Trade-offs Between Severance Tax Revenues and Coal Mining Employment

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A severance tax can provide local jurisdictions with additional revenues to finance economic development, yet the imposition of a tax may create coal industry employment losses. This research analyzes this issue by examining the demand for Pennsylvania steam coal, providing estimates of the unconditional own-price elasticities of demand for coal in each of two demand regions. These estimates in conjunction with labor/output coefficient estimates are used to determine the extent to which coal employment in a region already witnessing slow mining industry growth will be negatively affected.

A majority of those states possessing significant coal reserves have imposed coal severance taxes, either ad valorem or specific. Pennsylvania, although historically a major coal producing state, has not legislated a severance tax on coal, but proposals to adopt a severance tax as a means of generating additional state and local revenues have been made. A severance tax on Pennsylvania coal would clearly provide additional funds to the Commonwealth and could be structured to provide revenues for local economies, revenues that proponents argue are badly needed during this era of Federal fiscal restraint. But it is equally apparent that a severance tax would have negative impacts as well. Of particular concern is the potential negative impact that such a tax would have on coal industry employment. Given the high unemployment rates recently witnessed in rural Pennsylvania, a severance tax on coal could further exacerbate this problem in rural areas dependent on coal mining activity.

Perspective

In 1982, approximately 75 percent of the coal consumed in the New England and Middle Atlantic Census Regions was purchased by electric utilities, with Pennsylvania being the dominant supplier.[1] Although a portion of Pennsylvania's coal supply is used to produce coke, utilized by residential and commercial consumers directly, and purchased for other industrial uses, these purchases are small compared to those made by electric utilities. Since electricity generation is the predominant use of Pennsylvania coal, steam coal used to generate electricity is the focus of this study.

Depending on the structure of the market for Pennsylvania coal, a severence tax may negatively affect consumers, producers, or both. Fuel adjustment clauses legislated during the 1970s allowing electric utilities to pass on fuel cost increases directly to electricity consumers mean that a tax on coal affecting the utilities will have a direct impact on consumers of electricity in the Northeast. Coal producers may also be affected, with production of coal in the aggregate being curtailed by the higher production costs associated with the imposition of a severance tax. Given a tax, marginal mines currently earning low rates of return may no longer find it profitable to operate. If the aggregate quantity of coal mined is reduced as a result, it is reasonable to expect that mining employment will decrease in the long run. The burden of a severance tax on coal will most likely be shared between consumers in the form of higher utility rates, producers in the form of lower profits, and coal miners in terms of job losses.

The spatial distribution of Pennsylvania's coal supply between Pennsylvania and those states importing Pennsylvania coal will also affect the distribution of a tax. At present, approximately thirty percent of Pennsylvania's steam coal supply is exported to other states in Pennsylvania's market area, defined by

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[1] Estimate derived from U.S. Department of Energy. *Coal Distribution, January-December, 1982.* Washington, **D.C.** March, 1983.

Melmed using Hogarty's LOFI/LIFO[2] test to include New York, Pennsylvania, New Jersey, Massachusetts, New Hampshire, Delaware, and Maryland. While tax revenues will accrue to Pennsylvania and the burden of a tax will affect coal producers, miners and mining communities in Pennsylvania alone, affected consumers may be geographically diverse. If coal or products utilizing coal as an input are exported from Pennsylvania to other states, consumers in these states may confront higher prices. The extent to which the tax can be exported to other states will depend on the own-price elasticity of demand for Pennsylvania coal in the importing region and on the proportion of Pennsylvania's supply that is exported.

This research explores the demand for Pennsylvania steam coal both from within Pennsylvania and by those states importing Pennsylvania coal. Since the impacts of a coal severance tax depend on the characteristics of steam coal demand, conditional demand functions are estimated for each of the two demand regions. Estimates of the conditional own-price elasticities of demand are made and are converted to unconditional own-price demand elasticities by considering the feedback effects of changes in the quantity of electricity demanded on coal consumption, given that the initial impetus was a tax-induced increase in the price of coal. The unconditional elasticity can be used with reasonable assumptions about the elasticity of coal supply to analyze the impacts of alternative tax rates on steam coal production. Once production change estimates have been determined, the change in steam coal output due to a severance tax can be translated into changes in labor utilization by coal type (bituminous or anthracite) and by mining method (underground or surface).

