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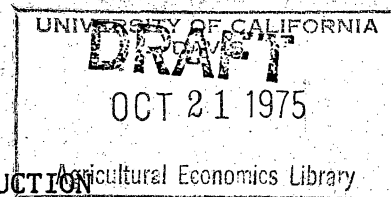
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LAND RECLAMATION AND STRIP MINED COAL PRODUCTION

IN APPALACHIA

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To be presented at the
American Agricultural Economics Association Annual Meeting
Columbus, Ohio, August 10-13, 1975

ORNL-NSF Environmental Program
Research sponsored by the National Science Foundation RANN
Program under Union Carbide Corporation's Contract with the
U.S. Energy Research and Development Administration

Systems Studies of Coal Production Program
Analysis & Evaluation Department
Energy Division

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Oak Ridge, Tennessee 37830

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LAND RECLAMATION AND STRIP MINED COAL PRODUCTION IN APPALACHIA*

William W. Lin, Robert L. Spore & Edmund A. Nephew**

ABSTRACT

Session Number 32

1

Session Title Land, Water and Energy

This study quantifies the short-run impacts of reclamation on strip mining cost, coal price, production and employment in Appalachia. Full reclamation would have reduced strip-mined coal production by 7.5 million tons, raised coal price by \$0.35 per ton, and cost 518 employment opportunities in the Appalachian coal industry in 1972.

Key words: strip mining, reclamation, process analysis

*Research sponsored by the National Science Foundation RANN Program under Union Carbide Corporation's contract with the U.S. Energy Research and Development Administration. The perceptive comments of R. S. Carlsmith, G. S. Maddala, and W. S. Chern have improved the quality of the paper.

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LAND RECLAMATION AND STRIP MINED COAL PRODUCTION IN APPLACHIA

I. Introduction

Several recent reports¹ of the energy situation in the United States have indicated that domestic coal supplies will likely play an essential role in the Nation's energy future. Yet, the promise of coal will largely be dependent upon the kind of national energy policy that eventually is chosen from the several alternatives now under discussion.

One of the most significant and controversial energy policies now under consideration is the proposed Federal regulation of coal surface mining. While control of the environmental degradation resulting from surface mining is clearly a vital environmental issue whose time has come, the problem is made complex by the possible adverse short-run impacts on coal production cost, delivered prices of coal, strip mined coal production and employment. Such concerns are legitimate at a time when independence of foreign supplies of energy is desired, and when energy prices are a significant component of domestic inflation. Quantification of the impacts of land reclamation on coal production cost, delivered prices of coal, strip mined coal production and employment is, therefore, essential in formulating energy policy.

In 1972, Appalachia² produced about 129 million tons of strip mined bituminous coal, which accounts for 47 percent of the total U.S. strip mining production of bituminous coal. "Without proper land reclamation, thousands of square miles of surface-mined 'moonscape' will be left as a legacy to future generations; large portions of some Appalachian states already have this appearance" (Dials and Moore, p. 15). Yet, for the

second time in five months, the President has vetoed a strip-mining bill which would forbid strip mining if the land cannot be reclaimed to its approximate original condition. The rationale for the President's veto was said to be based on estimates that the legislation would reduce coal production by as much as one-fifth of current production and cost 36,000 jobs in Appalachia³.

This paper attempts to provide some empirical evidence of the short-run impacts of land reclamation on coal production cost, delivered prices of coal, strip mined coal production and employment in Appalachia. In section II, a process analysis model is developed and applied to obtain preliminary estimates of the impact of surface mining regulations on costs of coal surface mining and coal supply in Appalachia. Then, an econometric model of the bituminous coal industry in Appalachia encompassing supply, demand, and price relations are developed and estimated in section III. In section IV, coal supply and demand curves are integrated to analyze the short-run impacts of land reclamation on coal price, strip mined coal production, and employment in Appalachia. Major conclusions are then summarized in the last section.

II. Reclamation and Costs of Coal Surface Mining: A Process Analysis Model

The strip mined coal marginal cost curves (with and without reclamation) show a set of output-cost relations, each providing minimum selling price for specified levels of coal production. Under the condition of competitive market structure, the marginal cost curves are equivalent to industry supply curves when marginal cost exceeds the minimum average variable cost. Although the concentration ratio in Appalachia is quite high, in 1970 the four largest coal companies accounted for 32.1% of the total coal

production in Appalachia, there is evidence that entry and exit to the industry is relatively easy (Kaufman). Therefore, market concentration is of some concern but not necessarily an indicator of deterioration in competitive structure or performance of the bituminous coal industry in Appalachia. Assuming a competitive structure, the coal supply curves were derived using the following process analysis model:

$$\begin{aligned} &\text{Minimize} && Z = C'X \\ &\text{subject to} && A X \leq b \\ &\text{where} && b = [b_1, \dots, b_i, \dots, b_m]' \\ &&& b_i = b_i^0 (1 \pm \delta k) \\ &\text{and} \end{aligned}$$

Z = value of the objective function (total variable cost),

c' = a (1 x n) row Vector of unit variable costs,

X = a (n x 1) column vector of levels of the possible production processes⁴, x_j , in terms of tonnage of coal extracted,

A = a (m x n) matrix including the following elements:

- (1) input-output coefficients denoting the amount of the i th constrained resources consumed per unit of process j ;
- (2) Coefficients (either -1 or 1) appearing in the material (inter-process) balance constraints.
- (3) Coefficients appearing in the land reclamation constraints.

b = a (m x 1) column vector of constraints including labor and equipment availabilities⁵, a pre-specified coal production level (b_i), right hand sides of material balance constraints and land reclamation constraints, if appropriate.

b_i^0 = the 1972 base-year strip mined coal production,

δ = a percentile increment in output for each corresponding observation along the cost curve,

k = a constant integer varying parametrically from zero to a maximum possible value at which the production of coal first becomes infeasible or simply irrelevant.

To reflect the differences in the regional characteristics of mining site and coal deposit, and the prevailing prices of labor, equipment, and other input material in the model, the coal producing region of Appalachia is disaggregated into three homogeneous producing sub-regions: (1) Northern Appalachia; (2) Central Appalachia; and (3) Southern Appalachia. Definitions of these regions, together with a statement of the physical parameters which describe the mining conditions in each region are presented in Table 1.

