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The Economics of Western Coal Severance Taxes*

Increases in oil and gas prices and the decline of nuclear power have led to an increase in the competitiveness of coal. This change in relative economics has been particularly great for the six western coal-producing states where large low-cost deposits of environmentally acceptable low-sulfur coal are found. Montana and Wyoming have responded to this situation by raising severance taxes substantially, and other states are considering similar actions. This has led to congressional attempts to limit state coal taxes. Using an integrated model of the U.S. coal and electric utility industries, this paper estimates how high coal severance taxes might rise with and without such legislation. Competition and incentives for cooperation between Montana, Wyoming, and other western states are examined. Efficiency and distributional implications are discussed.

Introduction

The recent upheavals in fuel markets have altered competitive relationships between fuels. Rising prices and government regulations have eliminated oil and gas from consideration as fuels for new electric utility plants. Further, public acceptance of nuclear power has diminished to the point that coal is the only practical alternative source of energy for new base-load generation facilities. This change in market structure creates opportunities for those with market power. The demand for coal has become less elastic, and those in a position to exert market power can take advantage of the situation to raise prices.

The coal industry itself is competitive. Coal producers will, in the long run, be forced to sell at long-run marginal cost where marginal cost reflects the cost of production as well as the competitive rent accruing to owners of depletable resources. Labor supply is, to an extent, controlled by the United Mine Workers union, yet competition from nonunion miners limits the union's ability to act.[1] Other elements of the in-

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1. Western coal production has expanded most rapidly and miners there are largely nonunion.

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dustry, however, are more favorably positioned to take advantage of the new market situation.

Those with the most favorable market positions are the railroads and state legislatures. The state legislatures, by raising taxes, and railroads, by raising rates, can take advantage of the less elastic demand. Railroad rates have increased rapidly in the last few years. State legislatures have raised their taxes, particularly in Montana and Wyoming. Montana currently has a 30% severance tax and Wyoming a 10.5% levy.[2] The Montana tax was unsuccessfully challenged as an unconstitutional burden on interstate commerce, and legislation has been proposed at a national level to limit coal tax increases.

Not surprisingly, these developments are focused on coal from the Powder River Basin of Montana and Wyoming. This coal is low in sulfur and lies in thick beds close to the surface. Mining costs are low and potential rents are consequently high. How high can the state legislatures raise taxes? How far can railroads raise rates? That is the subject of this paper.

The Model

The model and its constituent submodels are described in detail elsewhere (Baughman, Joskow, and Kamat 1979; Zimmerman 1979*a*, 1979*b*, 1981). It is beyond the scope of this paper to repeat that documentation. Here we provide an overview of the estimation and construction of the model.

The initial demand for coal by region is determined given an initial set of prices. These demands are passed to a linear program as constraints. The supply model establishes the cost of production for coal as a function of output by sulfur content and by region. A linear program then minimizes the cost of mining and transporting the coal necessary to meet the regional demand constraints and subject to limitations on sulfur emissions.

The solution of the linear program yields output by region and sulfur content, flows of coal from supply region to demand region, and the delivered price of coal to each region. The delivered prices are passed back to the demand model to estimate a new set of regional demands. The coal outputs are fed back to the supply model to establish a new set of supply prices, and the process is repeated.

The linear program is solved each year. However, the output in any year affects coal prices throughout the simulation period. The essence of the supply model is the "cumulative" cost function. This function

2. The severance taxes are 30% and 10.5%, respectively. Local county levies bring the total taxes up to 35% and 16.8%, respectively. (*Coal Week*, April 24, 1978, discusses local levies.)

estimates how costs increase due to depletion as output cumulates over time. In each year, the cost of producing any given amount of coal is updated to reflect the impact of cumulative output through that year.

The Coal Supply Model

The structure of the coal industry is continually changing. Depletion of lower-cost deposits raises costs. Changing regulations affect what coal can be produced and burned. The supply model deals with these problems by disaggregating those segments likely to be affected differently by policy actions and by integrating geological information into the estimation process to measure depletion.

There are three steps to the estimation of the coal supply model. In the first step, the relationship between geology and the productivity of a mining unit is estimated. The unit is an appropriately defined complement of miners and machines. The relationship is estimated using observations on actual mines. Once the productivity of a unit is known, given the geology of a deposit, the number of units required for any given level of production can be determined. A unit in an underground mine consists of a continuous mining machine and a complement of miners plus shuttle cars to haul the coal away. In strip mining, units measure the size of the earth-moving machinery.