Empirical Analysis

Several studies have estimated the demand for steam coal (Labys, Paik and Liebenthal; Melmed; Atkinson and Halvorsen). The quantity of coal demanded can be modeled as a function of the price of coal, the prices of substitute fuels, and the quantity of electricity generated, since the demand for steam coal is a derived demand. Since observed price and quantity data reflect the interaction of supply and demand, the demand for steam coal must be estimated in a simultaneous equation framework. The approach used here is an adaption of the models used by Labys *et al.* and Melmed in which steam coal demand and steam coal price equations are simultaneously estimated. For this study, the quantity of coal demanded (Qn^c) was initially modeled as a function of the price of coal (Pi_t^c), the prices of fuel oil and natural gas (P_{it}^f and Pit"), the quantity of electricity generated lagged one time period ($Qit\text{-}i^e$) and the change in coal stocks ($ASTK_{It}$). The price equation included the following independent variables: quantity of coal (Qit^c), average rail rates (R_{It}) and the average productivity of mining labor (APLit). The following specifications were used to estimate steam coal demand (eq. 1) and steam coal price (eq. 2):

(1) $Q_{it}^c = f(P_{it}^c, P_{it}^f, Pit^n, Q_{it-i}^e/\Delta STKit, €_{it})$

(2)

where:

Q_{it}^c = quantity of coal consumed in state i, in year t;

P_{it}^c = average delivered price of coal in

P_{it}^f = average delivered price of fuel Oil in state i, in year t (deflated);

P_{it}^n = average delivered price of

(deflated);

Q_{it-}^e = total generation of electricity in state i, in year t — 1;

$\Delta STK_{i\,t}$ = STKit - STKu-i, where STK_{it} represents the stock of coal held by electric utilities in state i, in year t;

R_{it} = average rail rate in state i, in year t (deflated);

APL_{it} = average productivity of mining labor in state i, in year t;

$€_{it}$ = random error for state i, in year t;

δ_{It} = random error for state i, in year t.

The two-equation simultaneous equation system was estimated using secondary data obtained from sources published by the Federal Power Commission, U.S. Department of Energy, U.S. Bureau of Mines, and the coal

[2] Hogarty's (1975) test requires that two criteria, LIFO (little in from outside) and LOFI (little out from inside), be simultaneously satisifed for market identification.

industry. All analyses were conducted on a Btu basis to ensure data compatibility.

The equations were estimated separately for Pennsylvania and for the remaining six states consuming significant quantities of Pennsylvania coal. The six states included in the importing region were Delaware, Maryland, New York, New Hampshire, Massachusetts, and New Jersey. A separate demand function for Pennsylvania was estimated to yield additional information on the spatial impacts of severance tax incidence. Due to the high cost of transporting coal, Pennsylvania produces large quantities of coal for consumption within the state at delivered prices significantly lower than prices paid by states importing Pennsylvania coal. The close proximity of Pennsylvania utilities to a relatively low-cost fuel source may cause the own-price elasticity of demand for coal by Pennsylvania (TJ_P^C) to differ from the own-price elasticity of demand ($T?O^C$) estimated for the other Northeastern states. In addition, a Chow test confirmed that the estimation of the demand for steam coal could be improved by estimating the demand by Pennsylvania separately.

Two-stage least squares (2SLS) was used to estimate the Pennsylvania steam coal demand function. The demand function for the six-state region was estimated using 2SLS in conjunction with the Parks Method to analyze pooled time-series cross-section annual state data. In both cases, the equations were initially estimated using post-Embargo data.

The six-state demand equation was readily estimated using the pooled 1973-1982 data, but the Pennsylvania function was difficult to estimate using post-Embargo data, since coal prices and coal consumption have simultaneously increased substantially since 1973. The difficulty associated with estimating Pennsylvania's demand function over this period was exacerbated by the low number of observations, but supports Bohi's contentions regarding the instability of coal markets since the Embargo. Consequently, to estimate Pennsylvania's response to a coal severance tax, the data set used to estimate equation (4) below included annual data from 1960 through 1982. The second stage demand equations for each demand region are shown below, with coefficient t-statistics being indicated in parentheses:

DEMAND FUNCTION FOR SIX IMPORTING STATES:

$$(3) \quad Q_{it}^c = 37.073 - 0.423\, P_{lt}^c + 0.392\, Q_{it}\text{-}1^e$$
$$\qquad\qquad (-1.242) \qquad (19.640)$$

PENNSYLVANIA DEMAND FUNCTION:

$$(4) \quad Q_{it}^c = 43.444 + 2.194\, P_{lt}^c + 2.630\, Q_{it}\text{-}i^e$$
$$\qquad\qquad (0.539) \qquad (18.567)$$

where:

Qit^c = quantity of coal consumed in state i, in year t, in trillion Btu;

P_{it}^c = average delivered price of coal in state i, in year t, in cents/10^6 Btu (defeated);

$Q_{it}\text{-}i^e$ = total generation of electricity in state i, in year t — 1, in trillion Btu.