Table 2 summarizes the results of the process analysis.⁶ The reader is cautioned that these results must be considered preliminary pending further validation. The marginal cost at each output level was found by the shadow price corresponding to the output constraint. As expected, the marginal cost curves increase in step functional form, and confirm the classical shape of marginal cost curves as they rise over the range of output. In addition, a comparison of the average costs at different pit fill factors⁷ for a given output level provides estimates of the cost of reclamation.⁸ For example, the cost of obtaining 100% rather than zero backfilling while maintaining 1972 output would have been \$0.75 per ton in Northern Appalachia.

Table 1. Description of Appalachian Sub-regions

Sub-region	Production parameters		
	Average terrain angle (deg)	Seam thickness (inches)	Maximum overburden height (ft)
1. Northern Appalachia (including Pa., Md., Ohio, and Districts 1, 3, 6 of Northern W. Va.)	15	42	110
2. Central Appalachia (including Districts 7 and 8 in Southern W. Va., Va., and Upper-east Tn.)	23	50	85
3. Southern Appalachia (including Alabama and District 13 in Tn.)	15	30	90

Table 2. Estimated average and marginal costs of coal surface mining in Appalachia, 1972

Production level (1,000 tons)	Zero backfill, \$/ton		50% backfill, \$/ton		100% backfill, \$/ton	
	Average Cost	Marginal Cost	Average Cost	Marginal Cost	Average Cost	Marginal Cost
Northern Appalachia						
56,701 (0.80) ^a	3.91	4.50	4.26	4.89	4.58	5.22
60,245 (0.85)	3.95	4.50	4.29	4.89	4.62	5.22
63,789 (0.90)	3.98	4.50	4.33	4.89	4.66	5.46
67,332 (0.95)	4.01	4.50	4.36	4.89	4.70	6.22
70,876 (1.00)	4.03	4.50	4.39	5.11	4.78	6.22
74,420 (1.05)	4.05	4.50	4.42	5.11	4.88	7.08
77,964 (1.10)	4.08	4.70	4.49	6.59	b	b
81,508 (1.15)	4.11	4.70	4.58	6.59	b	b
85,051 (1.20)	4.18	8.15	b	b	b	b
88,595 (1.25)	b	b	b	b	b	b
Central Appalachia						
35,643 (0.80)	2.93	2.99	3.38	3.45	3.60	3.67
37,879 (0.85)	2.94	2.99	3.38	3.45	3.60	3.67
40,098 (0.90)	2.94	2.99	3.39	3.45	3.62	3.82
42,326 (0.95)	2.95	2.99	3.39	3.59	3.63	3.82
44,553 (1.00)	2.95	2.99	3.40	3.59	3.64	3.82
46,781 (1.05)	2.95	2.99	3.41	3.59	3.65	3.82
49,009 (1.00)	2.96	2.99	3.42	3.59	3.66	3.82
51,236 (1.15)	2.96	3.11	3.43	3.59	3.67	3.82
53,464 (1.20)	2.97	3.11	3.44	3.59	3.68	3.82
55,692 (1.25)	2.98	3.11	3.45	3.59	3.69	3.82
57,919 (1.30)	2.99	3.11	3.46	3.59	3.71	4.95
60,147 (1.35)	2.99	3.11	3.46	3.59	3.76	4.95
62,375 (1.40)	3.00	3.11	3.47	3.59	b	b
64,603 (1.45)	b	b	b	b	b	b
Southern Appalachia						
11,043 (0.80)	3.94	4.84	4.45	5.38	4.82	5.90
11,734 (0.85)	3.99	4.84	4.51	5.53	4.88	5.90
12,424 (0.90)	4.04	4.84	4.57	5.53	4.95	7.01
13,114 (0.95)	4.09	4.98	4.62	5.53	5.06	7.02
13,804 (1.00)	4.13	4.98	4.67	5.53	5.16	7.02
14,494 (1.05)	4.17	4.98	4.72	5.77	b	b
15,185 (1.10)	4.21	4.98	4.79	7.49	b	b
15,875 (1.15)	4.25	5.19	b	b	b	b
16,565 (1.20)	4.29	5.19	b	b	b	b
17,255 (1.25)	4.41	9.13	b	b	b	b
17,945 (1.30)	b	b	b	b	b	b

^aFigures in the parentheses represent fractions of the 1972 production level.

^bInfeasible with specified labor and equipment constraints.

III. An Econometric Model of the Bituminous Coal Industry in Appalachia

The requirement of a given level of land reclamation tends to limit coal production potential, however, the impact cannot be fully assessed without knowing the structural relations of the bituminous coal industry, encompassing supply, demand and price equations. This is so because supply and demand determine the market price, which, in turn, determines the quantity of coal ultimately produced and consumed.

As shown in Table 3, the five major uses for coal in Appalachia are as boiler fuel for generating electricity (steam coal), as a raw material for making coke (coking coal), as fuel in the production of a variety of industrial products (industrial coal), domestic export⁹, and overseas export. In this paper, the first four coal demand equations were estimated simultaneously with coal supply and price equations. Overseas export demand was not estimated since it is more likely to be influenced by the economic conditions of the importing countries (mainly Japan and Canada) and worldwide coal production than by the delivered price of coal in Appalachia. Retail coal demand was also not estimated for two reasons: (1) its quantity is negligible, and (2) the retail demand is made principally on the basis of non-price factors, such as the cleanliness and convenience of competing fuels [Moyer].

Table 3. Consumption and exports of bituminous coal
in Appalachia, 1972

Consumer Class	Consumption & Exports (Millions of Tons)	Percent
Steam-electric utility industry	156.8	41
Coke industry	49.3	13
General industry	30.7	8
Exports:		
domestic	81.6	22
oversea	55.9	15
Retail deliveries	<u>3.2</u>	1
Total	377.5	

Source: Compiled from the following documents:

- a. National Coal Associations, *Steam Electric Plant Factors*, 1973 Edition.
- b. U.S. Bureau of Mines, *Mineral Yearbook*, 1972.
- c. National Coal Association, *Bituminous Coal Data*, 1973 Edition.

Since coal is primarily used for steam electric generation, for making coke, and for the production of a variety of industrial products, coal demands are derived demands. According to the theory of derived demand, demand for an input is a function of factor prices (e.g. labor and capital) and the product price. The coal demand equations are thus generally specified as functions of the delivered prices of coal, prices of substitute inputs, output and time trend. From an engineering standpoint, a proportional change of electricity generation requires the same proportional change of coal input, indicating steam coal demand is not likely to be a function of labor and capital prices. Therefore, wage rate was excluded as a variable in the steam coal demand equation.