The next step assumes that expenditures on labor, materials, and capital are a function of the number of units. The estimation of the relationship uses engineering models of mines prepared by the Bureau of Mines (1972, 1974*a*).[3]

The expenditure functions are combined with the productivity equation to yield cost as a function of geology. The productivity equation yields the number of units necessary to produce a given amount of coal in a seam of given characteristics. The expenditure functions predict the cost of buying and operating those units. In this way, an equation that predicts cost as a function of output and geology is determined. Solving the cost equation for the rate of output that minimizes the average cost of production, given the characteristics of the coal seam, yields long-run marginal cost as a function of the geological characteristics of the coal seam.

The long-run cost function is combined with geological information on the distribution of coal in the ground according to physical characteristics. The result is the distribution of coal in the ground according to the cost of mining. There is an estimated distribution for each state,

3. The most unsatisfactory part of these hypothetical mines is the productivity assumptions underlying the estimates. We use our own productivity estimates, derived from the econometric estimates described in the text. The only information we use from the engineering estimates is the relation between the number of producing units and expenditures.

sulfur category, and type of mine.[4] Finally, transport cost from supply region to consumption region, estimated from actual transport rates, is added to yield the delivered cost of coal.

The Demand Model

The demand model used is the regional electricity model (REM) developed by Martin Baughman, Dilip Kamat, and Paul Joskow (1979). The model begins by estimating econometrically the demand for energy in the residential and commercial sectors as a function of a weighted average of current and lagged energy prices, income, and population. This equation is estimated from combined time-series and cross-sectional state data. The proportion of total energy demand satisfied by a particular fuel is then related econometrically to the relative price of each fuel.

The industrial sector is treated in a similar way. Total energy demand is estimated as a function of an energy price index and value added in manufacturing. This total demand is allocated to states as a function of prices, income, and population in the state, relative to a reference state. Finally, the demand per state is divided into fuel types by fuel split equations.

The output of this procedure is a demand for coal in the industrial sector and the demand for electricity. The former is a demand for direct use of coal. The latter must be further decomposed into the demand for the different fuels used in generating electricity.

The essence of the electricity model is the economics of plant expansion (Turvey 1968). The electricity model solves for the optimum configuration of capacity given the pattern of demand fluctuations and the cost characteristics of alternative plants. The model then builds the difference between existing capacity and the optimum configuration. The demand model assumes utilities use a trend-adjusted moving average to forecast demand levels. In any given year, plant capacity is fixed and cost is minimized by using the plants with lowest variable costs to satisfy demand. In the model, as modified for this work, plant types available to the decision maker are the coal plants without stack-gas scrubbers, coal plants with scrubbers, nuclear plants, and oil and gas plants.[5]

The Link Between the Supply and Demand Models

Aggregation. Coal transport costs are large and make locational aspects of the industry important. Simulation of tax policies requires

4. For the distributions used see Zimmerman (1981). The total amount of coal is taken from the Bureau of Mines (1974*b*), Simon and Smith (1968), Matson and Blumer (1973). Each distribution is truncated since the cheapest deposits are mined first. Coal remaining in the ground is at least as expensive as the current cost of mining. The truncation point for each region and sulfur category is set equal to the present cost of mining.

5. Hydroelectric generation is specified exogenously.

TABLE 1 Regional Definitions

A. Coal supply regions:	
1. Northern Appalachia	Pennsylvania, Northern West Virginia, Ohio, Maryland
2. Southern Appalachia	Southern West Virginia, Virginia, Eastern Kentucky, Tennessee, Alabama
3. Midwest	Illinois, Indiana, Western Kentucky
4. Powder River Basin	Montana, Wyoming
5. Utah, Colorado	Utah, Colorado
6. Arizona, New Mexico	Arizona, New Mexico
B. Coal demand regions:	
1. New England	Census region 1
2. Mid-Atlantic	Census region 2
3. East North Central	Census region 3
4. West North Central A	Missouri, Iowa, Kansas, Nebraska
5. South Atlantic	Census region 5
6. East South Central	Census region 6
7. West South Central	Census region 7
8. Mountain region A	Utah, Colorado
9. Pacific	Census region 9
10. West North Central B	Minnesota, North Dakota, South Dakota
11. Mountain B	Idaho, Montana, Wyoming
12. Mountain C	Arizona, New Mexico

disaggregation by producing states. Tax policy is intertwined with sulfur regulations, necessitating disaggregation by sulfur content. Finally, disaggregation of supply into strip- and deep-mining components is important, because policy initiatives affect each segment of the supply function differently. Allowing for all this disaggregation yields 360 supply curves, a number that makes a solution to the linear program expensive.