Several variables, notably substitute fuel prices were eliminated from the original model specifications due to lack of statistical significance. This may reflect lack of fuel flexibility in existing generation units, with the demand for coal being relatively inelastic, at least in the short run, given the existing capital stock. The influence of changes in coal stocks held by utilities was also found to be statistically insignificant.

In contrast, the electricity generation variable lagged one time period was found to be highly significant in both regions, with variations in electricity generation accounting for a large proportion of the variation in coal purchases. The coefficient of the price variable was found to be negative for the six-state equation, as expected. However, the coefficient for the price of coal variable in the Pennsylvania equation was positive but had a very low t-statistic (0.539), indicating that the response of coal consumption to changes in coal prices approximately equals zero, at least in the range of prices being considered. This result was not surprising, given the large differential between steam coal and fuel oil prices. The Pennsylvania equation estimated here conforms with previous observations that changes in steam coal prices have had little impact on steam coal use in Pennsylvania, but that changes in electricity demand have caused coal consumption to increase substantially in recent years.

Derivation of the Conditional and Unconditional Elasticities of Demand

The conditional own-price elasticity of demand for steam coal indicates the responsiveness of the quantity of coal demanded to a change in steam coal price. Based on equations (3) and (4), conditional estimates of the own-price elasticity of demand (7?°) for Pennsylvania and the other Northeastern states in Pennsylvania's market area were derived using average 1980-82 coal price and quantity data. For the six-state importing region, TJ_O^C equalled —0.2077, while the conditional own-price elasticity of demand for Pennsylvania ($T7_P^C$) equalled O.[3] In both cases, the conditional own-price elasticity of demand is very inelastic. However, these elasticities are conditional on the quantity of electricity demanded which may change in response to changes in the price of steam coal, and further influence the quantity of coal demanded. The unconditional elasticity of demand (17°*) will reflect the total responsiveness of coal demand to changes in the price of coal by incorporating the feedback effects through the electric energy sector. The conditional and unconditional elasticities can be related by letting $C(P^C, Q^e)$ be the conditional demand for steam coal as a function of the price of coal (P°) and the total amount of energy generated in the demand region (Q^e), and $E(Pj^e)$ be the demand for electric power by power class j, where Pj^e is the average price of electricity to the jth class. Prices paid by the three major power classes (residential, commercial, and industrial) are determined by state utility commissions according to the formula $Pj^e = F^\wedge P^0)$. Using these relationships, the unconditional own-price elasticity of demand ($i7^c$*) can be written:

(5)
$$\eta^{c*} = \eta^c + \epsilon^{ce} \sum_{j=1}^{n} (\lambda_j \eta_j^{ee} \epsilon_j^{ec}) \qquad j = 1, 2, 3.$$

where:

η^{C*} = unconditional own-price elasticity of demand for steam coal;
η^{C} = conditional own-price elasticity of demand for steam coal;
ϵ_i^{ce} = elasticity of steam coal demand with respect to the quantity of electric power generated;
λ_i = proportion of total electricity pur chased by power class j;
η_i^{ee} = own-price elasticity of demand for electricity by power class j;
ϵ_i^{ec} = elasticity of the administered price of electricity to power class j with respect to the price of coal.