The production of bituminous coal depends, of course, on the geographic conditions (such as the thickness of seam mined and terrain angle), labor and machine availabilities, prices of inputs, and the price expectations of coal miners. These factors vary considerably among the three types of mining: strip, underground and auger. Hence, it becomes necessary to estimate coal supply equations for each type of mining. In addition, the prices which enter the producers' decision functions are prices received at the F.O.B. mine level. On the other hand, coal consumers' decision functions are in terms of delivered prices, suggesting the need to consider relations which determine price spread between the F.O.B. mine price and the delivered price.

The model presented in this report differs in many respects from the one originally formulated. Certain modifications were made because suitable data are currently lacking. For example, output per man-day was used as a proxy variable because a complete time series data on seam thickness by type of

mining is currently not available. Others were suggested by results of exploratory analyses based on the original formulation. Certain formulations were rejected because the signs of particular estimated coefficients were in contradiction to accepted economic theory.

The result is a model consisting of 14 equations in which there are 14 endogenous variables and 17 exogenous variables. All equations were specified in log-linear form. In matrix form, the system can be written as follows:

$$B \ln Y_t + \Gamma \ln Z_t = U_t$$

where,

t = the time period,

B = a 14 x 14 matrix of constant coefficients for endogenous variables,

Γ = a 14 x 17 matrix of coefficients for exogenous variables,

Y_t = a 14 x 1 vector of current endogenous variables,

Z_t = a 17 x 1 vector of exogenous variables,

U_t = a 14 x 1 vector of random disturbances, with the following properties:

$$E \left\{ U_t \right\} = 0$$

$$E \left\{ U_t U_{t-\tau}' \right\} = \begin{cases} 0 & \text{for } \tau \neq 0 \\ \Sigma_u & \text{for } \tau = 0 \end{cases}$$

The structural relations and variables involved in the system are as follows:

<u>Structural Relations</u>	<u>Variables</u>	<u>Equation No.</u>
Steam coal demand	Y_1, Y_2, Z_1, Z_2, Z_3	1
Coking coal demand	Y_3, Y_4, Z_4, Z_5	2
Industrial coal demand	Y_5, Y_6, Z_6, Z_7, Z_5	3
Domestic export	Y_7, Y_8, Z_8, Z_9, Z_5	4
Strip-mined coal supply	$Y_9, Y_{10}, Z_{10}, Z_{11}$	5
Underground coal supply	$Y_{11}, Y_{12}, Z_{12}, Z_{13}$	6
Auger-mined coal supply	$Y_{13}, Y_{14}, Z_{14}, Z_{15}, Z_5$	7
F.O.B. price of strip-mined coal	Y_{10}, Y_2, Z_5	8
F.O.B. price of underground coal	Y_{12}, Y_2, Y_4, Z_5	9
F.O.B. price of auger-mined coal	Y_{14}, Y_2, Z_5	10
Supply and demand identity	$Y_1 + Y_3 + Y_5 + Y_7 = Y_9 + Y_{11} + Y_{13} - Z_{16}$	11
Price spread identity between steam coal delivered price and F.O.B. price of strip-mined coal	$Y_2 = Y_{10} + Z_{17}$	12
Price spread identity between coking coal delivered price and F.O.B. price of underground coal	$Y_4 = Y_{12} + Z_{17}$	13
Price spread identity between industrial coal delivered price and F.O.B. price of underground coal	$Y_6 = Y_{12} + Z_{17}$	14

Endogenous Variables

- Y_1 Consumption of steam coal by the electric utility industry in Appalachia (millions of tons)
- Y_2 Average delivered price "as burned" of steam coal in Appalachia, weighted by steam electric generation by utility industry in each state of the region (cents per million Btu)
- Y_3 Consumption of coking coal in Appalachia (millions of tons)
- Y_4 Average cost of coking coal, weighted by coal carbonized in each of the states (dollars per ton)
- Y_5 Consumption of industrial coal by general industry in Appalachia (millions of tons)
- Y_6 Delivered price of industrial coal in the U.S. (dollars per ton)
- Y_7 Quantity of coal shipped from Appalachia to other domestic regions (millions of tons)
- Y_8 Average delivered price of coal, weighted by coal consumption in each submarket (cents per million Btu)
- Y_9 Production of strip-mined coal in Appalachia (million tons)
- Y_{10} Average F.O.B. price of strip-mined coal, weighted by strip-mined coal production in each of the states (dollars per ton)
- Y_{11} Production of underground coal in Appalachia (million tons)
- Y_{12} Average F.O.B. price of underground coal, weighted by underground coal production in each of the states (dollars per ton)
- Y_{13} Production of auger coal in Appalachia (million tons)

- Y_{14} Average F.O.B. price of anger-mined coal, weighted by auger coal production in each of the states (dollars per ton).

Exogenous Variables

- Z_1 Average cost of oil for electric generation in Appalachia, weighted by consumption of oil for steam electric gneration in each of the states (cents per million Btu).
- Z_2 Average cost of natural gas for electric generation in Appalachia, weighted by consumption of natural gas for steam electric generation in each of the states (cents per million Btu)
- Z_3 Steam-electric generation in Appalachia (billions of kilowatt hrs)
- Z_4 Pig iron production in Appalachia (millions of tons)
- Z_5 Time trend variable (1957 = 1, 1958 = 2, etc.)
- Z_6 Average industrial price of natural gas, weighted by the volume of natural gas consumed by general industry in each state of the region (cents per million cubic feet)
- Z_7 Federal Reserve Board Index of manufacturing industry production (1967 = 100)
- Z_8 Average cost of oil for steam-electric generation in the domestic importing region, weighted by coal shipment from Appalachia to each region (cents per million Btu)
- Z_9 Steam-electric generation in the domestic importing region (billions of kilowatt hrs.)
- Z_{10} Average strip-mined coal output per man-day, weighted by strip-mined coal production in each of the states (tons per man-day)
- Z_{11} Man-days worked at bituminous coal strip mines in Appalachia (thousand man-days)