To make the model computationally practical yet preserve necessary detail, the following procedures were adopted. All strip and deep supply functions within a state are summed and all state supply functions within a region are aggregated to yield six regional supply functions. This is done for eight different sulfur categories, so there are 48 supply functions fed to the linear program. In order to make the highly nonlinear cost distribution compatible with a linear programming model, the distribution is approximated by linear step functions. After the program solves for production by region and sulfur category the split by state and mining type can be calculated from the individual state supply function. The regions are defined in table 1.

The linear program is solved year by year. However, mining costs in each year are updated given the additional cumulative output represented by last year's output. Thus, the costs in any year are a function of the sum of previous years' outputs. In this way, depletion is explicitly accounted for. Each year a new set of step functions is calculated.[6]

6. The formulation, for computational ease, is not fully dynamic. Tests for biases introduced by myopic solution indicate no serious distortion (see Zimmerman 1981).

With eight different sulfur levels, it is computationally infeasible for the demand model to consider all possible combinations of coal for meeting sulfur regulations. The solution adopted is to create two categories of demand within each region. There is a demand for coal to be used in plants that find scrubbing the low-cost technology. Scrubbers are assumed efficient enough to meet environmental regulations with any coal.[7] In those plants (and for industrial uses) where scrubbers are not used, coal must meet the constraint on sulfur emissions. The linear program solves for the least-cost mixture of coals that satisfies both demand categories. The average price of each mixture becomes the low- and high-sulfur coal prices used in the demand model to determine plant choice. These prices are the marginal cost of the least-cost combination of coals satisfying the respective sulfur constraints.

Demand constraints. The most important feature of the demand constraints is that we calculate a set of "market-sensitive" demands. These are fed as the demands to the linear program to adjust for the fact that the model simulates the long-run equilibrium and the long-run equilibrium will be approached only gradually as existing contracts expire.

Thus what was fixed before the model runs begin, that is, before 1976, is subtracted from demand.[8] We assume that the coal shipments fixed by 1975 decline at a rate of 5% per year, the historical rate of mine closures. The total amount fixed before 1976 is assumed to be a fixed fraction of 1975 demand. In each period, the model minimizes the cost of satisfying an incremental demand equal to the net increase in demand over the fixed 1975 levels plus the cumulative amount of mine closures through that year. The model has the option of assuming shipments resulting from the optimization routine in years after 1975 are fixed by contracts for a given number of years. However, this analysis uses the simplest form.[9]

Sulfur Constraints

The coal used must satisfy restrictions on sulfur emissions. These constraints reflect the impact of federal and state air pollution regulations. There are four sets of air pollution regulations to be concerned with. New source performance standards (NSPS) limit plant emissions to less than 1.2 pounds of sulfur dioxide per million Btus burned. Furthermore, regulations force stack-gas scrubbing in plants for which construction began after 1978.[10] State implementation plans (SIPs) limit

7. We assume scrubbers remove 90% of sulfur emissions. This level of efficiency reduces emissions from the highest sulfur category to acceptable levels.

8. It is assumed that 90% of 1975 demand is fixed by contracts.

9. If subsequent contracts are fixed, high-cost coal would continue to be produced when lower-cost coal was available. Experiments with alternative forms indicate that not restricting contract comes closest to the dynamic optimum (see Zimmerman 1981).

10. The revised NSPS standards now call for a minimum level of scrubbing equal to 70%. Utilities are free to choose the level of scrubbing above that minimum as long as

emissions, in many cases plant by plant, in order to meet general ambient air standards. In most areas, NSPS standards are more stringent than SIP standards and are therefore binding on new plants. Last, in areas that are already below the applicable standards, there are nondegradation requirements. These standards mean that plants cannot contribute to increasing air pollution in the area.

To reflect these complicated standards, actual current emissions were calculated for each region. Nondegradation requirements mean that pollution must not increase above current levels. Secondly, incremental coal demand must meet new source performance standards of 1.2 pounds of SO_2 per million Btus. Only one of these constraints is binding in any region and that is entered as the constraint. In the runs reported here, the 1.2-pound standard takes effect in 1985. Between 1975 and 1985 the standard declines linearly from current average emissions to 1.2 pounds. This reflects the fact that not all incremental coal is subject to NSPS.[11] Finally, the best available control technology (BACT) requirements are imposed by forcing scrubbing on plants scheduled to come on stream after 1983.

A formal statement of the linear program is provided in the Appendix.

The Analysis

The analysis proceeds the following way. First, competition between Montana and Wyoming is examined. Then the incentives for Montana and Wyoming to cooperate in setting taxes are explored. Since cooperation can raise both states' revenues substantially, we next examine

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emissions are less than .6 pounds SO_2 per million Btu burned. In effect, only low-sulfur coal can meet that limit. We have modeled a more extreme version of NSPS requiring 90% scrubbing of all new plants. The difference in effect between these two policies is small because of the high cost even of 70% scrubbing and the high cost of low-sulfur coal.

