STRATEGY AND MARKET STRUCTURE IN WESTERN COAL TAXATION

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Abstract—This paper analyzes the potential market power of western states in setting coal severance taxes and the emphasis placed by these states on the development of their coal resources vs. obtaining tax revenues. Three market structures are analyzed. One involves a western regional cartel, setting taxes collectively. The other cases are noncooperative tax equilibria with Montana and Wyoming competing against each other. We conclude that the western states seem to be primarily concerned with revenue collection and are very efficient extractors of economic rent.

I. Introduction

THE past decade has seen phenomenal growth in coal production in the western United States, particularly in the states of Montana and Wyoming. This can be attributed to a national shift to coal in response to dramatically increased oil prices and a shift away from high-sulfur midwestern coal to low-sulfur western coal for environmental reasons. This new-found popularity of western coal has triggered mixed reactions in the western states. The rapid industrial development in these sparsely populated regions produces a variety of adverse social, environmental and economic consequences (e.g., boom town effects). As a result, in an effort to mitigate these adverse effects as well as exploit a favorable market position, several western states (particularly Montana and Wyoming) have imposed sizable severance taxes on coal.[1] Coal-consuming states (the midwest and south-central United States) have responded to these high taxes through the courts and the U.S. Congress, although without success to date.

A number of important policy questions surround this issue. Can these taxes be expected to rise or fall in the future? Are there serious inefficiencies associated with the current taxes? Why is Montana's tax so much higher than Wyoming's? The purpose of this paper is to answer these and other questions, exploring the strategies that producing states may be using to set severance taxes, focusing on the extent of market power possessed by the western states. Our emphasis is on the effect of nonrevenue objectives (e.g., stimulation of employment, disbenefits of coal production) on tax levels. Building on previous work (Kolstad and Wolak, 1983), the approach here is to posit a variety of market structures and behavioral models of the tax-setting process and then determine and evaluate the tax equilibria that result. States set taxes according to a utility function with tax-revenues *and* other benefits (or disbenefits) of coal production as arguments.

A number of conclusions result from this study. It appears that the market position of the western states is strong enough that if they could set severance taxes on coal in concert, they could set taxes at a much higher level than at present. However, "competition" between the states of Montana and Wyoming has a strong moderating influence on the setting of severance taxes. Current tax levels in those states are much more consistent with a noncooperative than a cooperative model of tax setting. For the noncooperative model, Wyoming appears to see the non-tax benefits of coal production positively, lowering its tax rate from the revenue-maximizing level. In contrast, Montana views non-tax benefits negatively, leading to a higher tax rate than is revenue-maximizing. However, on the basis of their current tax policies, western state governments are primarily concerned with revenue collection, placing little emphasis on stimulating (or discouraging) expenditures for coal production within their states. Finally, the western states seem to be very efficient redistributors of the economic surplus associated with coal production. Substantial tax revenues can be collected with little deadweight loss to society.

The next section presents a review of the structure of the western coal market and possible objectives of states in setting taxes. Section III presents a simple analysis of state taxation strategies. Sec-

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[1] Montana's tax rate on surface mined coal is 30% of value at the mine and Wyoming's tax rate is 10.5%. Since property taxes are so significant in Wyoming (6.5%), we include them for Wyoming, yielding an effective tax rate of 17% (Blackstone, 1983).

tion IV presents an empirical analysis of tax equilibria based on a spatial equilibrium model. This includes a discussion of non-revenue taxation objectives and welfare implications of severance taxes.

II. Market Structure and Taxation Objectives

A. *Market Structure and Conduct*

Much of the very cheaply extractable coal of the West is in the Powder River basin of Montana and Wyoming. With vast coal reserves in this basin, high rates of production can be sustained there for long periods of time without appreciable depletion effects. In the past, only one railroad (the Burlington-Northern) has served this producing area. This combination of rapidly increasing demand for very low-cost coal and concentration in political jurisdiction and transport has apparently endowed the two states and one railroad with a considerable amount of market power. Other western states also possess market power but to a lesser extent. The position of the Burlington-Northern railroad is expected to erode appreciably over the coming years as other railroads and other transportation modes (e.g., slurry pipelines) begin to serve the Powder River basin.

Thus, the states are the principal entities with the long-term potential to extract monopoly rent through the imposition of severance taxes. However, this power is limited. Given a high enough price for western coal, "dirty" midwestern coal can substitute for "clean" western coal through the use of sulfur control capital. Also, the large degree of substitutability between Montana and Wyoming coal allows the state charging the lower severance tax to capture a sizable portion of the midwestern market at the expense of the state with higher taxes. This is precisely the situation at the present time where Wyoming production is considerably in excess of production in Montana, a state with a significantly higher severance tax.

B. *Market Conduct*

It is possible to hypothesize several behavioral models for the setting of western state severance taxes. The simplest behavioral model is that of a cartel, where producers collectively decide upon tax levels (or rules for determining tax levels) for all cartel members.[2] The simplest model of operation for a taxation cartel is to set tax rates in each state to maximize joint profits. But unless side-payments are allowed (which is unlikely in our case), this may result in a perceived inequitable distribution of benefits among cartel members. Another possible way to operate such a cartel is to agree upon a fixed tax rate, common to all participants, which maximizes some combination of member tax revenues and employment-related benefits. (Alt et al. (1983) have examined revenue-maximizing taxes for a western coal cartel.)

