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UNIONISM AND PRODUCTIVITY IN WEST VIRGINIA COAL MINING

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This study presents econometric estimates of the effects of unionism on productivity in 83 West Virginia coal mines in the early 1920s. The size, detail, and panel structure of the data set permit investigation of many possible links between unionism and productivity, in contrast to the summary measures reported by most studies. The results show that the union effect was not uniform across mines and cannot be represented by a simple shift parameter. Rather, unionism significantly reduced productivity at small mines but not at large mines. Drawing on historical evidence, the author ascribes this differential effect to systematic differences between small and large operations in the quality of management and union leadership.

UNIONISM can conceivably influence productivity in a variety of ways. From a price-theoretic perspective, possible union effects fall into three classes. First, unions can affect productivity through input prices. Unions may raise the price of labor input relative to other inputs. They may also alter the relative wages of different types of labor, some of which may be substitutes for or complements of nonlabor inputs. For example, a union may raise or lower the wages of workers who use machines relative to the wages of those who do not. Such effects change the average product of labor, but they do not alter the firm's labor demand, cost, and production functions. This class of effects might be called "allocational effects."[1]

Second, unions may restrict the choices among resources available to the firm; that is, they may restrict input proportions, or impose maximum or minimum levels of certain inputs. Such restrictions have often been alleged in discussions of craft unionism in newspapers, railroads, construction, and the maritime trades,[2] but they might

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Data and programs used to generate the results reported in this paper are archived on a tape at the Interuniversity Consortium for Political and Social Research, P.O. Box 1248, Ann Arbor, Michigan 48106. A guide to the tape is available from the Consortium or from the author at the Department of Economics, The Ohio State University, 410 Arps Hall, 1945 High Street, Columbus, Ohio 43210-1172.

[1] Let x_1 and x_2 denote inputs with prices w_1 and w_2, respectively. Let the output y be produced with production function $y = f(x_1,x_2)$ and fetch price p. The firm's problem is to maximize profits, given by:

$$\text{profits} = py - w_1x_1 - w_2x_2$$

Changes in input prices induce changes in the optimal levels of inputs and therefore changes in the average products of factors: $AP_1 = y/x_1$ and $AP_2 = y/x_2$ without altering the production function $f(x_1,x_2)$ itself. By contrast, "input-restriction effects" add restrictions to the firm's choice of inputs, which might be denoted most generally by:

$$g(x_1,x_2) \leq 0.$$

Finally, "production-function effects" refer to changes in the function $f(x_1,x_2)$ itself, not its arguments.

[2] See Bok and Dunlop (1970:271–73) on the

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also characterize the demands of some industrial unions for job security. If the restrictions are binding, then the firm is displaced from its cost and labor-demand functions, but not from its production functions.[3] This class of effects might be called "input-restriction effects."

Third, unions may change the parameters of the production function itself. Effects in this class—which might be called "production-function effects"—are the focus of this paper and of most of the existing econometric literature.[4] Results reported by this literature have been mixed. Negative effects on productivity have been reported for turn-of-the-century British coal fields (Pencavel 1977) and for a sample of U.S. manufacturing plants (Bemmels 1987). Positive effects were reported for U.S. manufacturing, however, by Brown and Medoff (1970), who used aggregate data; for a multinational manufacturing firm (Mefford 1986); and, based on both project-level and aggregate data, for U.S. construction (Allen 1984, 1986a, 1986b). Clark (1980a and 1980b) reported small, barely significant positive effects for cement plants. Connerton, Freeman, and Medoff (1979) reported an effect for U.S. coal mining that appeared to change from positive to negative over time, but union effects were not distinguished from mine-specific effects in their methodology. Ehrenberg, Sherman, and Schwarz (1983) reported mixed effects for public libraries.

This literature has several shortcomings. First, those studies reporting the strongest positive effects of unionism have used cross-sectional data. If unions tend to organize the most productive firms or establishments, such studies will suffer from simultaneous-equation bias.[5]

Second, almost all econometric studies to date have used a simple specification of the union effect—a simple intercept shift[6]—and many have used aggregate data. The summary numbers that result, which provide an average union effect, are difficult to interpret. Such simple specifications stand in contrast to the institutional literature, which has long argued that the union effect is complex, varies across industries and establishments, and depends on many factors, including the course of technological change (Hartman 1969) and the quality of management and union leadership (Slichter, Healy, and Livernash 1960). The data are partly to blame for these shortcomings. Simultaneous-equation bias can be overcome with panel data sets (as in Clark 1980a, 1980b), but these are hard to find. More complex specifications for production and the union effect can be estimated, but significant results require larger data sets than those heretofore available to econometricians. It is nevertheless surprising that so few studies have investigated whether unionism affects more than one parameter in the production function.

In this study I attempt to overcome these shortcomings using an unusual data set pertaining to West Virginia coal mines in the 1920s. The panel nature of the data allows union effects to be distinguished from ongoing productivity differences across establishments. The data set is large enough to permit estimation of a flexible production function, with unionism allowed to affect *all* of the input parameters.

National Diesel Agreement of 1937, and Hartman (1969) on longshoring.

[3] Such an outcome is usually predicted by cooperative bargaining models of unionism in which a Pareto-optimal solution is attained.

[4] Intentions aside, it is a difficult matter empirically to isolate production-function effects completely. When unions influence wages, the possibility of unobserved allocation effects (such as changes in labor quality or managerial effort) can never be confidently ruled out.

[5] This issue has been widely recognized. See the discussion in Brown and Medoff (1978:373–74). Mefford's cross-sectional study appears to have avoided simultaneous-equation bias by using an international sample in which unionism is completely determined by geographic location.