11. There are biases introduced by this proceeding, but they are small. For the first 20 years of the simulation incremental demand is $ID(t) = D(t) + \sigma D(0)(.05\ t - 1)$, where $D(t)$ = demand in year t and $\sigma = .9$. NSPS demand will equal demand in new capacity plus replacement of obsolete coal capacity. Assume that $D(t) - D(t - 1)$ represents new capacity and retirements are 5% per year. Then

$$\begin{aligned}\text{NSPS demand }(t) &= D(t) - D(t-1) + .05\ D(0)t\\ \text{bias} &= (\text{NSPS demand} - DI)\\ &= D(0)(-.9 + .005\ t).\end{aligned}$$

In 1975, nonmetallurgical demand was 486.4 million tons. That yields the following year-by-year calculation of the bias:

	$D(t)$	Bias	Percentage
1975	486	...	...
1980	544	−36.5	−6.7
1985	705	−24.3	−3.4
1990	767	−12.2	−1.6

Montana and Wyoming as a unit competing with the most important alternative western coal producing region.[12]

Competition between Montana and Wyoming

At present Montana has an effective tax rate twice that of Wyoming.[13] Given the similar cost structures in these states, all new expansion is taking place in Wyoming. Montana, on the other hand, has larger coal reserves. Expansion in Wyoming in the early years will lead to some depletion and the eventual reemergence of Montana as an important supplier.

In order to understand the competitive relationship between Montana and Wyoming over time, we simulate competition between these states. Holding the Wyoming tax rate constant, we simulate the model for alternative tax levels in Montana and solve for the tax rate that maximizes the present value of Montana tax receipts. Then, holding the Montana tax fixed at that level, we alter Wyoming taxes until the maximum present value of revenues is obtained. This procedure traces out the reaction function of each state under this Bertrand-type assumption. Both states find it profitable to undercut each other. The result is that the reaction functions intersect where each state sets a tax of 7.5%. Competition between Montana and Wyoming, and the substitutability between coal production in Montana and Wyoming, leads to very low tax levels compared with the actual situation today.

The discount rate used in the analysis above is a real rate of 11.5%, approximately the private cost of capital for coal-mining firms.[14] The results, however, are sensitive to the discount rate. A lower discount rate means people are willing to wait longer for revenue. Using a 4.5% real rate of discount and repeating the analysis yields tax rates of 27.5% and 25% in Montana and Wyoming, respectively. Under both discount rates, substitution between Montana and Wyoming coal keeps tax rates in a competitive environment roughly equal.[15] The question that arises then is how much better off these states would be if, instead of competing, they set tax rates jointly.

A Powder River Basin Cartel

In order to examine the extent of market power for the Powder River Basin as a whole, we assume Montana and Wyoming set a single tax and act as a residual supplier. The "cartel" maximizes revenue given the coal demand curve and the supply functions in other regions.

Beginning at 20% we simulate the model at alternative tax rates and

12. A complete set of exogenous input assumptions is available from the authors.
13. Recall that local levies raise taxes in Montana to 35% and to 16.8% in Wyoming.
14. An investigation by Alt (1978) supports this discount rate.
15. Since we are simulating taxes in intervals of 2.5%, these taxes are approximately equal.

TABLE 2 **Present Value of Montana and Wyoming Tax Revenues and Wage Bill in Montana-Wyoming Cartel Case** (Billions of 1981 Dollars)*

	Base Case Nuclear Assumption		Optimistic Nuclear Assumption	
Tax Rate (%)	Tax	Wage	Tax	Wage
7.5:				
Montana	1.636	3.490	...	...
Wyoming	1.134	2.423	...	...
Total	2.772†	5.913	...	...
20	3.564	3.041		
35	5.662	2.626	5.379	2.496
50	7.420	2.422	7.012	2.291
62.5:				
Montana	5.278	1.343		
Wyoming	3.056	.818		
Total	8.336	2.161	7.717	2.028
75	7.539	1.664	6.384	1.513
100	6.477	1.096	5.496	.939
150	6.470	.754	5.827	.685
Current tax regime:				
Montana (35%)	1.613	.737	...	...
Wyoming (16.8%)	2.282	2.173	...	...
Total	3.895	2.910	3.848	2.867

* Discount rate = 11.5%.
† Individual figures do not sum to total because of rounding.

solve for an approximate maximum. The choice of an optimal proportional tax is made solely on the basis of maximizing the present discounted value of the ensuing tax revenues. The tax is held constant for the entire simulation. In this first exercise, we assume no changes from base levels in tax policy in other states.