It would seem hard to imagine that a formal cartel of states could arise in the western United States. A much more likely behavioral model is that individual states set their severance tax, keeping their neighbors' tax policies in mind. If we assume that each state sets its own tax rate (from its own perspective, optimally), then the rational policy for a state to follow is to set its own tax rate assuming other states follow their optimal strategy. Most theories of such oligopolistic behavior differ in terms of one state's perception of the strategies of the other states (e.g., the Bertrand, Cournot and Stackelberg models). In a game theoretic context, all such equilibria can be viewed as Nash equilibria.[3]

C. *Taxation Objectives*

Certainly a major determinant of the level of severance taxes is the perspective of the government body conducting the taxation.[4] There appear to be three levels of government that could impose a severance tax: state, regional and federal.

We would expect states to attempt to maximize net benefits to state residents. Assuming all consumption of the resource and all gains from production occur out of state (not an unrealistic assumption for coal in most western states), a possible objective is to maximize tax revenues. However, there are other benefits (wages and em-

[2] Interest in natural resource cartels has been rekindled with the rise of the Organization of Petroleum Exporting Countries (OPEC). Numerous authors (e.g., Pindyck, 1978; Cremer and Weitzman, 1976; Hnyilicza and Pindyck, 1976) have explored cartel pricing policies, particularly in the context of OPEC.

[3] A number of authors have examined various oligopolistic theories in terms of the pricing of natural resources (Salant, 1976; Gilbert, 1978).

[4] For a discussion of the rationales for severance taxes, see Church (1981).

ployment) and costs (environmental and social) associated with coal production within a state. Hence, a more realistic objective might be to maximize total net benefits, both private and public, as suggested by Shelton and Morgan (1977).

The objectives of a region in tax setting would be quite similar to those of a state but certainly much more difficult to implement due to the complexities of determining the preferences of a larger constituency. The political problems associated with coordinating the tax policies of several states are also severe.

The objectives of the Federal government would be to achieve the socially optimal levels of output which presumably occur when taxes are nil, assuming no externalities from coal production.

III. Tax-Setting

In this section we present two models of tax-setting. The first model is that of a single state or a cartel of states setting taxes. The second model is that of a group of states setting taxes noncooperatively. In both cases, utility to the region or state from coal production is due to tax revenues as well as other net benefits (positive or negative) of production.

A. Optimal Taxes for a "Monopolist" Region or Cartel

This analysis applies to a single state or to a cartel of states setting a single tax rate. In this case, assume that producer and consumer surpluses accrue totally outside the region and that the state or region has a tax objective which is a function of total revenues collected and other state benefits (or disbenefits). Associated with coal extraction are many positive benefits, besides severance tax revenues. Disbenefits are varied but certainly are a function of coal produced.

Major among the disbenefits are so-called "boom town" impacts from rapid economic development due to natural resource extraction in sparsely populated areas (see Cummings and Schulze, 1978). There is also the argument that some of the costs of resource extraction are irreversible, thus placing a cost on future generations as well as the current generation earning income from the resource development (Kneese and Schultz, 1975). Another disbenefit is the land disruption from strip mining (Kalt, 1983). For the state or region as a whole we can consider these aggregate disbenefits roughly proportional to total production costs.[5]

Certainly the various non-severance-tax positive benefits of coal production are related to total production costs. Wages and employment are the two major benefits within this category, from which accrue several ancillary benefits such as state income and sales tax revenue.

Thus, we assume that production costs can be thought of as a proxy for the state's net benefits from coal production exclusive of severance tax revenue. Given this assumption, the objective function of a state or region can be written as

$$\max_{t} U(T, C) \tag{1}$$

where U is the state's "utility" function, T is tax revenues, C is the cost of production, and t is the tax rate as a percentage of marginal production cost at equilibrium.[6] For simplicity, intertemporal considerations are ignored here. Providing U is well behaved, an optimum from (1) will be obtained where

$$\frac{dT}{dt} + \frac{U_C}{U_T}\frac{dC}{dt} = 0, \tag{2}$$

where U_i is the marginal utility with respect to the i^{th} argument of equation (1). Clearly, if the regional disbenefits of production are large enough, U_C could be negative. In this case, a situation can arise where the state uses the tax rate as a policy instrument to choke off coal production within its bounds to such an extent that tax revenue becomes a declining function of the tax rate. In words, the tax rate is set (in the case when $U_C < 0$) such that the incremental increase in utility from decreasing net disbenefits by increasing t by one unit just offsets the decrease in utility from the lost tax revenue as a result of this small change in t. Thus, if dT/dt is negative at the optimum tax rate then we can conclude that $U_C < 0$.