[6] One exception is Mefford (1986), who rejected structural change in the input parameters on the basis of individual t-statistics for his sample of 126 observations. Another exception is Bemmels (1987), who rejected structural change on the basis of likelihood-ratio test statistics for his sample of 46 observations.

The Historical Setting

The history of West Virginia coal mining in the 1920s provides a natural experiment for examining the effects of unionism on productivity. This history shows rapid but not quite simultaneous changes in unionism throughout the state.[7] After World War I, about half of West Virginia's coal fields were unionized by the United Mine Workers. Then, caught between falling coal prices and a rigid union wage policy, operators began to fight the union. The political environment became more favorable to the operators as wartime labor regulations were relaxed and a Republican president took office in 1921. The operators expelled the union successively from each West Virginia coal field until by 1927 the UMWA had no contracts in the state.[8] Over this relatively short period, one can compare the same establishments under union and nonunion operation. Thus, unionism effects may be distinguished from establishment effects. Also, because deunionization was not simultaneous throughout the state, unionism effects may be distinguished from time effects.

What sort of effects might the union have had on the production function for coal mining? Historical sources suggest various possible effects, some of which might depend on the levels of the inputs. First, the union might have had a *positive effect at all mines* due to reduced turnover and a likely improvement in labor quality. Second, the union might have had a *negative effect at mechanized mines* due to prolonged haggling in setting appropriate piece rates for machine mining. Third, the union might have had a *negative effect at small mines,* which appear to have been victims of economies of scale in labor relations.

Turnover and Labor Quality

Historical evidence indicates that union mines enjoyed lower turnover than nonunion mines. A 1921 survey by the U.S. Coal Commission revealed an "astonishing contrast" between the turnover rates at union and nonunion mines (see Table 1).[9] It is important to recognize that lower turnover had a direct effect on productivity by keeping workers more familiar with the mine layout, with mine-specific problems and procedures, and with each other. It is equally important, however, to consider the selection mechanisms causing lower turnover, two of which stand out.

First, union contracts made discharge of workers more difficult. Although these contracts promised that "the authority to hire and discharge shall be vested in the mine superintendent or mine foremen, and nothing in this agreement shall be construed to abridge the right of the employer in either of these respects,"[10] in practice, operators and government observers believed, firing a worker was difficult unless he violated an explicit provision of the contract.[11] To the extent that less capable workers might have been particularly protected by the union, this cause of lower turnover would have had an ambiguous, perhaps even negative effect on productivity. There is some evidence, however, that most of the workers protected from discharge by the union were merely unpleasant, not incapable (Emmet 1924:85).

Second, higher wages made union jobs more desirable. Higher wages undoubtedly reduced quits. In addition, they probably created queues for union jobs, which may have allowed mine foremen to hire selectively the most productive workers. Comparative accident rates support this hypothesis, assuming accident rates varied inversely with experience and productivity.[12] In general, accidents were

[7] For details, see Anson (1940) or Boal (1985).

[8] See District 17 Secretary-treasurer Fred Mooney's autobiography (1967:127–28) for an account of the destruction of the UMWA in West Virginia.

[9] U.S. Coal Commission (1925:1264–65).

[10] Language found in the New River field contract of 1919 (see *United Mine Workers Journal,* September 1, 1919, p. 13) and in the Fairmont field contract of 1924 (see Senate Hearings 1928:1081).

[11] See Bituminous Operators' Special Committee (1923:177); U.S. Coal Commission (1925:1325); Emmet (1924:85).

[12] This assumption was widely accepted by contem-

Table 1. Labor Turnover in West Virginia Coal Mines, 1921.

	Union Mines			*Nonunion Mines*		
Coal Field	*No. of Mines*	*Avg. % Turnover*	*Avg. % Stable Force*	*No. of Mines*	*Avg. % Turnover*	*Avg. % Stable Force*
Panhandle & Fairmont	50	97%	51%	7	153%	34%
Kanawha	21	167%	36%	1	245%	28%
Logan Field	0	—	—	10	246%	22%
Kenova-Thacker	0	—	—	5	240%	32%
New River & Winding Gulf	3	111%	56%	7	161%	44%
Pocahontas	0	—	—	12	185%	37%
All Fields	74	118%	47%	42	198%	33%

Notes: "% Turnover" is defined as the ratio of separations from roll to the average number on the roll for the year. "% Stable Force" is defined as the ratio of the number of men at work continuously during the year to the average number on the roll. Averages shown are simple averages over mines.
Source: Computed from sample collected in 1921 by the U.S. Coal Commission (1925, Part 5, pp. 490–95, Tables 13–24).

more frequently reported at nonunion mines.[13]

Taken together, reduced turnover and improved labor quality under unionism may have caused a simple upward shift in the production function.

Difficulties with Mechanization

Officially, the UMWA did not oppose the introduction of new mining machinery, but rather "encouraged" it, with the proviso that part of the resulting productivity gains be allocated to higher wages. If the union's reactions to mechanization had been limited to defending its official policy, the resulting effect on productivity would have been limited to an allocation effect as workers using new machines were paid more than workers using old machines. In fact, it appears that local unions sometimes directly resisted the introduction of new machinery by striking (U.S. Coal Commission 1925:1322). This reaction implies an input-restriction effect on productivity as well.