The optimum tax for the Montana-Wyoming cartel turns out to be 62.5% (see table 2). This optimum is insensitive to the discount rate. Similar results are obtained at a 4.5% and a 11.5% real discount rate. It is also insensitive to whether states are maximizing revenue or the sum of revenue plus wages. Only a large weight on wages would yield an "optimum" below 50%. This arises because of the capital intensity of western strip mining. In the East, where labor-intensive deep mining is more important, there is more trade-off between the wage bill and tax revenues.

Maintaining a cartel is somewhat problematic for Montana and Wyoming since side payments are not feasible. Even though total revenue is maximized by the 62.5% tax, it is possible Wyoming is better off with the current disparity in tax rates. As table 2 indicates, this is not true. Both Montana and Wyoming revenues increase over the base case when they jointly set tax rates. Since both states can be made better off with no explicit sharing mechanism necessary, we might expect future joint increases in tax rates.

What Limits the Tax?

As Montana and Wyoming raise their tax, they lose output to competition from other regions. Table 3 compares production and coal flows in the base case and in the revenues maximizing case in 1990. Montana and Wyoming output is down by 19%, and the largest beneficiary of this lost output is the Utah-Colorado producing region. Demand region 8 (mountain states) switches from almost exclusive reliance on Montana and Wyoming in the base case to almost exclusive reliance on Utah and Colorado.

Region 6 (Arizona, New Mexico) increases its production by 23 million tons. This gain comes at the expense of Utah and Colorado (supply region 5). As region 5 expands its production its costs rise, making Arizona and New Mexico more competitive on the west coast (demand region 9). The reserves in Arizona and New Mexico are too low, however, to support higher levels of production. Depletion sets in and this competitiveness disappears by 2000, as shown in table 4. Other producing regions experience small changes in 1990.

The pattern of western coal flows in 2000 is not as greatly affected, with Montana-Wyoming output down by only 7% (table 4). The pattern in the East changes substantially. Supply region 1 production declines by 88.8 million tons under the high-tax scenario. This is balanced by a production increase, not in the West, but in the Midwest (supply region 3). The Northern Appalachian region loses out as a competitor to the Midwest in the South Atlantic demand region (region 5). This result is due to the extreme closeness of competition between the two regions. The delivered cost of coal to the South Atlantic from each of these supply regions is quite close. The slightly greater production in the early years for the Midwest causes the balance to tip toward Northern Appalachia in the later years. All this indicates is the nature of competition between these two regions. No other implication can be drawn.[16]

While the Midwest gains mostly from Northern Appalachia, it increases its shipments to its own consuming region (demand region 3) by a relatively small amount at the expense of Montana and Wyoming.

Interregional competition with Utah and Colorado provide the elasticity in demand that limits the Montana-Wyoming tax. Total coal consumption is not greatly affected by the tax. This is seen also in the relatively small reductions in coal consumption in regions where Montana and Wyoming are the sole or primary suppliers under both tax regimes such as demand regions 4, 10, and 11.

Part of the explanation for the inelasticity of demand for coal lies with our constrained nuclear power scenario. We have limited nuclear power to plants already in the pipeline as of 1979. In the light of recent

16. For discussion of this see Zimmerman (1981, p. 69).

TABLE 3 **Coal Distribution and Production in the Base Case and Cartel Case in 1990** (Millions of Tons)

From Supply Regions	To Demand Regions 1	2	3	4	5	6	7	8	9	10	11	12	E + D*	Total
							A. Base Case							
1	8.77	74.46	14.77	.02	148.42	.12	.00	.00	.00	.00	.00	.00	68.33	314.88
2	.08	.83	5.44	.04	36.51	6.12	1.26	.00	.00	.00	.00	.00	126.14	176.42
3	.00	.00	41.01	4.30	3.20	91.57	.00	.00	.00	.35	.00	.00	5.49	145.92
4	.00	.00	207.47	124.51	.00	.06	.00	69.98	.00	30.59	68.35	.00	.00	500.97
5	.00	.00	.13	.09	.00	.00	15.68	1.27	35.97	.00	.00	.00	13.75	66.90
6	.00	.00	.00	.00	.00	.00	12.42	.94	24.87	.00	.00	47.24	.00	85.46
Total	8.84	75.29	268.81	128.97	188.13	97.86	29.36	72.19	60.84	30.94	68.35	47.24	213.71	1,290.55
							B. Cartel Case							
1	9.12	75.56	14.77	.02	162.24	.12	.00	.00	.00	.00	.00	.00	68.33	330.17
2	.08	.83	5.44	.04	24.20	6.12	1.26	.00	.00	.00	.00	.00	126.14	164.11
3	.00	.00	41.72	4.30	3.20	93.31	.00	.00	.00	.35	.00	.00	5.49	148.36
4	.00	.00	194.50	116.81	.00	.06	.00	.41	.00	28.42	64.17	.00	.00	404.36
5	.00	.00	.13	.09	.00	.00	15.61	53.09	14.38	.00	.00	.00	13.75	97.04
6	.00	.00	.00	.00	.00	.00	12.36	.94	49.67	.00	.00	45.38	.00	108.35
Total	9.19	76.40	256.55	121.26	189.64	99.60	29.23	54.44	64.05	28.77	64.17	45.38	213.71	1,252.39

