticity estimates are taken from Hamermesh (1976) and Berger (1984), electricity shares are calculated from the 1982 *Census of Manufactures* and the *1983 Annual Survey of Manufacturers*, employment levels are taken from *County Business Patterns*, and the statewide average increases in electricity rates under each scenario are used. The largest short-run employment losses are in SIC28 and SIC33 since they are the most electricity-intensive. The losses range from 338 to 953 jobs in SIC28 and 418 to 1179 jobs in SIC33. However, the long-run changes are smaller in SIC33 and are actually positive in SIC28 because of the substitutability of labor and energy. The biggest long-run employment losses occur in SIC23, Apparel and Other Textile Products. Less attention should be paid to the industry-by-industry estimates than to predicted employment changes for the manufacturing sector as a whole. For the manufacturing sector, the estimated declines in short-run employment range from 1183 for the 360 – $SO_2$ + $NO_x$ – switch scenario to 3338 for the 478 – $SO_2$ – no switch scenario. The long-run declines in employment range from 2410 to 6803, depending on the scenario adopted. These reductions range from .4 percent to 2.7 percent of total 1984 manufacturing employment in Kentucky. Since manufacturing is the most electricity-intensive sector of the economy, the biggest employment impacts will occur there. The 2.7 percent decline also represents an economy-wide upperbound estimate since manufacturing is the most electricity-intensive sector.

## Conclusions

This paper focuses on the control that one state, Kentucky, has over the economic impact of compliance with federal air pollution control requirements. The controls considered include those implemented in accordance with the Clean Air Act and the 1977 Amendments and proposed strategies for compliance with pending acid rain legislation. In contrast to the often used input-output approach, we obtain our estimates using an elasticity-substitution framework. We estimate the impacts of Kentucky's air pollution abatement measures on regional coal production, electric utility rates, and manufacturing costs and employment in Kentucky. From 1976 to 1984 the abatement cost share of the price of electricity rose from 1 percent to 6 percent. The real cost of abatement increased by 32.4 percent from 1980 to 1984. Over the same period, estimated employment declines in Kentucky manufacturing due to abatement were at most 444 employees, compared to the actual employment decline of 30,871. The acid rain abatement scenarios we considered consisted of several combinations of $SO_2$ and $NO_x$ emission reduction and fuel switching. With fuel switching, some coal production will shift from Western to Eastern Kentucky, but under the most restrictive scenario the decrease in production of high-sulfur Western Kentucky coal is less than 6 percent. The most restrictive scenario without fuel switching would induce an 18 percent increase in utility rates. The chemical and primary metal industries would experience the greatest increase in manufacturing cost—less than 3 percent. The employment decline in manufacturing, the most electricity-intensive sector, would be 3338 (1 percent) in the short run and 6803 (2.7 percent) in the long run.

Our projections consider only the effects of Kentucky acid rain control strategies on coal production, electricity rates, manufacturing costs, and employment in Kentucky. The small size of the estimated impacts implies that the acid rain control strategies pursued by other states may produce more noticeable effects. In fact, over 75 percent of Kentucky coal is exported to other states. If other states permit fuel switching, the demand for low-sulfur Eastern Kentucky coal would rise and the demand for high-sulfur Western Kentucky coal would fall. Fuel switching could also cause some states to substitute into low-sulfur Western U.S. coal at the expense of Kentucky coal. If other states install scrubbers so that sulfur content becomes less of an issue, then any adverse impact on the demand for Western Kentucky coal will be dampened. Other forces external to the Kentucky economy could alter our estimates as well. If OPEC and other factors increase the price of oil, coal becomes a more attractive fuel, thus reducing the adverse impact on Kentucky's coal industry. Lower oil prices exacerbate the estimated impacts.

The actions of other states are also important for other industries. If other states pursue strategies which result in smaller increases in electricity rates, the movement of manufacturing firms into and out of Kentucky may be altered. At the margin, firms may be less willing to move into Kentucky, and it is possible that some firms may want to leave. This movement would most likely occur between Kentucky and states having no mandated acid rain control strategy.

This paper looks only at the cost side of compliance with pending acid rain control legislation. The ultimate test of whether such legislation should be adopted depends on whether the benefits exceed the costs. One obvious benefit is cleaner air. However, there are difficult distributional issues involved—other regions such as New England and Canada benefit more than Kentucky does. The distribution of benefits may be less important than the total level of benefits from a national and international point of view. On the cost side, there is the potential adverse effect on the coal market, and higher electricity rates which adversely affect both consumers and producers. Other potential side effects include the costly removal of sludge if a strategy including scrubbers is chosen. While the full costs and thus the net benefits of the proposed legislation do not depend critically on the compliance strategies of any one state, they certainly depend on the overall set of compliance strategies of the states affected by the legislation.

NOTES

1. Other studies of the acid rain problem have analyzed some of the same issues as this report. The Office of Technology Assessment of the U.S. Congress completed an extensive examination of acid rain in 1984. ICF, Incorporated, was commissioned to study acid rain by a number of interest groups; their report was published in 1985. The Congressional Budget Office of the U.S. Congress considered the effect of the Clean Air Act on utilities and the coal markets in a 1982 report. Each of these studies, naturally, was national in scope, and thus assumed uniform national policies on pollution abatement.

   Another related strand of literature is the work on KLEM (capital-labor-energy-materials) models. The seminal paper is by Hudson and Jorgenson (1974). Berndt and Khaled (1979) and Berger (1984) incorporate their approach in analyzing energy substitution questions.
2. As noted by one reviewer, the expenses are an upper bound on true expenses for another reason also. The expenses are self-reported and utilities have incentive to overreport control costs.
3. The long-run estimates are based in part on estimates of $N_{LE}$ taken from Berger (1984). Another study, Field and Grebenstein (1980), reports estimates of $N_{LE}$ for 10 of 20 two-digit SIC manufacturing industries including the most electricity-intensive ones: 20, 24, 28, 29, 30, 32, 33, 34, 37, and 38. For these ten industries, the estimated employment change shown in the last column of Table 2 is − 39. Using the Field and Grebenstein (1980) elasticities, the estimated employment change is 77. While positive, the estimated change is small, which is consistent with the results reported in Table 2.
4. See PEI Associates (1986) for a discussion of the applicability of these techniques to Kentucky power plants.
5. For the stringent scenario, fuel switching is projected to reduce demand for Western Kentucky coal by 5.9 percent. Using elasticity estimates from Ali, Harvey and Stewart (1981), the price of Western Kentucky coal can be expected to fall 11.6 percent in the short run and 6.5 percent in the long run. Again using elasticity estimates from Ali, Harvey and Stewart (1981) the projected 1.1 percent increase in demand for Eastern Kentucky coal can be expected to increase the price of this coal by 2.6 percent in the short run and 1.9 percent in the long run. The price changes will mitigate in part the shift to Eastern Kentucky coal. Because the PEI Associates study assumed constant coal prices, our estimates of (small) shifts are overestimates.

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