Moreover, the union's reactions to mechanization went beyond allocation effects and input-restriction effects. True production-function effects may have occurred because of incentive problems stemming from the way in which miners were paid. All loaders and almost all machine runners were paid on piece because of the high costs of supervision in underground mining (Archbald 1922:27–43). New, more efficient machinery therefore required the negotiation of a new, lower wage scale. Until a new rate was determined, the union usually permitted the new machinery to be operated for a test period by workers paid on a temporary scale. Meanwhile, the productivity of these workers was measured as part of the process of determining a new scale. The temporary scale was sometimes just a high, outdated piece rate, but more often it was a day rate. The temporary scale often remained in place for some time, as the operators and the union haggled over the new scale.[14] The absence of a piece rate for these workers, coupled with their knowledge that any extraordinary work effort would penalize them in the eventual wage settlement, undoubtedly depressed their productivity compared with that of their counterparts at nonunion mines. This

porary observers, including both operators and unionists (Dix 1977:77–79), but little statistical evidence has been offered. Detailed data on the distribution of experience for accident victims were reported, but not for the mine work force as a whole (see, for example, West Virginia State Department of Mines). Fishback (1985:662–64) shows that the frequency of fatalities fell with experience, for the first eight or ten years, assuming a uniform distribution of experience over the work force.

[13] This pattern was borne out in the regression sample described below. Union mines and nonunion mines suffered an average of 15.4 fatalities and 32.0 fatalities, respectively, per million worker-days (with standard errors of 6.56 and 3.59, respectively).

[14] Bituminous Operators' Special Committee (1923: 184–85).

incentive problem would produce a negative production-function effect at mechanized mines during the test period.[15]

Difficulties with mechanization were transitory yet recurrent. It is true that each difficulty was eventually resolved in a new piece rate scale. Nevertheless, the coal industry was undergoing continuous technological change, and contract negotiators grappled with a stream of new machines.[16] Although no specific accounts are available from West Virginia outside the Fairmont field, it is possible that the same difficulties with mechanization were experienced everywhere, that union haggling over the appropriate new wage scale left workers operating the new machines with inadequate incentives, and that the production function for mechanized union mines using new machines was thereby lowered relative to that of nonunion mines using the same machines.

Although production-function effects of the union's reaction to mechanization are theoretically distinct from allocation effects and input-restriction effects, they may not be empirically distinct if machine quality cannot be observed. The data described below do not distinguish between arc-wall and earlier machines. Delayed introduction of arc-wall machines (whether due to high wages or direct resistance) should therefore produce the same effect on the production function as incentive problems would.

Poor Labor Relations at Small Mines

Historical evidence suggests that union-management relations were, on average, worse at small coal mines than at large mines. The evidence is only circumstantial, but it appears that managers and union officials at smaller mines were less aware of their rights and responsibilities under the union contracts and hence more likely to lock horns. A phenomenon of economies of scale in labor relations appears to have benefited both large companies and large union locals.

The evidence is stronger on the management side. Major changes in management style were apparently necessary to deal with unionism. Said one official of a very large company in the Fairmont field:

> Management in unionized mines has to work harder, be more up-to-date, more progressive, and more watchful than in nonunion mines. The importance of effective labor administration and centralized labor control is paramount. When the men know the management is on the job, much of the looseness in individual conduct, due to union psychology, gradually disappears. It is true that, on average, we produced as much coal per employee [after unionization as before] but we had to make terrific efforts to achieve these results.[17]

Large companies were apparently able to take advantage of scale economies in expending these "terrific efforts." They

[15] An example of this difficulty was reported in the Fairmont field of West Virginia in the early 1920s. The arc-wall cutting machine was introduced there in 1920 and immediately proved more productive than older designs. Negotiations began on a new, lower machine runner's scale in August 1920, while the union permitted a few operators to operate the new machine on a test basis. Tests during 1920 showed major gains in productivity using the new machine: 45.1 tons cut per hour versus 23.1 tons cut by the old machine (U.S. Coal Commission 1925: 1322). Negotiations with the union dragged on for several years as the union demanded an upward adjustment in the wages paid to loaders as well (*Coal Age*, Jan. 13, 1921, p. 78). A tentative compromise scale was established in the spring of 1923 for use at certain mines. A permanent scale for the entire field was not established until the Baltimore agreement of March 1924, four years after the machine was first introduced in the field (Senate Hearings 1928: 1085–86, 1421–22).

[16] At about the same time that the scale for the arc-wall machine was finally signed in the Fairmont field, operators elsewhere were complaining about the lack of a scale for loading machines, which had not yet been introduced in West Virginia. The union's reaction was to encourage testing with workers paid on a day (not tonnage) basis, to procrastinate on negotiating a tonnage wage scale, and to insist that the new scale permit workers to earn more than they had when using the old machines. (See International President John L. Lewis's address to 1924 UMWA Convention, reprinted in *Coal Age*, January 31, 1924, p. 177.)

[17] Emmet (1924:61). The context indicates that the official was employed by the Consolidation Coal Co., the largest unionized company in West Virginia. In contrast, Emmet reported that other, smaller operators in the same field thought that the union had reduced their productivity.

tended to centralize labor relations responsibilities in a single manager, a specialist with thorough knowledge of the union and the contract, whose job was to tackle problems before they became grievances. Several large companies also had training programs for mine foremen, whose behavior often determined the quality of labor relations at a particular mine.[18] The U.S. Coal Commission praised centralized labor responsibilities and training programs as two of the "essential elements" of good labor relations (U.S. Coal Commission 1925:1357–63).

Small companies[19] struggled with the same challenges without the advantages of scale. They usually relied on the labor commissioner of the local coal operators' association for advice on labor relations. These labor commissioners were less effective than the specialized managers employed by large companies, probably because they were farther from the problems they were expected to solve and because, frequently, they were only part-time employees of the association (U.S. Coal Commission 1925:1352–57).