* Export and domestic metallurgical.

TABLE 4 **Coal Distribution and Production in the Base Case and Cartel Case in 2000** (Millions of Tons)

From Supply Regions	To Demand Regions 1	2	3	4	5	6	7	8	9	10	11	12	E + D*	Total
							A. Base Case							
1	38.94	117.75	0.00	.00	102.91	.00	.00	.00	.00	.00	.00	.00	83.79	343.38
2	.00	.00	.00	.00	27.86	2.44	.00	.00	.00	.00	.00	.00	154.67	184.98
3	.00	.00	175.25	.00	215.83	161.45	.00	.00	.00	.00	.00	.00	6.74	559.27
4	.00	.00	189.77	188.14	.00	6.15	.00	137.85	159.65	48.39	118.48	23.45	.00	871.88
5	2.13	5.06	.00	.00	6.47	.00	15.60	.00	20.16	.00	.00	.00	16.86	66.29
6	.00	.00	.00	.00	.00	.00	26.30	.00	.00	.00	.00	69.17	.00	95.47
Total	41.07	122.81	365.02	188.14	353.07	167.60	41.90	137.85	179.81	48.39	118.48	92.62	262.06	2,121.27
							B. Cartel Case							
1	40.17	124.89	.00	.00	5.73	.00	.00	.00	.00	.00	.00	.00	83.79	254.57
2	.00	.00	.00	.00	45.40	4.08	.00	.00	.00	.00	.00	.00	154.67	204.15
3	.00	.00	191.15	.00	306.72	165.98	12.63	.00	.00	.00	.00	.00	6.74	683.21
4	.00	.00	165.01	175.68	.00	.00	.00	130.99	162.16	44.68	110.69	22.06	.00	811.28
5	2.18	.00	.00	.00	6.59	3.06	19.82	.00	19.72	.00	.00	.00	16.86	68.22
6	.00	.00	.00	.00	.00	.00	7.01	.00	.00	.00	.00	66.61	.00	73.63
Total	42.35	124.89	356.16	175.68	364.44	173.12	39.46	130.99	181.88	44.68	110.69	88.67	262.06	2,095.06

* Export and domestic metallurgical.

cancellations, even this is an optimistic scenario. Would a more promising future for nuclear power alter the conclusions? To examine that issue, we alter the scenario to allow for new nuclear construction. We assume all doubts about safety are resolved, financial difficulties do not affect construction, and plants are built wherever cost minimization leads to a nuclear decision. The realism of these assumptions is not important, because we want an upper bound on the effects of nuclear power.

The results of such a scenario do not alter the conclusion (table 2). Revenue is maximized at the same 62.5% severance tax. In effect, the lead time in constructing new plants is so large that nuclear substitution, while important by the end of the century, has relatively little effect on the present value calculations. The total tax collections go down, but it does not pay to lower the tax and sacrifice near-term tax revenues for later ones.[17]

In sum, market power exists for Montana and Wyoming. Incentives exist for cartelization, and the limits to taxing power come from interregional competition, primarily with Utah and Colorado.

The analysis has been conducted so far on the assumption that all other states maintain constant tax rates. In reality, if Montana and Wyoming raise their taxes we would expect to see other states responding. In fact, current debates are going on in many state legislatures over appropriate tax rates.

Cooperation between the West and the Midwest is difficult, given the large number of states involved and the more complicated market patterns. The midwestern states compete with each other and, as we saw, will compete with Appalachia. Cooperation among all these agents is unlikely. Furthermore, the level of competition between the West and Midwest, as we have seen, is not great. In essence, it is the degree of competition between western regions that will affect western tax levels.

Cost structures in other western regions are quite different than in Montana and Wyoming. Utah and Colorado produce higher-quality coal, increasingly from underground deposits, at much higher cost than in Montana and Wyoming. Furthermore, the absence of side payments and the highly dissimilar cost structures make a cartel of all these states extremely unlikely. Reserves in Arizona and New Mexico are too small to be a big factor in any production limitation through taxation. With cooperation difficult, some competition between western regions is bound to exist.