[5] It can be argued that environmental disbenefits are nonlinearly related to coal produced. Small amounts of mining can be assimilated within the existing natural and social environment without adjustment. Large amounts of mining entail significant dislocations. However, given that western states considered here are already heavily involved in coal mining, over the relevant range of output levels, environmental disbenefits are approximately linearly related to production costs.

[6] Assume tax is applied to coal price excluding the amount of the tax.

Assume U_T is the numeraire in equation (2). In order to solve equation (2) for an optimal tax rate, we must examine the market equilibrium condition

$$S(q)(1+t) = P(q), \tag{3}$$

where S and P are marginal cost and inverse demand functions, respectively, for a quantity q of coal. Differentiating equation (3), we obtain

$$\frac{dq}{dt} = \frac{S(q)}{P'(q) - S'(q)(1+t)}. \tag{4}$$

We can differentiate the identity $T = t[S(q)]q$, with respect to t. Using this result, equation (4), and remembering that costs are the integral under the marginal cost curve, equation (2) can be reduced to

$$t^* = \frac{q[S'(q) - P'(q)] - (U_C/U_T)S(q)}{S(q)}. \tag{5}$$

Note that as $U_C/U_T \to \infty$, $t^* = -(U_C/U_T)$, which is clearly negative, suggesting that as benefits arising from production costs become of paramount importance, there is a tendency to subsidize production at all costs. If $U_C/U_T \to -\infty$, t^* becomes arbitrarily large. Where tax revenue becomes of overriding importance, $U_C/U_T \to 0$ and t^* becomes

$$t^* = \frac{q[S'(q) - P'(q)]}{S(q)}. \tag{6}$$

Consider further equation (5). For a fixed U_C/U_T, it appears that a significant determinant of the tax rate is the sum of the absolute slopes of the marginal cost and inverse demand curves, $S'(q) - P'(q)$. The larger the sum of the absolute values of the slopes of these curves, the larger the optimal tax rate will be. The opposite result holds for heavy emphasis on benefits arising from production costs.

B. *Tax Equilibria with Several States*

The discussion of the previous section applies to a single state with market power or to a collection of states with a formal or tacit agreement among themselves to set severance taxes uniformly. It is more interesting to consider the tax equilibria that arise from several states "competing" in the same markets. Thus we will now focus on noncooperative tax equilibria.

Market Equilibrium Conditions: We first consider what prices and output will result from a given set of taxes. Assume there are n coal-producing states supplying coal to a single demand region. We assume all other producing states maintain tax rates at current levels. In each producing state, coal production is determined by private producers on a competitive basis,

$$p_i = S_i(q_i)(1+t_i), \tag{7}$$

where p_i is the price of q_i coal including tax t_i in state i, and $S_i(q_i)$ is an aggregate marginal cost curve for the private producers. Let the inverse demand for the homogeneous product of the n states be given by $P(\Sigma_j q_j)$. Finally, there will be a price difference between coal at the state of origin and at its destination—principally the coal transport cost.[7] We assume here that this per unit transport cost is a function of the price of coal in the state of origin, including tax.[8]

$$\tau_i = r_i(p_i) \tag{8}$$

where τ_i is the per unit price difference between mine-mouth and delivered coal. Market equilibrium will exist if supply and demand price are equal:

$$p_i + r_i(p_i) = (1+t_i)S_i(q_i) + r_i[(1+t_i)S_i(q_i)] = P\left(\sum q_j\right) \quad \forall i. \tag{9}$$

This equation (9) defines the market equilibrium for the problem. This equation can be solved for output (q_i) as a function of the vector of tax rates, $\mathbf{t}$.

Reaction Function Equilibria: Now that we have determined how the market will respond to specific tax rates, we consider how states might set taxes. Specifically, we examine conditions for a noncooperative tax equilibrium. As before, assume that each state seeks to maximize utility:

$$\max_{t_i} U^i(T_i, C_i), \qquad \forall i. \tag{10}$$

The first-order condition for a maximum for state i is

$$\frac{dT_i}{dt_i} + \frac{U_C^i}{U_T^i}\frac{dC_i}{dt_i} = \frac{\partial T_i}{\partial t_i} + \frac{U_C^i}{U_T^i}\frac{\partial C_i}{\partial t_i} + \left[\frac{\partial T_i}{\partial q_i} + \frac{U_C^i}{U_T^i}\frac{\partial C_i}{\partial q_i}\right]\frac{dq_i}{dt_i} = 0. \tag{11}$$

[7] Since states serve different markets and we deal with only one average delivered price for coal, some of this price difference is due to the spatial heterogeneity of coal markets.

[8] As mine-mouth prices (including taxes) increase, distant marginal markets are lost, lowering the average shipment cost.