On the union side, many local officials were poorly trained and did not understand their own contracts. The U.S. Coal Commission found this problem in all coal fields, but cited District 17 (West Virginia) as an "extreme case."

> We were surprised to find how little contact there is between local unions in this district and their district and national officers. . . . Not only are the local men unfamiliar with union business in general, but many of the committeemen are unfamiliar with the provisions of the scale agreement. Apparently few international or district officers ever make a serious endeavor to educate men to their duties under the scale agreement.[20]

A U.S. Labor Department investigator corroborated this finding in a detailed study of the Fairmont field (Emmet 1924:84–85).

The ignorance on the part of the local union officials was understandable under the circumstances. Many West Virginia locals were young and inexperienced, having been organized only since the World War. The district leadership was preoccupied with organizing battles in the nonunion fields, as the Commission noted.[21] District 17 was not the only district to suffer from lack of communication with and training of local officials. Though assistance to local leaders was extremely scarce in West Virginia, it was scarce throughout the entire UMWA.

It seems likely that the problem was felt most acutely at small union locals. The costs to district officials of assisting a union local (personal visits, meetings with operators) were probably independent of its size, but the benefits (dues payments, district election votes) were probably proportionate. It follows that district officials would probably have chosen to allocate whatever resources they possessed primarily to assist the larger union locals and that the larger mines should have possessed more competent local union leadership.

The competence of local union leadership was also to some extent a reflection of the competence of the local mine management. The Commission (1925:1357) found that

> whenever a poor management of labor relations obtained, there was usually found in consequence a poor mine committee, irresponsible leadership in the union, wildcat strikes and rumor of limitation of production [by the workers]. We find that pettiness of management tends to be reflected in pettiness of the mine committee.

[18] One UMWA official claimed that "difficulties arising from unfairness of the mine boss constituted one of our two major causes of complaint." U.S. Coal Commission (1925:1358).

[19] This discussion implicitly equates large companies with large mines. The two phenomena were not equivalent, because it was common for a company to operate more than one mine, but they were certainly correlated. The individual mines operated by a large company also tended to be large.

[20] U.S. Coal Commission (1925:1370). The identity of this "extreme" district is not given but is obvious from context. See also general discussion of UMWA on pp. 1371–74.

[21] "A studious approach to labor relations and union administration is hardly possible where [district] leaders are mainly concerned with keeping themselves out of jail, and the operators seem equally concerned about getting them in." U.S. Coal Commission (1925:1370).

If management were less competent at smaller mines, then union leadership would have also been less competent, on average.

In summary, officials on both sides were probably more competent at larger mines. In contrast, petty disputes caused by ignorance of the contract were probably more frequent at smaller mines. The resulting mistrust and poor morale would probably have lowered productivity under unionism at smaller mines.

Expected Findings

The net effect of unionism on productivity in coal mining in this historical setting is thus expected to be the result of three components: (1) *a positive effect at all mines* due to reduced turnover and higher labor quality; (2) *a negative effect at mechanized mines* due to difficulties in introducing more efficient machines; and (3) *a negative effect at small mines* due to especially poor labor relations. Because effects (2) and (3) depend on the levels of the inputs, a proper test for them must allow *many* of the coefficients of the production function—not just the intercept—to vary with unionism.

Of course, all three effects may not be present. If effect (1) were present alone, one should find an upward shift in the production function at all mines under unionism, similar to that found by Brown and Medoff (1978) and Clark (1980a and 1980b). If effects (2) or (3) (or both) were present without effect (1), one should expect the production function to be lowered under unionism at heavily mechanized mines or small mines (or both). If all three effects were present, the sign of the net effect of unionism would depend on their relative magnitudes and could not be anticipated. In that case, however, one should expect the union effect to be less positive or more negative at small mines and mechanized mines. If none of the three effects were present, then the production function under unionism would be identical to the nonunion production function.

Econometric Estimates

The Sample

The sample consists of 83 underground coal mines in West Virginia observed over four years: 1920–21, 1922–23, 1923–24, and 1925.[22] Of these, 55 mines, mostly in the New River and southern Kanawha fields, operated under union contract for only the first year of the sample. The remaining 28 mines, mostly in the northern Kanawha and Fairmont fields, operated under union contract until the last year of the sample. Every mine in the sample was observed first under union operation and then under nonunion operation, so unionism effects may also be distinguished from mine-specific differences in productivity. Furthermore, the mines in the sample were deunionized at two different times, so union effects may also be distinguished from time effects.[23] The sample appears to be free from selection bias because changes in union relative wages and in the political environment—not changes in union productivity effects—seem to have prompted deunionization.[24]

Sample summary statistics, broken down by union status, are given in Table 2. A comparison of the two subsamples shows that the nonunion observations produced more coal output with fewer workers, cutting machines, and horses than did the union observations. Partly this higher output was accomplished by operating more days per year, but nonunion observations also produced more output per worker-day than did union observations.

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[22] The data are further described in the Appendix. The West Virginia Department of Mines used fiscal years from July 1 to June 30 through 1923–24, and calendar years thereafter.

[23] It is still possible that union effects on productivity were different at mines in this sample than at mines that were never unionized. Because no mines of the latter type are included in the sample, this issue cannot be investigated here. Similarly, the possibility of asymmetric effects of unionization and deunionization cannot be investigated using this sample.

[24] See Lunt (1979) for an analysis of the changing political environment. See Lewis (1963:73–80) for estimates of union relative wages.