17. More complicated strategies could set low taxes at first and raise them as contracts and shipments are committed for long periods. Such simulations would require assumptions about the state of knowledge of consumers and producers and involve complicated game-theoretic formulations. This would take us far beyond the goal of this analysis.

We push this type of decision making further and investigate what sort of equilibrium would emerge if the two primary western regions maximize their respective revenues, assuming the other region's tax level remains constant. This Bertrand-type assumption is a reasonable characterization of a complex situation and yields insight into the interregional nature of state tax policy.

The reaction functions of both areas are traced out, as was done separately for Montana and Wyoming above. The intersection of the resulting reaction functions is at a tax of 74% in Montana and Wyoming and 23% in Utah and Colorado. If Utah and Colorado begin to react to high tax levels in Montana and Wyoming, substantially higher tax rates in both Montana and Wyoming and Utah and Colorado could emerge.

Gainers, Losers, and Deadweight Loss

The intense public policy debate that is now going on in Congress arises because of the large transfers between producing states and consumers. Producers of coal in the taxing states lose rents while producers in nontaxing states gain. Table 5 shows the regional and functional breakdown of gains and losses for the case in which Montana and Wyoming act as a residual supplying cartel. The changes are measured against the present situation.[18]

The size of the transfer is substantial. In 1990 consumers would lose approximately $1.7 billion (1981 dollars) under the Montana-Wyoming cartel. Producers of coal in the aggregate gain $0.24 billion with a large loss in Montana-Wyoming counterbalanced by gains in other areas. Total increased tax revenues in 1990 amount to $709 million. The interregional transfer is interesting since it represents a new pattern of rent collection in the United States. Traditionally the Southwest gained rents on oil production from the large consuming regions of the Midwest and Northeast. The new transfer goes from midwestern and western consumers to the western producers. The East Coast is largely unaffected.

The net difference between increased producer surplus and state tax revenues, on the one hand, and consumer surplus lost, on the other, represents a deadweight loss to society as a whole of about $740 million (1981 dollars) per year in 1990. In 2000 the deadweight loss totals $630 million per year. Similar calculations in the Bertrand equilibrium between Montana-Wyoming and Utah-Colorado yield a deadweight loss relative to the base case of an estimated $793 million in 1990 and $980

18. The measures of producer and consumer surplus changes are calculated by comparing the equilibria under two cases and assuming linear supply and demand curves over the region of change. Producer surplus changes are calculated for each sulfur supply schedule net of taxes in a region and then summed. Consumer surplus changes are calculated in the electricity demand model from consumption of high-sulfur coal, scrubbed and unscrubbed, and low-sulfur coal.

TABLE 5 **Calculated Changes from Base Case in Producer and Consumer Surplus by Region for Montana-Wyoming Cartel, 1990 and 2000** (Millions of 1981 Dollars)

Region	1990	2000
	Change in Consumer Surplus	Change in Consumer Surplus
Demand:		
New England and Mid-Atlantic	−.15	31.21
East and West North Central	−1110.82	−1105.3
South Atlantic and East South Central	−6.01	−43.41
West South Central	−167.44	−777.32
Mountain	−364.06	−951.10
Pacific Coast	−39.24	−472.28
Total	−1,687.72	−3,380.66
	Change in Producer Surplus	Change in Producer Surplus
Supply:		
Northern Appalachia	+18.21	−35.06*
Southern Appalachia	+6.89	+11.40
Midwest	+6.96	+112.91
Montana, Wyoming	−28.62	−226.44
Utah, Colorado	+162.46	+184.45
Arizona, New Mexico	+70.69	+366.98
Total	+236.59	+414.24
Total change in tax revenue	+709.46	+2,332.94
Total deadweight loss	741.67	633.48

* The decline here is due to substitution between regions 1 and 3, discussed above in text.

million in 2000 (calculations not shown). The total national coal bill in 1979 for comparison, was $18 billion. Deadweight loss therefore amounts to about 5% of the total coal bill.

Public Policy toward Coal Severance Taxes

A recent constitutional challenge to the Montana tax was denied by the U.S. Supreme Court. Without the possibility of judicial action, Congress is now considering legislation to limit state severance taxes to 12.5%. What would be the efficiency gains from such an action? We investigate this issue by setting the Montana-Wyoming tax at 12.5% and solving for revenue-maximizing Utah-Colorado tax. At an 11.5%

discount rate, the result is a severance tax in Utah and Colorado of 7.5%.