Beierlein, Dunn, and McConnon provide estimates of the own-price elasticity of demand ($T?j^{ee}$)[4] for electricity for each of the three power classes in the Northeast region (i.e., j — 1, 2, 3). The elasticity of steam coal demand with respect to electricity generation (e^{ce}) for each demand region can be derived from equations (3) and (4) in conjunction with average 1980-82 coal production and electricity generation data. These estimates can be used with the conditional own-price elasticities of demand to find the unconditional own-price elasticity for each demand region, given specific assumptions regarding ϵj^{ec}, the elasticity of the administered price of electricity to sector j with respect to the price of coal. Given that most states have adopted fuel adjustment mechanisms that allow utilities to pass on fuel cost increases to electricity consumers, it is reasonable to assume that coal price increases will be passed through to electricity consumers in proportion to the cost of coal as a percentage of the total cost of electricity. Using these concepts, the unconditional own-price elasticities of steam coal demand for Pennsylvania and for the six-state region equalled —0.0061 and —0.2122, respectively. In both cases, the unconditional own-price elasticity of demand was found to be more elastic than the conditional elasticity of demand, as would be expected. These elasticities are critical for assessing the impacts that imposition of a severance tax could have on mining employment.

Analyzing the Impacts of a Severance **Tax** on **Pennsylvania Coal**

To analyze the impacts of a severance tax on steam coal prices and steam coal production, the unconditional own-price elasticity of demand (η^{C*}) as well as the elasticity of coal supply (ϵ_s^c) must be known. The distribution of impacts will depend on these elasticities and the magnitude of the tax imposed. The uncon-

[3] Since $5Qit^o/dpit^c$is statistically equivalent tc zero for Pennsylvania, the conditonal own-price elasticity of demand ($3Qi_t^c$ • Pit^0)/ (3Pit° • Qit^0) is also approximately equal to zero.

[4] Beierlein, *et al.* estimated *t j *ᶠ for* the Northeast based on 1967-1977 data. The elasticities were estimated using a combination of error components methods and seemingly unrelated regressions.

ditional own-price elasticity of demand for Pennsylvania coal in each demand region has been estimated here. Although the elasticity of supply for Pennsylvania coal is believed to be relatively elastic in the long run, the relationships embodied in e_s^c are particularly difficult to estimate accurately without detailed technical information. The elasticity of supply for coal will not be estimated here. Rather, a different approach will be taken: By assuming alternative values for e_s^c, the range of employment losses and tax revenue gains created by a tax can be determined.

From a development perspective it is particularly desirable to know the maximum potential mining employment losses projected to occur as a result of tax imposition. If large numbers of mining employment opportunities are lost in rural Pennsylvania as a result, the wisdom of imposing a severance tax should be questioned. This is particularly true if the number of jobs lost is large compared to the revenue generated. The "worst case" scenario analyzed here provides an upper limit on employment losses and a lower limit on tax revenues generated. Given the estimated unconditional price elasticities, the "worst case" scenario would occur if supply was perfectly elastic. Alternatively, minimum losses in mining employment would equal zero man-days of employment, corresponding to a "best case" scenario where coal production losses equal zero and tax revenue is maximized.

The impacts of alternative specific severance tax rates on coal prices and production are illustrated under a "worst case" scenario in Table 1. Alternative tax rates are applied to the average delivered price of steam coal in each demand region (Pennsylvania and the six importing states), using 1983 observed prices as a base. Using estimates of the percentage change in the price of steam coal due to a tax, changes in the quantity of steam coal supplied by Pennsylvania given a tax can be derived using the unconditional own-price elasticities of demand estimated for each region. Changes in steam coal output under a "worst case" scenario are derived separately for each region and then summed to yield estimates of the total change in steam coal output.

Due to the inelastic nature of the demand for Pennsylvania steam coal, changes in coal consumption due to a severance tax on steam coal are small, even under a "worst case" scenario. This is particularly true for Pennsylvania coal sold to Pennsylvania's electric utilities. When the delivered price of coal increases by $0.50 to $2.00 per ton, coal purchased in Pennsylvania maintains its substantial price advantage over fuel oil. When the delivered price of coal increases, electric utilities continue to purchase coal in quantities comparable to pre-tax consumption rates, although the resulting higher electric rates cause some decrease in electricity consumption and thus some decrease in coal consumption. This

Table 1. Steam Coal Price and Quantity Change Estimates with Varying Specific Tax Rates Under a "Worst Case" Scenario