Table 2. Sample Summary Statistics by Union Status: 83 West Virginia Coal Mines, 1920–25.

Variable	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*
193 Nonunion Observations:				
Total coal output (net tons)	135,920.21	116,262.66	1,191	614,476
No. of miners	79.80	60.01	0	500
No. of other workers	75.43	57.24	4	310
Total no. of workers	155.23	111.59	10	610
No. of cutting machines	5.54	3.66	1	24
No. of mine locomotives	7.97	6.72	0	40
No. of horses and mules	6.90	8.84	0	58
No. of days of operation	181.30	70.50	4	311
Coal output per worker-day	5.15	2.60	1.61	29.77
% output from pick mining	16.80	21.14	0	98.11
139 Union Observations:				
Total coal output (net tons)	134,192.01	118,424.00	8,423	607,597
No. of miners	94.18	67.13	8	265
No. of other workers	90.36	74.51	9	365
Total no. of workers	184.54	135.66	22	622
No. of cutting machines	7.52	6.90	0	39
No. of mine locomotives	6.18	5.40	0	28
No. of horses and mules	12.88	12.81	0	52
No. of days of operation	163.08	59.29	20	289
Coal output per worker-day	4.65	1.74	1.34	13.64
% output from pick mining	21.26	28.56	0	100

Source: West Virginia Department of Mines. The data are further described in the Appendix.

On the other hand, nonunion observations are concentrated in the later years of the sample period, and perhaps they therefore reflect the use of improved technology. Also, it is possible that inherent productivity differences across mines were correlated with the timing of deunionization. Regression analysis is needed to sort out the unionism effects from the time and individual mine effects.

Estimation Method

Production functions were estimated that related coal tonnage output to five inputs: miners (who loaded coal at the face), other workers (including machine runners, maintenance workers, and laborers), mining machines (used for cutting into the coal face), mine locomotives, and horses. All inputs were measured in physical terms.[25] All input coefficients, including the intercept, were allowed to differ between union and nonunion observations.[26]

Additional variables were included that were likely correlated with unionism but the influence of which should not be ascribed to unionism. For example, mines differed with respect to seam width, faulting, and other geological conditions, as well as layout and age of the mine, so dummy variables were included for all mines. (Because of the large number of dummy variables, they were not estimated directly. Instead, the data were first-differenced, reducing the number of years of data from 4 to 3, and the number of observations from 332 to 249.) Furthermore, technical knowledge advanced over time and national coal demand conditions may have influenced the level of capacity utilization, so dummy variables for these factors were included for all years. Thus, a "fixed effects" model was specified. Finally, mining efficiency depended in part on continuity of operation, so a variable

[25] For estimation, inputs were defined as factor-days: the number of units times the annual days of operation reported by the mine.

[26] Put differently, the union dummy was interacted with all the input regressors.

for the number of days of operation during the year was included in log form with its square. The coefficients of these additional variables were not allowed to vary between union and nonunion operation.

Several functional-form specifications for the production function were estimated. The estimation method allowed for arbitrary serial correlation and heteroscedasticity over time. Where additional heteroscedasticity across mines was detected, standard errors were computed in the robust way suggested by White (1980). The results are discussed below. (The parameter estimates themselves and a detailed description of the estimation method are given in a supplementary appendix available from the author on request.)

Results for the Cobb-Douglas Specification

First, a Cobb-Douglas function, which specifies log output to be a linear function of the logs of the inputs, was estimated, allowing all the input coefficients to change. Joint tests on the Cobb-Douglas coefficients are reported in Table 3. None of the individual input coefficients[27] change by an amount significant at the 5% level, but a joint test shows a significant change. Interpreting this change requires a closer examination of the parameter estimates.[28]

The estimates show the union effect as a striking drop in the intercept term and a less striking rise in the coefficients of three of the inputs, especially that of miners. These changes suggest that unionism was tilting (not shifting) the production function. Also, the coefficient of machines drops from the nonunion to the union production function. Although this drop is not significant at conventional levels, it suggests that any positive effects of unionism on productivity were more likely to be found for less mechanized coal mines.

Return to scale, measured as the sum of the input coefficients, is less than one for both union and nonunion production functions, suggesting decreasing returns to scale (but also perhaps reflecting the omission of unobserved inputs). Of central interest for this study is the sharper drop-off of nonunion returns to scale (.62) than of union returns (.74). Also, the intercept is much smaller for the union production function. These results suggest that nonunion operations produced more coal output than union operations for low levels of inputs, but union operations produced more at high levels of inputs.

This scale effect is confirmed in Table 4, where the difference in the logarithm of output between union and nonunion operation is predicted at various levels of inputs. The predictions shown are obtained by multiplying the estimates of the changes in the input coefficients due to unionism[29] by the logarithms of the sample quantiles of the inputs (reported in the Appendix). The estimates of the difference in logs are converted to percent differences in levels and graphed in Figure 1. The positive predictions at the higher sample percentiles indicate a positive effect of unionism on output at large mines of as much as 28%, whereas negative predictions for the lower percentiles suggest a negative effect of unionism at small mines of as much as −17%.

Results for the Translog and Constrained Translog Specifications

Although it is parsimonious in parameters and easy to interpret, the Cobb-Douglas specification imposes restrictions that may not be appropriate to this data

[27] Because of space constraints, individual coefficient estimates cannot be included in this paper, but they are in a supplemental appendix available from the author on request.