What does such legislation accomplish? Under a national tax limitation bill, deadweight loss calculated as above relative to the base case is $76 million and $316 million in 1990 and 2000, respectively (calculations not shown). Of course, the total social savings of such legislation depends on how high taxes would go without legal limit. Were the Bertrand behavior between Montana and Wyoming and Utah and Colorado to result, for example, the saving would amount to $600–$700 million per year. The distributional shifts due to taxes are much greater than the social loss, and it is the shifts that motivate the policy debate.

The Role of the Railroads

The partial monopolization of western coal markets could be accomplished by railroads that haul the coal. At present, only the Burlington Northern railroad originates coal shipments in the Powder River Basin and the Union Pacific is responsible for the bulk of shipments from the coal basins of Utah and Colorado. These roads then could play exactly the role played by the states in our analysis above. Furthermore, the problems of coordination between the individual states in each region do not exist for the single railroads.

There are, however, significant differences between the railroads and the states that make an analysis of railroad pricing behavior much more complicated and a fertile area for future research. The states must set a single tax regardless of destination. Discriminating severance taxes in the Supreme Court's view are the only type of tax prohibited by the Constitution. As state legislatures raise taxes they earn revenue from nearby regions with less elastic demand for their coal while sacrificing revenue from the more distant regions with more elastic demands. Railroads, on the other hand, can discriminate between destinations. This discrimination was somewhat limited under regulation, but recent legislative changes in railroad regulation provide ample opportunity for such discrimination. For these reasons, railroads are more efficient collectors of rents. They can capture the consumer surplus while causing fewer distortions in efficient production patterns.

Other factors operating in the long-run suggest that railroads may not be a policy problem. Competition from new rail lines and other transport sources, slurry pipelines in particular, will limit the market power of railroads. These pipelines transport a mixture of pulverized coal and water. The current difficulty is that long-distance pipelines need permission to cross railroad rights-of-way. Legislation granting pipelines eminent domain is being sought in Congress. No one knows when or if such legislation will pass, but if passed it will limit railroads' market power.

Summary and Conclusions

There is potential for significantly higher taxes in the western coal-producing states. Montana and Wyoming both have incentive to form a minicartel. A response by Utah and Colorado to such a cartel would evoke even further tax increases in Montana and Wyoming. Utah and Colorado would also benefit. The transfers between consumers and producers are quite large. The social efficiency losses, while substantial, are small relative to the national coal bill. Government efforts to limit state severance taxes could limit social losses by about \$600–\$700 million per year.

Appendix

A Formal Statement of the Linear Program

Following is an algebraic expression of the problem:

$$\text{Min} \sum_{i=1}^{6} \sum_{j=1}^{12} t_{ij} \sum_{s=1}^{8} \sum_{k=0}^{1} Z_{ijsk} + \sum_{i=1}^{6} \sum_{s=1}^{8} \sum_{m=1}^{6} C_{ism} \, Y_{ism}$$

$$\text{s.t.} \sum_{m=1}^{6} Y_{ism} - \sum_{j=1}^{12} \sum_{k=0}^{1} Z_{ijsk} = 0 \qquad \begin{aligned} i &= 1, \ldots, 6 \\ s &= 1, \ldots, 8 \end{aligned}$$

$$\sum_{m=1}^{6} B_i \left| \sum_{s=1}^{8} Z_{ijsk} \geq D_{jK} \right. \qquad \begin{aligned} j &= 1, \ldots, 12 \\ k &= 0, 1 \end{aligned}$$

$$\frac{2000(2) \displaystyle\sum_{i=1}^{6} \sum_{s=1}^{8} P_s Z_{ijso}}{\displaystyle\sum_{i=1}^{6} B_i \left| \sum_{s=1}^{8} Z_{ijso} \right.} \leq S_j \qquad j = 1, \ldots, 12$$

$$Y_{ism} \leq U_{ism} \qquad \begin{aligned} i &= 1, \ldots, 6 \\ s &= 1, \ldots, 8 \\ m &= 1, \ldots, 6 \end{aligned}$$

$$Z_{ijsk}, Y_{ism} > 0,$$

where

- t_{ij} = transport cost in dollars per ton from supply region i to demand region j;
- Z_{ijsk} = shipment of coal in tons from supply region i to demand region j of sulfur type s and scrubbing activity k; a value of 1 for k indicates scrubbing, 0 indicates no scrubbing;
- Y_{ism} = production in region i of coal of sulfur category s from step m;
- C_{ism} = cost of coal from step m in supply region i of sulfur category s;
- B_i = Btu value per ton of coal in region i;

D_{jk} = demand in region j for coal from scrubbing category k, in Btus;
P_s = sulfur content percentage by weight of coal of sulfur category s;
U_{ism} = length, in tons, of step m in supply curve of region i, sulfur category s.

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