In the same manner as equation (5), this can be rewritten as

$$\left[t_iS_i(q_i) + t_iS_i'(q_i)q_i + \frac{U_C^i}{U_T^i}S_i(q_i)\right]\frac{dq_i}{dt_i} + S_i(q_i)q_i = 0. \tag{12}$$

Equation (12) implicitly defines the reaction function for state i. But to evaluate the expression it is necessary to determine dq_i/dt_i, which involves evaluating the derivative of q_i defined implicitly by the equilibrium condition (9). The solution of equation (12) yields an expression for the optimal tax rate t_i as a function of all the other states' tax rates $\mathbf{t}_{\langle i \rangle}$ and U_C^i/U_T^i:

$$t_i = f_i\left(\mathbf{t}_{\langle i \rangle}, \frac{U_C^i}{U_T^i}\right). \tag{13}$$

This approach can be taken for each state i yielding a tax reaction function such as (13) for each t_i. The tax equilibrium for the n states can be determined from the simultaneous solution of n equations of the form of (13). The difference among the various types of reaction function equilibria depends on how one calculates dq_i/dt_i. This calculation is discussed in Kolstad and Wolak (1983).

IV. An Applied Analysis of Tax Equilibria

We turn now to an analysis of optimal coal severance tax rates in the western United States. Based on estimates of coal supply and demand, we will estimate equilibrium tax rates for a variety of behavioral models of tax rate determination. Since it is difficult, if not impossible, to econometrically estimate the supply and demand curves for western coal using only historic market information (refer to Zimmerman, 1981), we have taken an alternate approach, detailed and justified in Kolstad and Wolak (1983). To summarize, we have used an activity analysis partial equilibrium static[9] model of coal markets in the United States. Since the model cannot be solved explicitly for even the optimal regional cartel tax rate, our approach instead is to use this model to simulate a market response to alternate severance tax levels. We then statistically condense the output of the model into aggregate supply and demand curves that can be easily manipulated to determine optimal tax rates.

To generate a set of market equilibrium points we exercised the model for the year 1990 for a number of cases.[10] We let western[11] regional severance taxes, applied at varying rates uniformly throughout the region, rise from nothing to 120%. Taxes in states outside the region are set at current rates. These equilibrium points can then be used to estimate aggregate supply and demand functions that are readily manipulated in order to determine equilibrium tax rates under alternate assumptions about the taxsetting process. Long-term contracts have been ignored since in practice they are frequently renegotiated and can be broken if market conditions change dramatically.[12]

The following analysis is in two parts. In the next section we examine the simplest situation, where all western producers are treated as a unit. Although a cartel structure may be unrealistic, it is important to examine for three reasons. Since the cartel has been examined by others (e.g., Alt et al., 1983), it represents a connection to past work. Further, it represents a maximum market power situation. Also, the cartel is a simple enough market structure to enable us to examine easily other

[9] Cremer and Weitzman (1976) have shown that when depletion effects are small (as with western coal), a static analysis of monopoly power gives essentially the same results as an intertemporal analysis. Although depletion effects could potentially be greater in the midwest than in the west, much of the recent increase in western production has displaced midwestern production, leading to much excess capacity in the midwestern coal industry. Consequently, depletion effects in the midwest should also be modest through the rest of the century. In an intertemporal analysis of a western coal cartel, Alt et al. (1983) find the present-value-of-revenue maximizing tax-rate to be insensitive over a wide range of discount rates, adding further justification to our static analysis.

[10] The year 1990 was chosen for several reasons, including data availability and model validity (see Wolak et al., 1981). An examination of years much earlier than 1990 would undoubtedly encounter market rigidities which would bias this type of analysis. We selected an analysis year far enough into the future for market rigidities to be of a minor concern, but also close enough to the present to have relevance to current market conditions. Additionally, it was felt that by 1990 the western coal industry would be more mature and hence able to exercise more fully market power than at the present. The relative newness of western mining capital and anticipated demand for coal suggest that the market power of western states will remain roughly the same from 1990 through the rest of the century. Thus, although the choice of 1990 is somewhat arbitrary, it is expected that analysis of other years would give qualitatively similar results.

[11] The West is defined as the states of Arizona, Colorado, Montana, New Mexico, Utah, and Wyoming.

[12] The model presented here is a deterministic one. In a world of certainty and perfect foresight, the existence of long-term contracts is neutral since firms will not make contractual errors. Because our analysis is of the long-run, within a world of certainty, ignoring long-term contracts should introduce little bias into our results.

TABLE 1.—SELECTED MODEL RESULTS[a] FOR ALTERNATIVE REGIONAL SEVERANCE TAXES

Western Severance Tax Rate[b] (%)	Severance Taxes Collected West ($10^6/yr)	FOB Coal Prices, West[c] ($/ton)	Delivered Coal Prices, Midwest[d] ($/ton)	Delivered Coal Prices, U.S. ($/10^6 Btu)	(10^6 tons) Annual Coal Prodn. MT & WY	West	U.S.	Estimated Deadweight Loss[e] ($10^6/year)
Current Rates	Not Available	9.50	23.00	0.98	570	660	1320	Not Available
0	0	8.30	21.30	0.94	650	740	1350	—
10	560	8.70	21.80	0.96	610	710	1340	15
20	1030	9.35	22.80	0.99	570	660	1330	60
40	1820	10.60	23.90	1.03	520	600	1300	210
60	2270	12.15	26.10	1.09	420	500	1260	550
100	2680	14.25	27.40	1.14	310	380	1210	1300
105	2720	14.65	27.40	1.15	290	360	1210	1430
120	2710	15.85	28.00	1.17	250	310	1190	1850