[28] A quick check for the reasonableness of Cobb-Douglas coefficients recognizes that they equal factor cost shares, assuming factors were paid their marginal products. Here, the estimates indicate that labor's total share was 55% for nonunion production and 71% for union production (the difference is significant at the 1% level). Such estimates are compatible with estimates given by historical sources, which range from 55% to 80% (Boal 1985:59–60).

[29] Reported in a supplementary appendix, available from the author on request.

Table 3. Tests of Null Hypotheses.

Null Hypothesis	*Cobb-Douglas Production Function*[a]	*Translog Production Function*	*Constrained Translog Production Function*[b]
Effects of Unionism:			
No change in input coefficients due to unionism.	χ^2 (6) = 23.26***	χ^2 (21) = 31.05*	χ^2 (21) = 41.35***
No change in input coefficients due to unionism, but intercept may change.	χ^2 (5) = 22.25***	χ^2 (20) = 30.85*	χ^2 (20) = 41.27***
Functional Form:			
Nonunion production function is homogeneous.	(imposed)	χ^2 (5) = 14.12**	χ^2 (5) = 13.17**
Union production function is homogeneous.	(imposed)	χ^2 (5) = 1.62	(imposed)
Production function is Cobb-Douglas.	(imposed)	χ^2 (30) = 109.72***	χ^2 (25) = 105.78***

[a] Tests for Cobb-Douglas computed according to White's (1980) robust formula.
[b] Union production function constrained to be homogeneous.
* Rejected at the 10% level of significance; ** at the 5% level; *** at the 1% level.

set. First, the Cobb-Douglas function assumes that elasticities of substitution in production are constant and unitary for all pairs of inputs. This may be an unrealistic assumption for coal mining. For example, mine transportation services were provided by locomotives or by animal power or by a combination of the two. The fact that many mines chose a corner solution, using only locomotives or only horses, suggests a large elasticity of substitution for those two inputs. Similarly, the coexistence of pick mining and machine mining at different mines (which probably faced only slightly different input prices) in the same year suggests a

Table 4. Predicted Union Effect by Scale.

Sample Percentile of Inputs	*Cobb-Douglas*	*Translog*	*Constrained Translog*[a]
5th percentile	−.183*	−.358*	−.426**
	(.102)	(.183)	(.183)
10th percentile	−.145	−.331**	−.373**
	(.094)	(.168)	(.169)
25th percentile	−.065	−.278*	−.274*
	(.081)	(.146)	(.146)
Median	.088*	.004	.059
	(.052)	(.066)	(.058)
75th percentile	.171***	.030	.075
	(.061)	(.090)	(.088)
90th percentile	.223***	.011	.047
	(.073)	(.128)	(.118)
95th percentile	.244***	.020	.040
	(.079)	(.139)	(.126)

Notes: Estimates show the predicted difference in the logarithm of output of otherwise identical union and nonunion mines at various levels of inputs. Estimates may be converted to percent differences in levels using the formula $(e^x - 1) \times 100$. For example, with all inputs at sample median values, the log of output is predicted by the constrained translog function to be .059 higher at union mines (6.1% higher in levels). Predictions are based on sample percentiles reported in the Appendix and estimates reported in a supplemental appendix available from the author on request. Standard errors (in parentheses) are computed for the Cobb-Douglas function using White's (1980) robust formula.
[a] Unionized production function constrained to be homogeneous.
* Significantly different from zero at the 10% level; ** at the 5% level; *** at the 1% level.

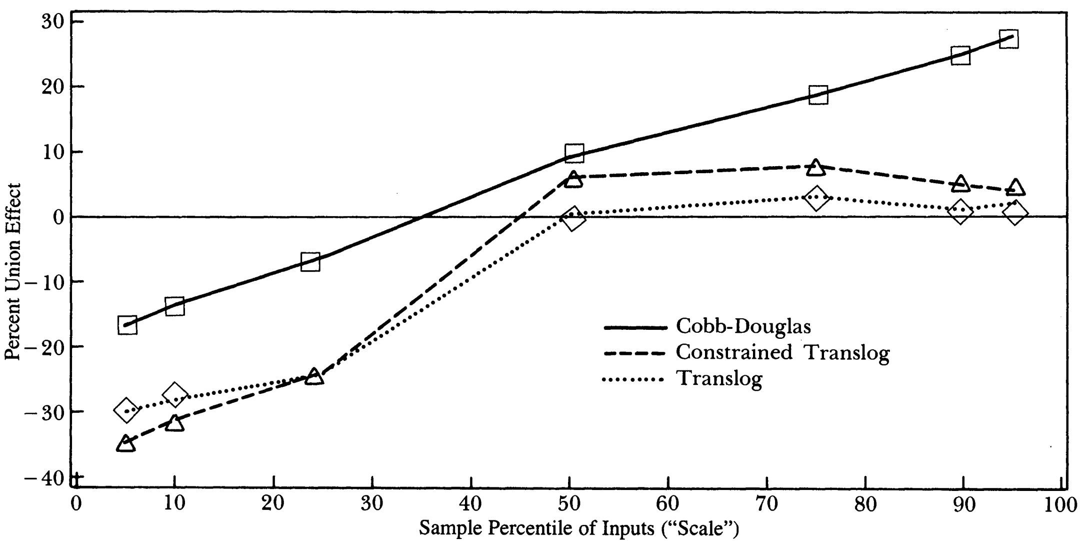

Figure 1. Predicted Union Effect by Scale.
(Source: Estimates in Table 4, Converted to Percents)

large elasticity of substitution of machines for miners.

Second, the Cobb-Douglas function is homogeneous[30] in inputs. This restriction may distort the effects of unionism relating to scale of operation, because two homogeneous production functions can cross no more than once as all inputs increase proportionately. As a result, one mode of production—say, unionized production—can appear to gain steadily on the other as inputs are scaled up, which may be incorrect if unionism depresses productivity only for a narrow range of scale.