- Z₁₂ Average underground coal output per man-day, weighted by underground coal production in each of the states (tons per man-day)
- Z₁₃ Man-days worked at underground bituminous coal mines in Appalachia (thousand man-days)
- Z₁₄ Average auger-mined coal output per man-day, weighted by auger coal production in each of the states (tons per man-day)
- Z₁₅ Man-days worked at auger bituminous coal mines in Appalachia (thousand man-days)
- Z₁₆ Oversea export and retail deliveries of bituminous coal in Appalachia (millions of tons)
- Z₁₇ Railroad freight rate (dollars per ton)

Time series data on coal consumptions by consumer use were drawn from several different sources. The Steam-Electric Plant Factors of the National Coal Association provides data on steam coal price and consumption by state, The U.S. Bureau of Mines Mineral Yearbook (volume of fuels) furnishes data on coking price and consumption by state, and industrial coal distribution by region of origin and destination. It was found that distribution data by region of destination alone cannot approximate industrial coal consumption data accurately. Therefore, industrial coal consumption data were derived by incorporating the annual net stock change of industrial coal into the distribution data for the region of Appalachia. The rest of the data comes mostly from the U.S. Bureau of Mines Mineral Yearbook and the Bituminous Coal Data of the National Coal Association. Regional data were used in as-much as possible. In the cases of Federal Reserve Board Index of industrial production, railroad freight rate, and industrial coal price, national data were used because regional data are currently lacking. All price variables were deflated by the wholesale price index of intermediate material.

The number of exogenous variables in the system is seventeen. The largest number of exogenous variables included in any equation is three, while the largest number of endogenous variables included in any one equation is also three. Hence, by the order criterion, all equations are over-identified.

The large number of exogenous variables although is helpful in identifying the system, nevertheless, creates a problem which is commonly known as the undersized sample problem [Theil, p. 532]. When this problem is presented, the two-stage least square (TSLS) method of estimation would generally yield results similar to that of ordinary least square. In addition, there is a serious problem of degrees of freedom in the first-stage reduced form estimation. Since complete regional coal consumption data by consumer use prior to 1957 are currently not available, it is decided to adopt a modified TSLS according to the causal ordering criterion suggested by Fisher. In essence, Fisher's idea is to subdivide the set of predetermined variables according to closeness of causal relation to a given endogenous variable in the equation to be estimated based on the a priori structural information. For example, consider the right-hand side endogenous variable Y_2 (zero causal order) in the steam coal demand equation (eg. 1). The structural equation 12 indicates it is equal to the sum of Y_{10} and Z_{17} (first causal order) at equilibrium, suggesting Z_{17} is a direct causal variable to be first considered. Then, according to the structural equation 8, time trend variable (second causal order) is the next direct causal variable to be considered in the first-stage reduced form estimation for the right-hand-side endogenous variable Y_2 . Based on this type of causal ordering, we regress the zero causal order endogenous on the first T-2 instrument in the preference

ordering, where T is no. of observations. Drop the least preferred of these instruments from the regression. Observe whether the multiple correlation of the regression drop significantly as a result. If correlation drops significantly, the T -2nd instrument should be retained; otherwise, it should be omitted. Proceed to the T -3rd instrument and continue in this way. At every step, a given instrument is tested to see whether it contributes significantly to multiple correlation in the presence of all instruments which are a priori preferred to it. When all instruments have been so tested, the ones remaining are the ones to be used. Once the right-hand-side endogenous variable have been estimated, the endogenous variables are replaced by their predicted values and the second-stage regression of the left-hand endogenous variable on the resulting right-hand variables is proceeded as is the classical version of TSLS.

The estimated relations of the complete structure during the study period of 1957-1973 are presented in Tables 4 and 5. As expected, coal demand (except domestic export) and supply seem to be highly price inelastic in the short run. The characteristics of inelastic short-run price elasticity for coal supply and demand implies that the impact of land reclamation on coal production is likely to be moderate, as will be shown in the next section. All relevant variables have the expected signs.

In the structural equation of steam coal demand, oil and natural gas were found to be two major fuel substitutes for coal in electric generation and steam coal demand seems to be highly price inelastic in the short-run. Contrary to Reddy's empirical finding, the price of natural gas for steam electric generation not only shows a correct positive sign, but is also statistically significant.

Table 4. Estimated Structure of the Bituminous Coal Industry in Appalachia: B Matrix
(Endogenous Variables)

Eq. Nos	Y ₁	Y ₂	Y ₃	Y ₄	Y ₅	Y ₆	Y ₇	Y ₈	Y ₉	Y ₁₀	Y ₁₁	Y ₁₂	Y ₁₃	Y ₁₄	R ²	d
1	1.000	0.167 ^b (0.065) ^d													.998	2.55
2			1.000	0.172 (0.174)											.660	.97
3					1.000	0.578 ^b (0.176)									.785	1.20
4							1.000	0.968 ^a (0.076)							.971	2.22
5									1.000	-0.177 ^b (0.097)					.996	2.19
6											1.000	-0.123 (0.120)			.665	1.48
7													1.000	-0.304 ^c (0.220)	.917	1.24
8		-0.954 ^a (0.064)								1.000					.962	1.28
9		-0.891 ^b (0.365)		-0.589 ^c (0.429)								1.000			.972	1.82
10		-1.299 ^a (0.180)												1.000	.889	2.04
11	1.000		1.000		1.000		1.000		-1.000		-1.000		-1.000		-	-
12		1.000								-1.000					-	-
13				1.000								-1.000			-	-
14						1.000						-1.000			-	-

^aStatistically significant at 1% level.

^bStatistically significant at 10% level.

^cStatistically significant at 20% level.

^dFigures in parentheses are estimated standard error; R is the correlation between the observed and estimated values of the dependent variables, d is the Durbin-Watson statistic.