[a]All figures for 1990; monetary quantities in 1975$.
[b]Tax rate defined as percentage of marginal production cost, net of tax.
[c]West is Arizona, Colorado, Montana, New Mexico, Utah, Wyoming.
[d]Midwest defined as Illinois, Indiana, Michigan, Ohio, Wisconsin.
[e]Let q_t be western coal production with unit tax $\hat{t}$($/ton). Then a *rough* estimate of deadweight loss from tax $\hat{t}$ is $\hat{t}(q_0 - q_t)/2$. This assumes no externalities of production and no effect on markets other than western coal.

objectives in tax-setting besides revenue maximization.

Following the cartel analysis we focus on the two principal western producers, Montana and Wyoming, and investigate noncooperative Nash equilibria for the two states. Within this context, we try to infer the value states place on nonrevenue objectives by comparing several Nash equilibria to existing severance taxes and the effect of relative valuations of a state's equilibrium output and tax levels.

A. *The Regional Cartel*

The first case we examine is where all western coal-producing states are treated as a unit; i.e., they are assumed to act in concert. The first step is to exercise the spatial equilibrium model to generate a set of pseudo-data. Some results from the model execution are presented in table 1. Note that maximum tax revenues occur in the range of 100%–120%, and that there is a significant drop in western coal production and a modest drop in coal prices net of tax as severance taxes rise to 120%. Note also that a good portion of the drop in western production is picked up elsewhere in the country.

As the tax rate increases from 0% to 120%, western production drops from 740 to 310 million tons whereas total national production drops from 1.35 to 1.19 billion tons. This indicates that the midwestern and eastern producers satisfy most of the demand previously supplied by the West without substantial effects on delivered coal prices to the Midwest (for a tax rate increase from 0% to 120%, the delivered coal price to the Midwest increased only 30%). Note also that most of the drop-off in production occurs in Montana and Wyoming. The other states of the West face more inelastic demand. This is because their market is mostly local. Local consumers in these states generally have few alternate sources of coal.

Also shown in table 1 is an estimate of the deadweight loss associated with severance taxes. This is only an estimate, assuming, among other things, that there are no distortions in other markets affected by the tax. For "modest" levels of the tax (≤ 40%), the deadweight loss is quite small, particularly when compared to revenue collected. For tax rates in this range, the tax is a fairly efficient redistributor of surplus. However, for tax rates on the order of 100%, the loss becomes substantial, on the order of 50% of the tax revenues collected.

Although each of the seven model runs represents a different market equilibrium, the underlying supply and demand curves are not shifting—it is the changing tax rate that results in different equilibria. The equilibria (including tax) trace out an aggregate demand curve for western coal; the equilibria net of tax trace out an aggregate western coal supply curve.

Assuming that the marginal cost and inverse demand curves for western coal are straight lines,

TABLE 2.—REGRESSION RESULTS FOR AGGREGATE WESTERN COAL MARGINAL COST AND INVERSE DEMAND FUNCTIONS (FUNCTIONAL FORM: $p = a + bq$)

	a	b	R^2
Marginal Cost	6.34 (44.2)	0.0023 (8.5)	0.90
Inverse Demand	21.15 (104.2)	−0.0176 (−45.1)	0.99

Note: t-statistics (coefficient/standard error) for coefficients are in parentheses. Units are \$/ton (p) and millions of tons per year (q). Estimation via two-stage least squares on seven observations.

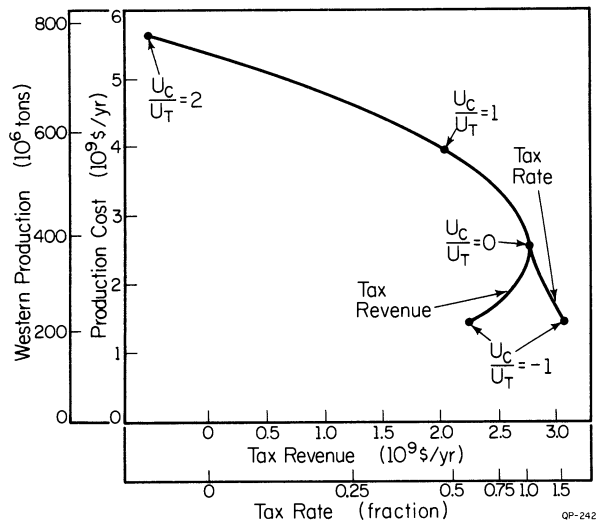
denote these functions by $p_s = a_s + b_s q$ and $p_d = a_d + b_d q$ where the marginal cost curve is net of tax. Results from two-stage least squares regression[13] of each of these functions are presented in table 2. Equations (3) and (5), using the coefficients from table 2, imply that for $U_C/U_T = 0$ (tax revenue maximization paramount), the optimal tax is 102%.[14] However, suppose $U_C/U_T \neq 0$. Figure 1 traces out an efficient frontier for optimal cost/tax pairs depending on the value of U_C/U_T. At any point along this curve, the slope of the tangent line is the ratio of the marginal valuation of taxes to the marginal valuation of production costs. When tax revenue and production costs are weighted equally and thus the objective is to maximize total (public and private) revenue (excluding rent), then the optimal tax rate falls to just over 40%, which is not an exceptionally high tax rate.