For these reasons, the so-called translog function[31] was estimated for the same data in an attempt to fit coal mining technology more precisely. The translog function is quadratic in the logs of the inputs. It does not impose unitary or even constant elasticities of substitution, but rather nests the Cobb-Douglas as a special case. It also does not impose homogeneous production, but rather nests homogeneity as a somewhat less special special case. Thus, the translog allows union and nonunion production to differ in more interesting ways. Joint tests on the translog coefficients are reported in Table 3.[32] The Cobb-Douglas specification is rejected in favor of the translog. Homogeneity is rejected for nonunion production but cannot be rejected for union production.

The translog estimates confirm the general qualitative conclusions of the Cobb-Douglas estimates. A joint test of the equality of union and nonunion input coefficients indicates a difference between union and nonunion production that cannot be described simply by a shift in the intercept (see Table 3). Because the translog function contains a large number of parameters, interpretation of this difference based on the raw parameter estimates is quite difficult. An easier approach is to *predict* the effect of unionism on output at various levels of inputs.

Predictions of the difference between the logs of union and nonunion output at

[30] Homogeneity implies that if increasing returns or decreasing returns occur anywhere, they must occur everywhere. Further discussion is in a supplemental appendix, available from the author on request.

[31] The translog function was apparently first used by Berndt and Christensen (1973).

[32] Again, individual coefficient estimates are in a supplemental appendix available from the author.

various scales of operation are shown in Table 4 and Figure 1 for both the translog specification and the translog with union production constrained to be homogeneous. The sample percentiles refer to values given in the Appendix. The estimates predict a negative effect of unionism for small mines larger in magnitude that the negative effect predicted by the Cobb-Douglas estimates. Point estimates of the union effect at levels above the 25th percentile, however, remain close to zero, in contrast to the Cobb-Douglas prediction. Thus, the translog estimates confirm the negative prediction for small mines found by the Cobb-Douglas specification, but cast doubt on its positive prediction for large mines.

The production function effects of unionism may be further elucidated by predictions that vary the input proportions.[33] Table 5 accordingly predicts the effect of unionism for various combinations of mining machines and other inputs. Predictions for small mines occupy the upper left corner of the table and predictions for large mines occupy the lower right. The diagonal replicates the last column of Table 4. Predictions above the diagonal represent relatively mechanized mines and predictions below the diagonal represent relatively unmechanized mines. Table 5 again demonstrates the negative effect of unionism at small mines, as shown by significant negative predictions in the upper left corner. However, it does not support the hypothesis of a negative effect at mechanized mines. Point predictions of the union effect are large and negative above the diagonal and large and positive below the diagonal, but most of these predictions are not significantly different from zero at conventional levels.

[33] Caution is normally necessary in applying this technique because it risks extrapolation outside the sample. The risk, however, is much smaller here than with, say, aggregate data sets, where inputs typically vary in nearly fixed proportion. In this data set, the number of machines in use varied widely across mines that otherwise operated at the same scale.

Conclusions

The results of this study may be summarized as follows. First, the production function for coal mines *is* affected by unionism. Second, this effect cannot be reduced to a simple intercept shift, as might be expected if unionism's effect stemmed only from changes in labor quality. The effect of unionism is not uniform—it depends on the level of the inputs. This result does not refute the hypothesis that unionism influenced productivity through changes in labor quality, but demonstrates that other effects must have also been present.

Third, a negative effect of unionism at mechanized mines, as might be expected if the union haggled over the introduction of machines, is not demonstrated. Point estimates of unionism's effect were large and negative at mechanized mines, but standard errors were also large. Fourth, an interaction between unionism and scale, as might be expected on the basis of the differences in labor relations reported at small and large mines, is clearly demonstrated. Estimates for the translog functions show that unionism significantly reduced productivity at small mines. Cobb-Douglas estimates show a lesser effect at small mines, but agree with the qualitative conclusion that scale influenced the unionism effect.

The operators had several reasons for wanting to deunionize their mines. They complained of high union relative wages (Mooney 1967:127) and input restriction effects in the form of frequent strikes and excessive union-sanctioned holidays (Bituminous Operators' Special Committee 1923:168–71). This study suggests that production function effects were probably not a reason for deunionization except at small mines. On average, mines in this sample did not suffer adverse production effects due to unionism.[34] Formal tests

[34] Simulation of the log difference in output due to unionism in 1920–21 (when all mines in the sample were unionized) produced a mean difference in log output (over all 83 mines in the sample) of 0.04 using the constrained translog estimates or 0.01 using the translog estimates. These results are

Table 5. Predicted Union Effects by Scale and Mechanization.