Table 5. Estimated Structure of the Bituminous Coal Industry in Appalachia: [Matrix
(Exogenous Variables)

q. o.	z ₀ (Constant term)	z ₁	z ₂	z ₃	z ₄	z ₅	z ₆	z ₇	z ₈	z ₉	z ₁₀	z ₁₁	z ₁₂	z ₁₃	z ₁₄	z ₁₅	z ₁₆	z ₁₇
1	0.743 ^b (0.280) ^a	-0.170 ^b (0.081)	-0.113 ^c (0.072)	-0.872 ^a (0.019)														
2	-1.545 ^b (0.581)				-0.756 ^a (0.151)	0.063 ^{b,d} (0.029)												
3	-0.229 (2.44)					0.037 ^b (0.194)	-0.403 (0.365)	-0.702 ^b (0.371)										
4	-0.058 (1.59)					0.087 ^a (0.018)			-0.103 (0.084)	-1.330 ^a (0.262)								
5	6.049 ^a (0.536)										-0.998 ^a (0.029)	-0.860 ^a (0.080)						
6	10.72 ^b (4.33)												-1.057 ^a (0.244)	-1.342 ^a (0.363)				
7	9.887 ^a (1.85)					0.016 (0.016)									-1.191 ^a (0.364)	-1.355 ^a (0.190)		
8	1.699 ^a (0.200)					-0.005 ^a (0.002)												
9	2.458 ^a (0.317)					-0.005 ^c (0.003)												
0	2.912 ^a (0.559)					-0.015 ^a (0.434)												
1																	1.000	
2																		-1.000
3																		-1.000
4																		-1.000

^aStatistically significant at 1% level.

^bStatistically significant at 10% level.

^cStatistically significant at 20% level.

^dThis variable in this equation was expressed by log form.

^eFigures in parentheses are estimated standard error.

Bituminous coal appears to be the primary fuel source for making coke, which, in turn, is used for making pig iron and steel. Hence, there is no price variables of substitutes appearing in the coking coal demand structural equation. The negative coefficient of time trend variables implies less coal has been consumed per ton of pig iron. In fact, coking coal used per ton of pig iron has been declined steadily from 2.2 thousand pounds in 1960 to 1.8 thousand pounds in 1972.

The primary users of industrial coal include steel and rolling mills, portland cement industry, ceramic plants, chemicals and allied products, paper and allied products, and a host of other manufacturing industries. Since the Federal Reserve Board Index of industrial production is considered to be an appropriate indicator of demand for manufacturing products, it is used as the output variable.

As shown in Table 3, the region of Appalachia exported about 22% of its coal production to the domestic importing regions in 1972, primarily the census regions of Middle Atlantic, East North Central, South Atlantic, and Middle South Central. In theory, the volume of trade is determined by price differential between the exporting region and importing region, assuming a constant transport cost. Here, the price differential was simplified somewhat by using the delivered price of coal in Appalachia as a proxy.

Although the results of the process analysis discussed in the previous section allows us to derive strip-mined coal supply curve in step functional form, information regarding underground and auger mined coal supply is necessary for the purpose of this study. In addition, coal demand structural equations can conceivably be better specified and estimated by combining coal supply and demand in a simultaneous equation system. Hence, three coal

supply equations including the strip-mined coal supply are specified and estimated. It is found that coal supplies, in general, are highly inelastic in the short run.

The F.O.B. mine price of coal seems to be influenced largely by the delivered price of steam coal. This is understandable because steam coal submarket by far is the largest coal market, which accounts for about 65% of the total domestic coal consumption in the United States. The structural equations 12, 13, and 14 indicates that, at equilibrium, delivered price of coal in each submarket, will differ from the F.O.B. price of coal which dominates the market by transportation cost. For example, it is well known that coking coal demand generally demands high quality coal and thus is dominated by underground coal. Hence, the delivered price of coking coal is found to be more closely linked to the F.O.B. price of underground coal.

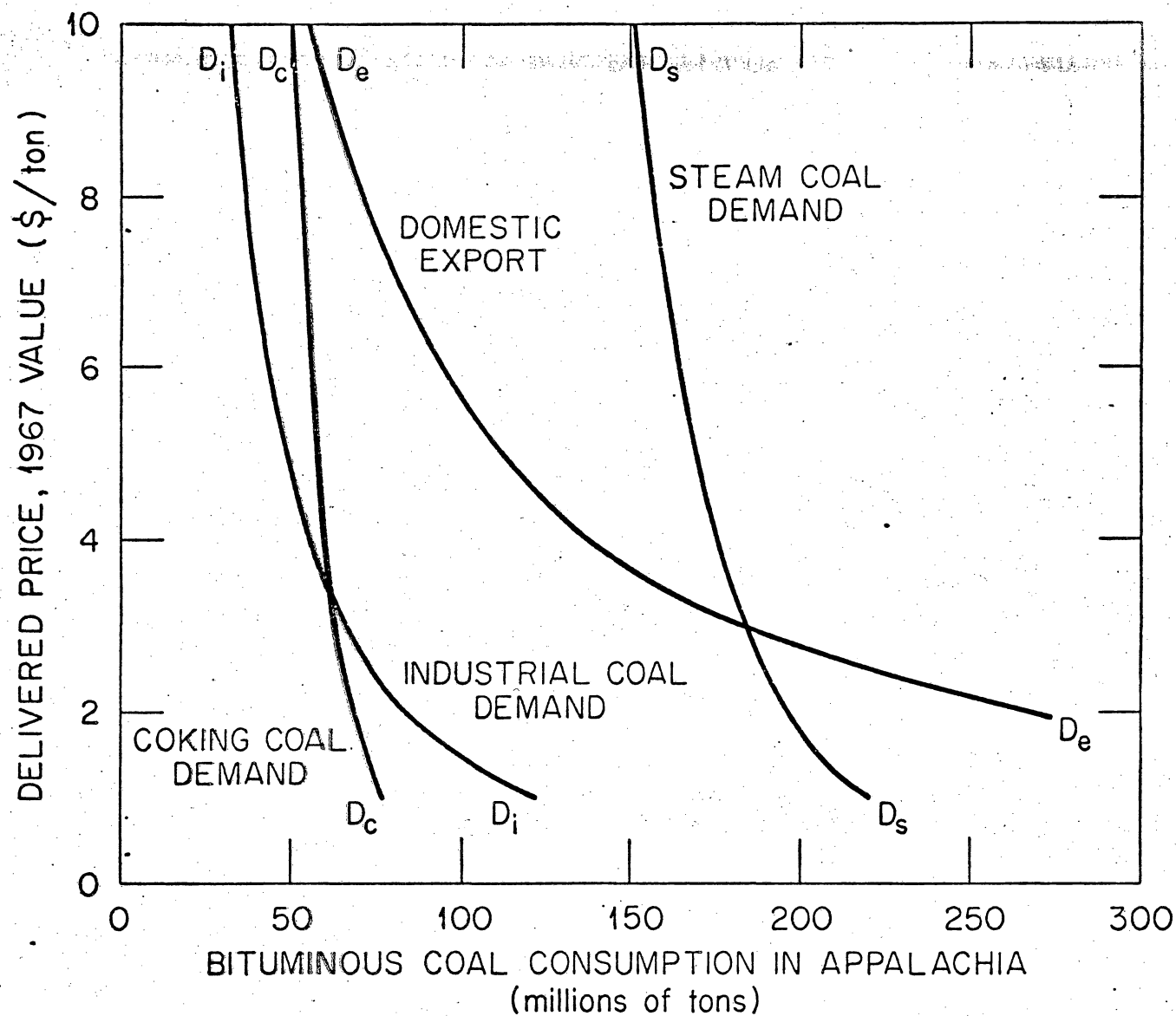
IV. Impacts of Reclamation on Coal Price, Production and Employment

As stated before, it is necessary to integrate coal supply and demand together in a market equilibrium framework before the impacts of land reclamation on coal price, strip-mined coal production, and employment can be fully ascertained.