Can anything be said about the revealed value of U_C/U_T, based on current tax rates? An examination of table 1 suggests that current severance tax rates (which vary from state to state) "average" about 20% over the region. This follows from the fact that current rates would result in approximately the same average regional coal price and regional aggregate production level as a uniform regional tax of 20%. Thus if we assume that a cartel is an appropriate market structure and 20% is a regionally optimal tax rate, from figure 1 (or equation (5)) this implies a marginal valuation of an extra unit of production costs of about 1.3. That is, there is an indifference between earning an extra dollar of severance taxes and the coal industry spending \$1.30 on production costs (assuming a regional cartel market structure). Given the relatively high social and environmental costs of coal development in the West (as discussed by Kalt, 1983), this would imply an unrealistically high valuation on non-severance-tax net benefits from coal production. Thus we have additional indirect evidence that a cartel is an inappropriate model for severance tax setting in the West.

[13] Two-stage least squares is thought to be more robust than full-information techniques when samples are small and there is the potential for misspecification, since any error is restricted to a single equation and is not allowed to propagate throughout the entire system (Johnston, 1984).

[14] For a Montana-Wyoming coal cartel, Kolstad and Wolak (1983) found 87% to be revenue maximizing while Alt et al. (1983) reported 67%.

FIGURE 1.—EFFICIENT FRONTIER: TAX REVENUE VS. PRODUCTION COSTS (REGIONAL SEVERANCE TAX CASE)



B. *A Montana / Wyoming Tax Equilibrium*

In search of a more plausible market structure, we now expand our applied analysis by treating the western states individually. Unfortunately, as the number of agents or states that are participating in such tax-rate-setting increases, the complexity of the problem also increases dramatically. Consequently, we will restrict our analysis to the two principal western coal producers, Montana and Wyoming, and assume all other states adhere to their current tax policies. This assumption is not as limiting as it would at first seem because the rest of the western states, in total, contribute less than 15% to total western production in the analysis year (table 1). As mentioned earlier, these minor producers sell most of their output within their own state or to a neighboring state; this politically limits their market power. Further, in the previously examined regional cartel case, most of the revenue gain and production loss occurred in

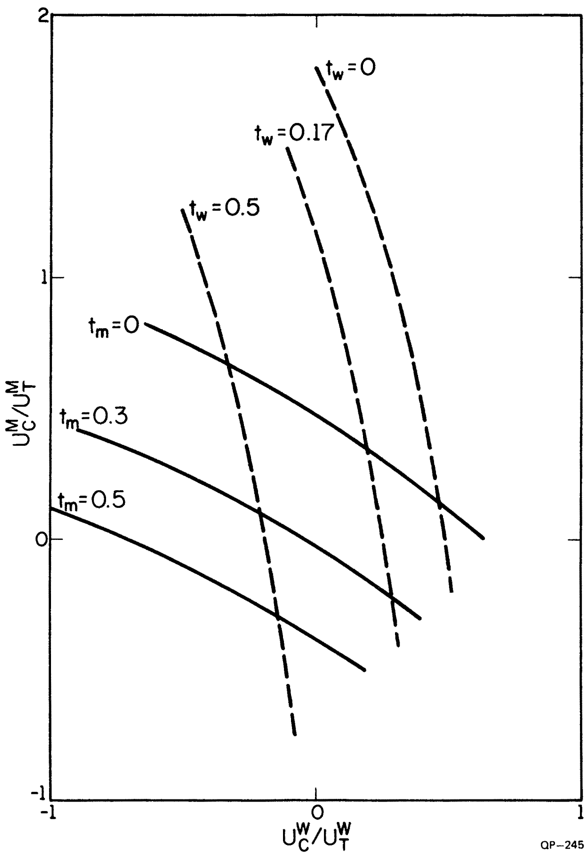
Montana and Wyoming, due to the slopes of their marginal cost curves and their market shares. Since the focus of our previous work (Kolstad and Wolak, 1983) was competition between Montana and Wyoming in coal taxation, we focus here on the nonrevenue objectives of the two states in setting taxes.

To summarize our previous results, when tax revenues are the sole objective in tax-setting, then a simple Nash tax rate equilibrium is approximately 27% for Montana and 33% for Wyoming. These are considerably smaller numbers than were obtained above for the case of collusion in regional tax setting. The effect of the competition between the two states is quite significant, dropping the optimal tax rates from 87% (for the case of the same tax rate with only Montana and Wyoming colluding) to near 30%. Revenue is 40% less than the collusion solution. Another tax-setting model that was considered is that one of the states is a leader in the spirit of Stackelberg. The "tax leader" would set his tax to maximize revenue, assuming the other state stays on his reaction function. In these cases, both the leader and the follower have slightly higher tax rates than for the simple Nash equilibrium. However, the leader can raise his tax rate more than the follower.