Origin/Destination	Specific Tax Rate ($/Short Ton)	Average Delivered Price with Tax ($/Short Ton)[a]	Change in Consumption of Pennsylvania Steam Coal (Short Tons)[b]
Pennsylvania to Pennsylvania	0.00	35.59	0
	0.50	36.09	- 2,087
	1.00	36.59	- 5,614
	1.50	37.09	- 8,421
	2.00	37.59	- 11,228
Pennsylvania to Importing Region	0.00	45.77	0
	0.50	46.27	- 30,803
	1.00	46.77	- 61,605
	1.50	47.27	- 92,411
	2.00	47.77	-123,213
Pennsylvania to All Regions	0.00	38.31	0
	0.50	38.81	- 33,610
	1.00	39.31	- 67,219
	1.50	39.81	-100,832
	2.00	40.31	-134,441

[a] Based on 1983 observed prices for Pennsylvania steam coal.
[b] Based on 1980-1982 average coal consumption by electric utilities from Pennsylvania's steam coal supply.

process is reflected in the quantity change estimates for the Pennsylvania demand region in Table 1.

Similarly, changes in coal consumption in the six-state importing region reflect the relatively inelastic demand for coal in that region. However, the change in coal utilization due to a tax levied on Pennsylvania coal is greater in the importing region than in Pennsylvania. This may reflect the greater importance and use of alternative generation fuels in these states as well as the smaller relative difference between coal and fuel oil prices. While there is a greater negative output response to a tax in the importing region, this response is still very small. If the elasticity of supply (e_a^c) is less than the supply elasticity assumed under the "worst case" scenario, changes in the quantity of Pennsylvania coal imported to this region will be even smaller.

Changes in coal consumption in Table 1 can be translated into changes in coal industry employment using simple output-employment relationships estimated in Findeis and Shortle. The equations embodying these relationships for Appalachian coal are included in Appendix A. Output-employment relationships were estimated for the two coal ranks found in the Appalachian region, bituminous and anthracite, and for the two predominant mining methods, surface and underground.

The equations in Appendix A were estimated using annual state data from 1960 through 1980 for those states mining significant quantities of coal in Appalachia. Employment measured as annual man-days of employment was modelled as a function of coal production and other exogenous variables influencing coal labor productivity. Until the early 1970s the coal industry experienced substantial growth in labor productivity on average throughout the U.S. Productivity growth reflected both the adoption of advanced mining methods in both surface and deep mining and the growing percentage of total output obtained by surface mining methods. However, in the early 1970s this trend reversed. The cause of this reversal is widely attributed to the Federal Coal Mine Health and Safety Act of 1969. Factors influencing average productivity over time are incorporated in the equations in Appendix A by inclusion of a time variable and a dummy variable for the Federal Coal Mine Health and Safety Act of 1969 for both coal types and mining methods, while regional variations in factors influencing employment such as geologic conditions are incorporated by inclusion of state dummy variables. Other variables hypothesized to better capture productivity trends (e.g., a time-output interaction variable) were initially included but were rejected.

The output-employment relationships in Appendix A were used in conjunction with the output changes in Table 1 to determine the employment impacts of severance taxes under a "worst case" scenario. Since most of the anthracite coal mined in Pennsylvania is sold within Pennsylvania and not exported, changes in the quantity of coal exported were assumed to affect only bituminous coal employment. Changes in the quantity of coal used in Pennsylvania was assumed to affect both coal ranks, anthracite and bituminous.

Table 2 includes the resulting changes in coal mining employment by demand region as well as total losses in mining employment in Pennsylvania as a result of severance taxes on steam coal. In Table 2 employment losses are calculated for alternative specific tax rates. Again, reflecting the inelastic nature of the demand for steam coal, these losses are small, even under a "worst case" scenario.

The total losses in coal mining employment

Table 2. Changes in Coal Mining Employment by Coal Rank and Mining Method Under a "Worst Case" Scenario

Specific Tax Rate ($/Short Ton)	Employment Change Attributable to Severance Tax[a]				
	Bituminous		Anthracite		
	Underground	Surface	Underground	Surface	Total
	(annual man-days of labor)				
0.50	-1,378	765	- 3	-10	-2,156
1.00	-2,757	-1,530	- 6	-19	-4,312
1.50	-4,135	-2,295	- 9	-29	-6,468
2.00	-5,513	-3,059	-12	-40	-8,624

* Estimated using output-employment equations in Appendix A in conjunction with output change estimates in Table 1.