On the demand side, this means the demand for each submarket needs to be combined into an aggregate coal demand, which is the horizontal summation of demand schedules for steam coal ($D_S D_S$), coking coal ($D_C D_C$), industrial coal ($D_I D_I$), domestic export ($D_e D_e$), oversea export, and retail deliveries,¹⁰ as shown in Figure 1.¹¹ The individual demand schedules were derived separately by substituting proper values of the explanatory variables (except delivered

Figure 1. Demand Curves for Coal in Appalachia, 1972:

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prices of coal, of course) in 1972 into the demand equations estimated from the regression analysis.

On the supply side, three adjustments also have to be made in order to maintain consistency with our demand estimation. First, the FOB minimum selling prices at each output level as obtained from the process analysis were converted into the equivalent delivered prices. The discrepancy between the average delivered price (\$10.99/ton) and F.O.B. price of coal (\$9.14/ton) in Appalachia in 1972 was estimated as \$1.85 per ton (National Coal Association), mainly due to transportation cost and royalty. Second, the 1972 delivered price level was deflated by the wholesale price index of intermediate material. This is necessary because deflated prices were used in the demand and supply equations estimation throughout, as reported in the previous section. Third, the strip mined coal supply curves, with 100% backfill and 50% backfull, are then combined separately with the estimated underground and auger coal supply curves. The step supply curves, with full reclamation (100% backfilling) and with current typical land reclamation practice (50% backfilling), are shown as $S_{s2}S_{s2}$ and $S_{s1}S_{s1}$, respectively, in Figure 2.

As expected, the supply curve shifts upward and to the left when full reclamation is required (see Figure 2). However, it is noted that our supply functions tend to overestimate the actual coal production figure. In 1972, Appalachia has its strip-mined production at 129.2 million tons. Nevertheless, given the 1972 F.O.B. price of strip-mined coal as \$5.29 per ton in 1967, value the step supply function $S_{s1}S_{s1}$ derived from process analysis indicates 151.3 million tons, leaving the difference of about 22 million tons. Perhaps this is

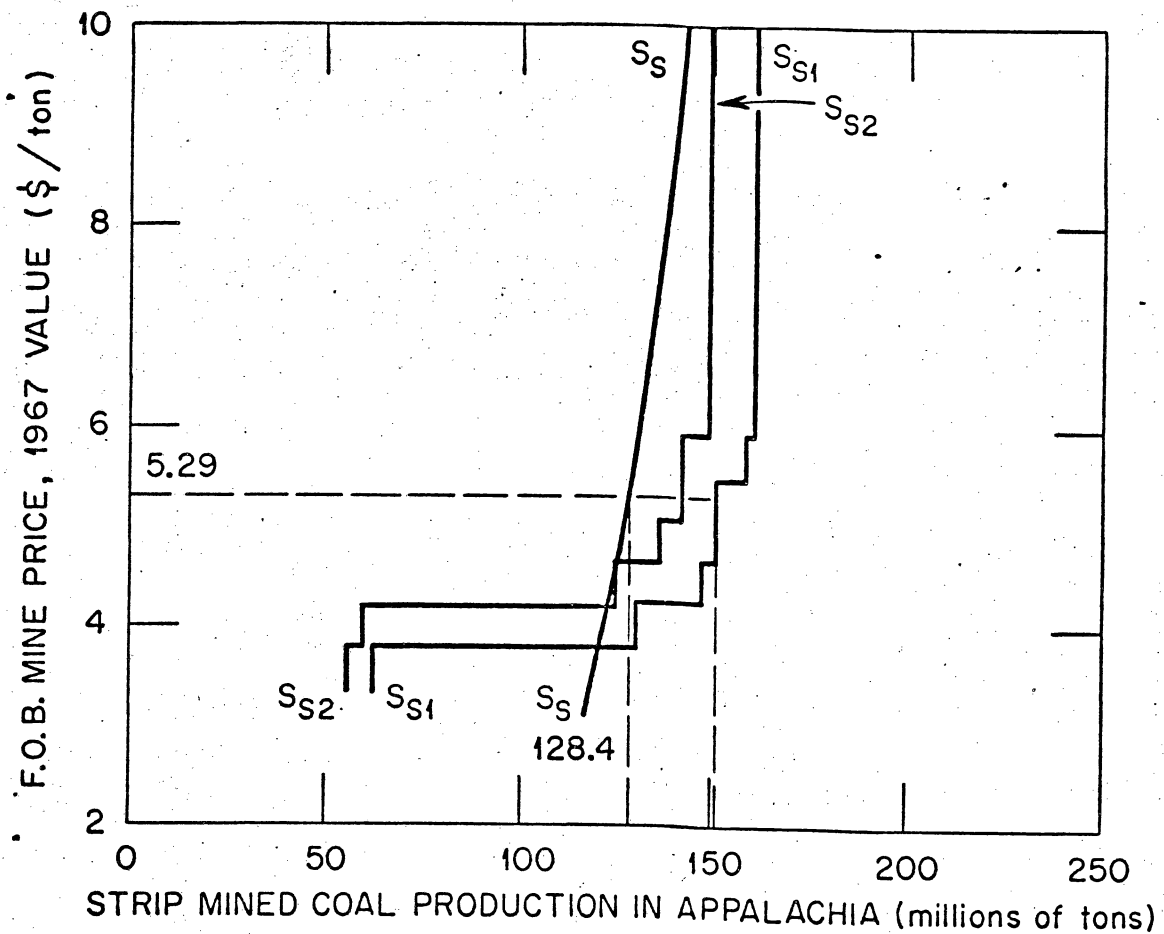
Figure 2. A Comparison of Strip Mined Coal Supply Curves Derived from Process Analysis and Regression Analysis