Percentile, Other Inputs	*Percentile, Mining Machines*						
	5th	*10th*	*25th*	*Median*	*75th*	*90th*	*95th*
5th	−.426**	−.492**	−.606**	−.692*	−.750	−.775	−.784
	(.183)	(.196)	(.263)	(.357)	(.459)	(.531)	(.574)
10th	−.306*	−.373**	−.491**	−.581*	−.642	−.668	−.678
	(.170)	(.169)	(.224)	(.316)	(.421)	(.495)	(.539)
25th	−.056	−.134	−.274*	−.386*	−.468	−.507	−.525
	(.185)	(.147)	(.146)	(.229)	(.337)	(.414)	(.460)
Median	.217	.173	.102	.059	.042	.044	.049
	(.166)	(.134)	(.084)	(.058)	(.967)	(.094)	(.115)
75th	.273	.226	.148	.098	.075	.073	.076
	(.271)	(.232)	(.167)	(.119)	(.088)	(.087)	(.096)
90th	.212	.169	.100	.059	.044	.047	.053
	(.365)	(.322)	(.247)	(.185)	(.137)	(.118)	(.115)
95th	.192	.149	.082	.042	.029	.033	.040
	(.385)	(.342)	(.267)	(.204)	(.155)	(.132)	(.126)

Notes: Estimates show the predicted difference in the logarithm of output of otherwise identical union and nonunion mines at various levels of inputs. Estimates may be converted to percent differences in levels using the formula $(e^x - 1)100$. For example, with machines and other inputs at sample median values, the log of output is predicted by the constrained translog function to be .059 higher at union mines (6.1% higher in levels). Note that estimates above the diagonal correspond to relatively mechanized mines, and estimates below the diagonal correspond to relatively unmechanized mines. Predictions are based on sample percentiles reported in the Appendix and estimates for the constrained translog production function reported in a supplemental appendix available from the author on request.

[a] Significantly different from zero at the 10% level; ** at the 5% level.

demonstrate, however, that these effects were not spread evenly across all mines.

Although many other studies of unionism and productivity have appeared recently, the present study is unique with respect to method and data. Most previous research has used the simple Cobb-Douglas functional form because of its ease of interpretation. My analysis of the data for this study, however, led me to reject the Cobb-Douglas in favor of the translog, a flexible functional form containing many more parameters. Interpretation of the parameter estimates was facilitated here by *predicting* the union effect at various levels of inputs.

The data set used in this study is also new, although some previous productivity studies have examined coal mining. Pencavel (1977) found a negative change in the intercept for a sample of British coal fields at the turn of the century. He did not test, however, for changes in the other coefficients—estimation of such subtle effects would be difficult given the aggregate nature of his data and relatively small sample size. Connerton, Freeman, and Medoff (1979) found a decline in the union effect over time for a longitudinal sample in the 1960s and 1970s, which they interpreted as indicating a deterioration in labor relations. The influence of unionism on parameters other than the intercept was not estimated, however, and no mines in their sample changed union status over the sample period. Byrnes, Fare, Grosskopf, and Lovell (1988), using a nonstatistical method to study a sample of surface mines in the Midwest and West during the late 1970s, discovered few differences in efficiency between union and nonunion mines.

It would be extremely interesting to attempt replication of the present study using the same estimation methods on more recent data.[35] I conjecture that the results found here would *not* be repeated

roughly similar to the predictions using median inputs, reported in Table 4 above.

[35] Unfortunately, such a replication is impractical because very few coal mines in the United States have changed union status since 1940.

for more recent data, because they depend crucially on the historical setting. In particular, economies of scale in labor relations are probably less important today than in the 1920s. The recent development of a market for labor-relations services (such as those offered by consultants and lawyers) has meant that a small firm no longer must produce these services internally. Similarly, increased literacy and the advent of telecommunications have given isolated union locals cheap access to the knowledge and experience of the international union.

Appendix
Detailed Description of the Data

Data on coal production, employment, capital equipment, and number of days of operation are taken from annual reports of the West Virginia Department of Mines in the early 1920s. (Unfortunately, the data are less complete for the late 1920s. In particular, data on capital equipment were no longer reported at the mine level after 1925.) All inputs were defined by multiplying the number of physical units by the number of days of operation. Sample distributions of output and inputs are given in Table A1.

Data on unionism are also available, although not so neatly collected in one source. No single systematic record of the UMWA's activities in West Virginia has survived. Fortunately, union struggles in the West Virginia coal fields attracted great public attention, and many of the union's victories and defeats were documented in newspapers, magazines, and Congressional testimony. Sources used in this study, in decreasing order of usefulness, included: *Coal Age* (a magazine), the *New York Times,* testimony before various Committees of the United States Senate (in 1921, 1928, and 1932), *Convention Proceedings* of the UMWA and of the West Virginia State Federation of Labor, monographs by Anson (1940) and Corbin (1981), and Freeburg's (1925) article. The history of unionism at a sample of mines was pieced together for this study from these sources.

Unionism is a discrete variable in this data set, determined by whether a mine was operated for the entire observation year under contract to the United Mine Workers of America. The UMWA insisted on a closed shop during this period, so all workers at a unionized mine were union members. Years in which a mine operated for only part of the period under contract were dropped from the sample. No other union succeeded in winning contracts at these mines during this period.

Table A1. Sample Distributions of Output and Inputs, 83 West Virginia Coal Mines, 1920–25.

Quantile	*Coal Output (net tons)*	*Miner-Days*	*Other Worker-Days*	*Mining Machine-Days*	*Loco-motive Days*	*Horse & Mule-Days*
Minimum	1,191	0	40	0	0	0
5th percentile	17,559.5	1,675.7	1,421.1	125.3	93.6	0
10th percentile	25,048.3	2,343.6	2,018.7	180.6	137.8	0
25th percentile	44,554.9	4,681.5	3,742.25	381	309	0
Median	102,549	12,216.5	11,570	798	790.5	919.5
75th percentile	188,081	24,026.3	23,221.8	1,615.25	2,178	2,238.5
90th percentile	291,824	37,040	38,384.2	2,532.6	3,653.3	4,757.6
95th percentile	380,664	44,851.2	46,565.7	3,264.94	4,242.8	6,680.99
Maximum	614,476	59,354.4	98,185	9,953	8,040	13,572

Source: West Virginia Department of Mines.

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