Table 3. Changes in Coal Mining Employment and Severance Tax Revenues Under a "Worst Case" Scenario

Specific Tax Rate (S/Short Ton)	Employment Change Attributable to Tax (annual man-days of labor)	Severance Tax Revenues (mil. $)
0.50	-2,156	23,022
1.00	-4.312	46.044
1.50	-6.468	69.066
2.00	-8,624	92.087

under alternative tax rates are compared in Table 3 to the tax revenue generated. The estimates in Table 3 represent the *maximum* employment losses due to taxation compared to the *minimum* severance tax revenues that could be generated given alternative tax rates. If the elasticity of supply is more inelastic than that assumed under the "worst case" scenario, employment losses will be less than in Table 3, while revenues will be more. It is likely that this will be the case.

Conclusions and Implications

The unconditional elasticities of steam coal demand in the Northeast will have significant implications for the distribution of impacts resulting from the imposition of a severance tax on Pennsylvania coal. In this study the demand for steam coal was shown to be very inelastic in Pennsylvania and in those states in Pennsylvania's market area. The unconditional elasticities estimated in this study imply that consumers of Pennsylvania steam coal and ultimately consumers of electricity will be most affected by severance taxes levied on Pennsylvania coal, with coal miners and producers being affected to a lesser extent.

The estimates in Table 3 indicate that a severance tax will not have a major impact on mining employment in Pennsylvania. However, this result is contingent on Pennsylvania's ability to maintain its market advantage in the Northeast. Given that a severance tax on Pennsylvania coal can be passed along, in large part, to the electric utilities and to electricity consumers, increases in the post-tax delivered price of Pennsylvania coal may severely weaken Pennsylvania's market advantage, encouraging coal imports. If this is the case, the mining employment impacts may be greater than estimated here.

Whether or not Pennsylvania's position as the dominant supplier of coal to the Northeast is threatened or diminished will depend on the ability of other coal-producing states to supply coal to the Northeast at prices competitive with Pennsylvania's post-tax price. At present, the delivered prices of coal in Pennsylvania from coal-producing states bordering Pennsylvania are on average higher than the delivered price of Pennsylvania coal within Pennsylvania. This may partially reflect the high cost of transporting coal. However, if Pennsylvania loses this advantage, unemployment in rural areas of Pennsylvania which have been witnessing high unemployment rates will be further exacerbated.

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Table Al. Coal Employment Equations for the Eastern U.S. Coal Production Region[a]

Anthracite: Underground

$L_{lt}^{a} = -213969 + 0.2249Q_{lt}^{a} + 217641D_{t}$ — R^2 = 0-975

(-2.871) (16.441) (3.124) — F = 335.818

Anthracite: Surface — n = 20

$L_{2t}^{a} = 161162 + 0.0626Q_{2t}^{a} - 160281 + 143341D_{t}$ — R^2 = 0.967

(1.097) (4.694) (-3.348) (4.925) — F = 135.041

*Bituminous: Underground** $L_{lrt}^{b} = 3884086 + 0.08900_{m}^{b} - 256687S_{1(} - 4120526S_{at} - 3037636S_{3t}$

n = 18 R^2 = 0.977

(15.536) (1.952) (-1.594) (-15.789) (-14.063) — F = 649.509

$- 3790250S_{4t} - 1908278S_{5t} + 4017257S_{6}t + 518378D_{t}$ — n = 133

(-15.305) (-10.707) (13.018) (6.213)

Bituminous: Surface[0]

$Lart'' = 52808.431 + 0.0426Q_{2r}t^{b} + 12290t - 764072S_{lt} - 175405S_{2t}$ — R^2 = 0.922

(0.623) (15.753) (3.112) (-7.933) (-1.605) — F = 181.856

$- 325517S_{3t} - 161633S« - 2l0621S_{5t} - 120262S_{6t}$ — n = 132

(-4.365) (-1.541) (-2.156) (-1.455)

[*] t-statistics are shown in parentheses.

[b]Includes labor employed in mechanical cleaning plants.

Symbols:

L_{it}^{a} = annual man-days of labor employed in anthracite mining by mining method i in year t;

L_{in}^{b} = annual man-days of labor employed in bituminous mining by mining method i, in state r, in year t;

Q_{it}^{a} = anthracite production by mining i in year t;

Q_{irt}^{b} = bituminous production of mining method i, in state r, in year t;

D_{t} = legislative dummy variable for the Federal Coal Mine Health and Safety Act of 1969(1 = legislation in effect; 0= legislation not in effect);

t = time trend variable

S_{rt} = state dummy variables for state r in year t.