The above results apply to the case where tax revenue is the sole state objective in setting taxes. Understandably, these results change significantly if states also value (positively or negatively) coal production for its own sake. The reaction function (13) for the two states can be solved simultaneously[15] giving each state's tax rate solely as a function of each state's relative valuation (U_C^M/U_T^M and U_C^W/U_T^W). In figure 2 we have plotted iso-tax curves for each state. For Montana (solid lines) each curve shows the U_C^M/U_T^M and U_C^W/U_T^W combinations consistent with the indicated equilibrium tax rates. Of course, for a single iso-tax curve, the tax rate for the other state will vary as a function of relative valuations. The broken lines in the figure show the iso-tax curves for Wyoming. Each curve in the figure is a line *segment*, reflecting the fact that coal output from each state is constrained to be non-negative.

Points at which a Montana iso-tax line and a Wyoming iso-tax line intersect represent tax equi-

FIGURE 2.—ISO-TAX-RATE CURVES



libria. Associated with each equilibrium is a pair of relative valuations. The current Montana tax is 30% corresponding to the $t_m = .3$ curve and the current Wyoming tax is 17% corresponding to the $t_w = .17$ curve (Blackstone, 1983). These curves intersect at $(U_C^W/U_T^W,\ U_C^M/U_T^M) = (.30, -.23)$. Thus if current tax rates are optimal and set according to the duopoly model developed here, the two states have dramatically different objectives in setting severance taxes. Wyoming views the non-tax benefits of coal production positively; Wyoming sets severance taxes to collect revenue but moderates the tax rate so as not to excessively discourage coal production. Montana, on the other hand, views coal production as a negative activity for the state, outside of tax revenue generation. These results are consistent with the common view that Wyoming is more "pro-development" than Montana. Although this is a subjective view, Montana has appeared to have a more vocal opposition to coal production than Wyoming. This is in part due to the partial Indian control over

[15] The functional forms utilized for the demand, supply and transport cost functions are given in Kolstad and Wolak (1983) as are the corresponding pseudo-data parameter estimates.

TABLE 3.—SENSITIVITY OF EQUILIBRIA

(U_M, U_W)	$\frac{dt_m}{dU_M}$	$\frac{dt_w}{dU_M}$	$\frac{dq_m}{dU_M}$	$\frac{dq_w}{dU_M}$	$\frac{dt_m}{dU_W}$	$\frac{dt_w}{dU_W}$	$\frac{dq_m}{dU_W}$	$\frac{dq_w}{dU_W}$
(0, 0)	−.58	−.13	310	−140	−.36	−.73	−210	360
(−.23, .30)	−.58	−.11	310	−140	−.43	−.73	−300	480

Note: $U_M \equiv U_C^M/U_T^M$; $U_W \equiv U_C^W/U_T^W$.

Montana coal as well as the seemingly more vocal environmental movement in the state. These results lend credence to the noncooperative duopoly model developed here.

These results are also qualitatively consistent with the revenue maximizing tax-rates previously reported ($t_m = .27$, $t_w = .33$). Current Montana rates are slightly higher than revenue maximizing rates, indicating a negative view of coal production. Current Wyoming rates are lower than revenue maximizing rates in order to encourage coal production.

Further, note that the set of Wyoming iso-tax curves is much more steeply sloped than those of Montana. Wyoming tax rates are much more strongly influenced by U_C^W/U_T^W than U_C^M/U_T^M. In contrast, Montana's tax rates are strongly affected by both states' relative valuations. Compare the tax-revenue-maximizing equilibrium with the equilibrium associated with current rates. As U_C^W/U_T^W moves from 0 to 0.30, Wyoming's tax rate drops appreciably. The fact that U_C^M/U_T^M moves to -0.23 is of little consequence to t_w. However, in the case of Montana, the interplay between U_C^M/U_T^M and U_C^W/U_T^W results in very little change in the equilibrium tax rate in moving from the tax revenue maximization case to the case associated with current rates.

The sensitivity of equilibrium tax rates can also be inferred from figure 2. Consider either the equilibrium with tax-revenue as the sole objective or the equilibrium that is the same as current tax rates. At either point, an increase in Montana's relative valuation of 0.1 results in a decrease in t_m of 0.06 and t_w of 0.01. Similarly, an increase in Wyoming's relative valuation of 0.1 results in a decrease in t_m of 0.04 and t_w of 0.07. The asymmetry between the effects of the two relative valuations is due to the steeper slope of the Wyoming iso-tax curves. Changes in output for the two states as a result of changes in relative valuation follow a similar pattern, ranging from 14 to 48 million tons per year per state for a change in relative valuation of 0.1. Note from table 3 that in both cases a change in Wyoming's preferences has the greatest impact on the output of the two states. However, for both Montana and Wyoming, if either of the two state's relative valuations increase, the result is an increase in the total production from the two states.