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S_{S1} S_{S1} : 50 % BACKFILLING, PROCESS ANALYSIS

S_{S2} S_{S2} : 100 % BACKFILLING, PROCESS ANALYSIS

S_S S_S : REGRESSION ANALYSIS



due partly to the use of inaccurate engineering data in the process analysis, it, however, suggests that aggregation bias may still have remained as a problem in our supply function estimation in spite of our efforts to divide the Appalachian region into the three homogeneous sub-regions. In fact, we have recently found that as much as 9.5 million tons of coal was overestimated at the 1972 F.O.B. price of strip-mined coal (\$8.07/ton) for the case of zero backfilling in Northern Appalachia. Strip mined coal supply function ($S_s S_s$) derived from our econometric analysis, on the otherhand, shows good prediction. Due to our primary interest in quantifying the impacts of reclamation on the coal industry in Appalachia, which the regression results failed to yield any meaningful distinction, the step supply functions for strip-mined coal were used in the following analysis. Further disaggregation of the coal producing region may not significantly alter our following conclusions since all the resulting supply curves would be shifted upward and the difference is likely to be small.

Combining the step strip-mined coal supply functions with the continuous supply functions for underground and auger mined coal, we obtained the discontinuous aggregate coal supply functions, $S_1 S_1$ and $S_2 S_2$, for the cases of 50% backfill and 100% backfill respectively (see Figure 3). In the context of comparative-static analysis, strip mined coal production is expected to be reduced as a result of full reclamation; however, the new market equilibrium price at point R is higher than the equilibrium price at point S by about \$0.35 per ton. Therefore, the higher market equilibrium price at point R offsets a portion of the reduction in strip mined coal production. A reduction of a 7.5 million tons of strip mined coal

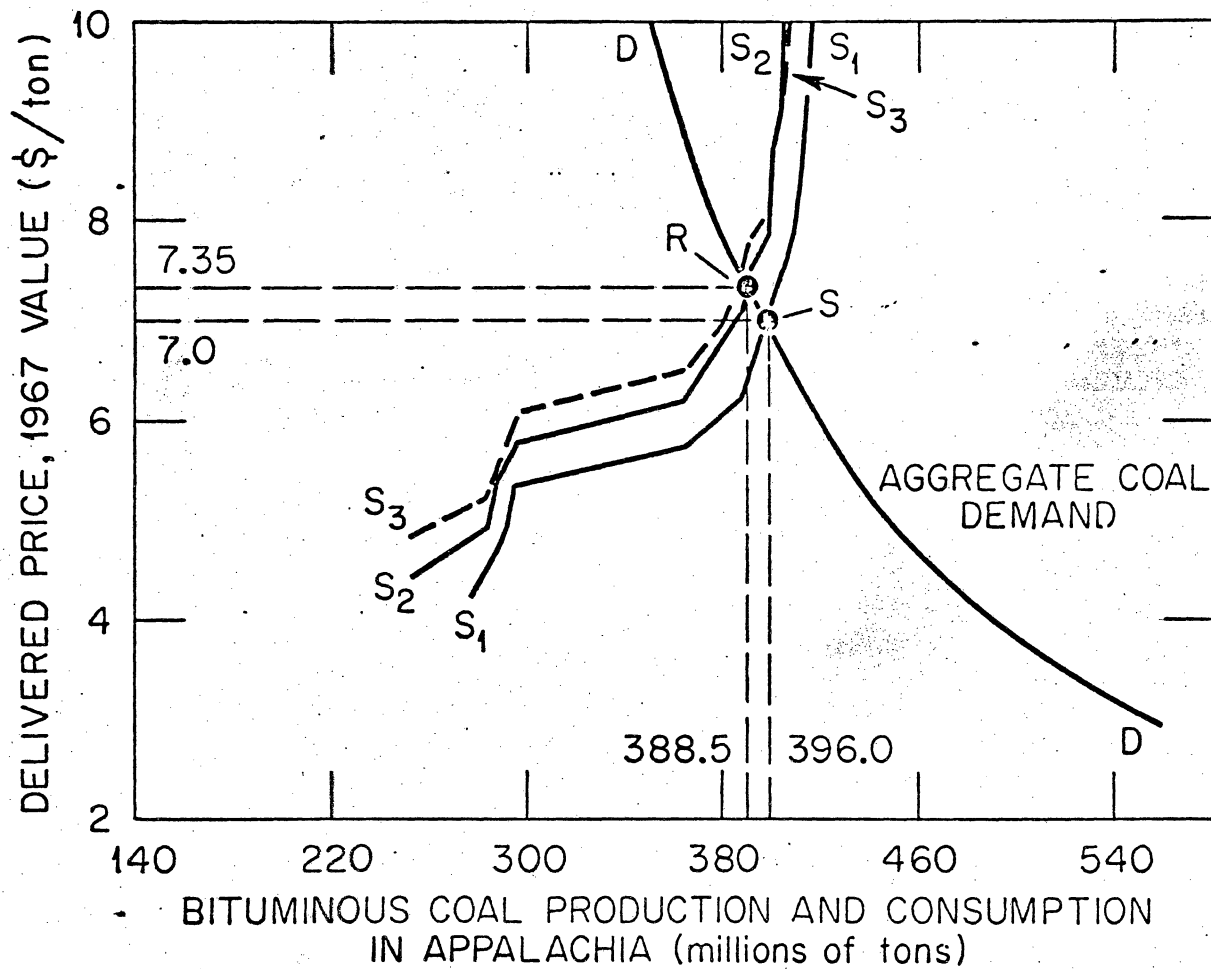
Figure 3. Impact of Reclamation on Strip Mined Coal Production in Appalachia, 1972

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S_1 S_1 : 50 % BACKFILLING

S_2 S_2 : 100 % BACKFILLING

S_3 S_3 : 100 % BACKFILLING + 35 ¢/ton COAL TAX



production in Appalachia would have occurred in 1972 as a result of changing reclamation requirements from current typical reclamation practice to full recalculation. This represents about 6% of the actual 1972 strip mining production of bituminous coal or 2% of the total coal production in Appalachia.

The proposed strip mining regulation requiring restoration of land to approximately its original contour is aimed at preventing further land deterioration in the future. How about lands scarred by the strip mining in the past? The congressional proposal to levy a 35¢/ton surface coal tax on future surface coal production to help pay for restoring the destroyed lands amounts to adding 35¢/ton to the marginal cost previously obtained for the case of 100% backfilling in the process analysis. The resulting supply curve, S_3S_3 in Figure 3, almost intersects with the aggregate coal demand curve DD at point R, indicating very little additional reduction of strip mined coal would occur. Accordingly, it is concluded that in the short run, coal production is insensitive to the change in coal supply arising from the imposition of surface coal tax.

The direct short-run effect on employment in Appalachia resulting from legislation requiring full reclamation of strip-mined lands can be estimated once the short-run impact on coal production is known. First, the reduction in labor requirements, in terms of labor man-days, is calculated by dividing the 7.5 million tons by the average labor productivity at strip mines in Appalachia, 30.44 tons per man day. The result obtained is then divided by the average annual number of working days for strip mines in the region to give the total number of employees affected. Our results show that imposing full reclamation requirements would have resulted in the loss of

some 1100 jobs for coal production workers in Appalachia in 1972. However, it should be noted that a portion of this estimated job loss would have been offset by the enhanced opportunities for employment arising from the expanded reclamation activities. In fact, it was found that about 582 employment opportunities would have been created as a result of the expanded reclamation activities, as shown in Table 6. The above estimation was based on the results of our process analysis, in which labor hours employed for each activity is shown in the optimal solution. According to the market equilibrium points R and S, as shown in Figure 3, we can thus easily identify the output levels and labor man-hours employed for reclamation activities. Hence, the additional reclamation requirement would have only left a fairly moderate net direct impact on employment, costing 518 employment opportunities or about 3% of the labor supply in the Appalachian strip mining industry.

Of course, the severity of short run impacts on coal production and employment can be mitigated if the law provides for an extended period before compliance or a gradual transition to the new reclamation requirements. Furthermore, these impacts tend to be temporary in nature. Given today's demand condition and allowing longer time, the demand curves would be shifted outward to the right. On the other hand, the effect of the employment multiplier would increase the severity of short-run unemployment. Assuming a national employment multiplier of 1.80 for the coal industry (Miernyk), preliminary evaluation shows an overall job loss of no more than 932 production workers in Appalachia for the year 1972.

Table 6. Employment Opportunities Created by Reclamation Activities in Appalachian Coal Mining Industry

Subregion	Man-hour Employed for Reclamation			Employment Opportunity Created by the Additional Reclamation Activities ^a
	50% Backfill	100% Backfill	Difference	
Northern Appalachia	326,362	1,100,449	774,087	323
Central Appalachia	249,871	706,251	456,380	190
Southern Appalachia	91,797	258,549	166,752	<u>69</u>
Total				582

^aIt is assumed, as was employed in the process analysis, that one man-year is equal to 2400 man-hours.

V. Conclusions

This study provides a preliminary evaluation, in quantitative terms, of the impact of land reclamation on coal production cost, delivered price, strip mined coal production, and employment in the coal industry. In the past, much land damage from strip mining could have been avoided if full reclamation after mining had been practiced.

In 1972, the imposition of requirement for full recalamation of strip-mine disturbed lands would have resulted in a reduction of about 7.5 million tons of strip-mined coal production in Appalachia and an increase of about \$0.35 per ton in the delivered price of coal. Coal production, in the short run, appears to be insensitive to the induced change in coal supply arising from the modest surface coal tax. The short-run direct impact of full reclamation on employment is the loss of 518 jobs for production workers in the Appalachian coal mining industry. The direct and indirect impact is the loss of no more than 932 job opportunities.

Footnotes

1. See Federal Energy Administration, National Petroleum Council, and Ray for example.
2. The region of Appalachia is defined as the geographic area in the Federal Coal Producing Districts 1, 2, 3, 4, 6, 7, 8, and 13, as so defined in the Bituminous Coal Act of 1937.
3. See Knoxville News-Sentinel, Tuesday, May 20, 1975.
4. See Appendix A, Table A-1 for a typical list of tasks and processes in coal surface mining without reclamation. Tasks such as topsoil removal and replacement and backfilling are added in cases where land reclamation are required.
5. It is recognized that labor supply may not be fixed, even in the short-run. To the extent that additional labor forces can be added to coal extraction process by paying higher wage rate, our labor availability does present an unnecessarily rigid restriction.
6. Discussions on sources of data and the calculation of matrix elements are available in Spore, et al.
7. The pit fill factor refers to the extent to which the mine pit is backfilled with spoil material following coal extraction. Usually, but not always, the greater the pit fill factor, the higher the level of reclamation obtained.
8. Includes topsoil replacement and backfilling and excludes revegetation.
9. In 1972, Appalachia exported 81.6 million tons of coal to other regions in the U.S., primarily Middle Atlantic, East North Central, South Atlantic, and Middle South Central, as classified by the Bureau of Census.
10. Since overseas export and retail deliveries are both treated exogenously in our demand estimation, coal consumption and export are thus treated as constants along the price schedule.
11. Since the delivered price of steam coal is expressed in terms of cents per million Btu in the steam coal demand equation, it is necessary to be converted into the unit of dollars per ton. The conversion factor used by the U.S. Bureau of Mines, 23,750,000 Btu per ton for consumption, was used in this conversion process.

Appendix A, Table A-1

Tasks and Processes in Coal Surface Mining

Task	Alternative Processes
A. Access Road Construction	1. Dozer
B. Clearing and Scalping	1. Dozer
C. Drilling	1. Vertical Drill 2. Horizontal Drill
D. Overburden Removal	
1. Transverse	1. Dozer 2. Loader 3. Dozer/Loader 4. 6-15 cy Dragline or Shovel 5. 16-50 cy Dragline or Shovel 6. >50 cy Dragline or Shovel
2. Lateral	7. Loader/Truck 8. Dozer/Loader/Truck 9. 6-15 cy Dragline or Shovel/Truck 10. 16-50 cy Dragline or Shovel/Truck 11. <6 cy Scraper 12. 6-15 cy Scraper 13. 16-50 cy Scraper
E. Coal Loading	1. Loader 2. <6 cy Shovel
F. Coal Haulage	1. 20 ton Truck
G. Auxilliary	1. Auxilliary Equipment

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