In summary, by considering objectives other than tax revenue maximization, we are able to explain current severance tax rates on the basis of Montana slightly discouraging coal production and Wyoming encouraging it. In both cases, however, the absolute marginal utility of an extra unit of production costs is only 0.2 to 0.3 that of an extra unit of severance tax revenues. This is not large and can be contrasted with the result of 1.3 for the regional cartel discussed earlier.

C. *Distribution and Welfare Effects*

It must be emphasized that the severance taxes computed in the previous two sections are optimal only from the point of view of the state or region levying the tax. For the market as a whole, there are the standard welfare losses resulting from output levels deviating from the no-tax situation, assuming negligible externalities associated with coal production. There is also a substantial redistribution of social surplus from producers and consumers to the taxing authority. One interesting question to ask is how efficient is this redistribution process and how producers or consumers share in bearing the burden of the taxation. We have calculated approximate values of consumer surplus, producer surplus and total surplus (including tax revenue) for both the regional severance tax and the Montana-Wyoming tax cases (ignoring effects on other markets besides western coal, particularly midwestern coal markets).[16] Normalized by the surplus level in the no-tax cases, these three measures of surplus are shown in table 4 for several tax equilibria.

[16] As argued by Harberger (1971) and others, in general only the market with the distortion (tax) need be examined for deadweight loss.

TABLE 4.—RELATIVE WELFARE SHIFTS[a]

	Consumer Surplus	Producer Surplus	Producer and Consumer Surplus	Total Surplus[b]
A. Western States Cartel				
No tax	100	100	100	100
Cartel (t = 102%)	25	25	25	75
Present taxes (t = 20%)	80	80	80	99
B. Montana-Wyoming Market				
No tax	100	100	100	100
Joint revenue maximum	28	13	23	70
Nash—tax revenue[c]	71	44	62	94
Nash—current rates[d]	73	89	78	98

[a] For each column, welfare levels are measured as percentages of value in respective no-tax case.
[b] Includes producer surplus, consumer surplus and tax revenue. For computational reasons, for the Montana-Wyoming market, total surplus was calculated using, for all cases, the unit transport cost associated with the no-tax case.
[c] Tax revenue alone is in each state's objective function.
[d] $(U_C^M/U_T^M, U_C^W/U_T^W) = (-.23, .30)$, yielding a Nash equilibrium equal to current tax rates

For the six state simple regional cartel, assuming the cartel values only tax revenue ($t^* = 102\%$), we find that although total surplus (including tax revenues) only declines to 75% of that for the no-tax solution, producer and consumer surplus both fall substantially, to 25% of the no-tax value. For the case of $t = 20\%$ (the "average" of current rates), the total surplus hardly drops, being 99% of the no-tax solution, although total consumer and producer surplus (excluding tax revenues) drops to 80% of its no-tax value. Table 1 indicates an average tax in the neighborhood of 20% results in relatively small deadweight losses. These welfare losses seem to suggest that the region's governments are currently quite efficient in severance taxation. This conclusion, of course, depends on how well a 20% tax rate reflects current heterogeneous rates.

For the Montana-Wyoming tax setting equilibria these same conclusions seem to carry over. We consider both the cooperative solution (the joint revenue maximizing solution) and the two noncooperative Nash solutions. For the joint revenue maximizing solution, total surplus drops to 70% of its no-tax level, a figure comparable to that for the western states cartel. For the revenue-maximizing Nash equilibrium, total surplus is still 94% of its no-tax value. In both cases, although both coal producers and consumers sustain noticeable welfare losses, the producers are affected to a much greater extent. However, the last Nash equilibrium, that associated with current tax rates, proves to be very efficient. There is practically no loss in total surplus relative to the no-tax case. Whereas consumers are affected in approximately the same way for both Nash equilibria, producers fare much better under the current rate equilibrium. This is no doubt due to the emphasis the dominant producer (Wyoming) places on encouraging coal production within its boundaries.

In both of these cases we can see that producers and consumers of coal lose substantial surpluses to the taxing states or governments with most of the lost surpluses going to state coffers and little to deadweight loss to society, at least for modest tax rates. Hence, it would seem that western states are currently quite efficient at extracting economic surpluses from coal produced within their boundaries.

V. Conclusions

This paper has served three purposes. Independent of the exact numerical results, several conclusions can be derived. Even a modest valuation on the economic development aspects of coal mining can drop the equilibrium severance tax significantly. Stated differently, the state governments of Montana and Wyoming, on the basis of their severance tax policies, seem to place major emphasis on severance tax collection with the development of the coal mining industry and its ancillary *net* benefits only a minor concern.

Our results for the noncooperative model suggest that Montana sets its tax-rates in excess of revenue maximizing rates in order to discourage coal production. In contrast, Wyoming rates are below revenue maximizing rates, suggesting that

Wyoming wishes to encourage coal production. There is some evidence that this accurately describes public attitudes in the two states, adding credence to our model.

Finally, our results indicate that the western states are very efficient redistributors of the economic surplus associated with western coal, at least given current tax rates. These states seem capable of collecting substantial tax revenues with little deadweight loss to society.

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