BY THE COMPTROLLER GENERAL ~~17397~~

Report To The Congress

OF THE UNITED STATES

114639

Low Productivity In American Coal Mining: Causes And Cures

This report identifies the factors responsible for depressed productivity in the U.S. coal mining industry. GAO analysis revealed that the fall in underground mining productivity since 1969 is closely tied to poor labor-management relations, 1974 union contract requirements, and Federal mine safety and health regulation. State reclamation laws and the opening of new surface mines lowered productivity in surface mining. Coal mining technology has not advanced sufficiently to offset the loss due to these causes.

Federal and State regulations have been successful in reducing both fatalities and the environmental costs of coal mining. Thus far, lower productivity is a price the Nation has paid for imposed health, safety, and environmental regulations. Industry and public officials must find ways to offset the effects of regulation on productivity without compromising safety or environmental quality. GAO recommends increased Federal efforts to promote the development and greater use of safe, productivity enhancing technologies and improved labor management relations.

Because of the importance of higher productivity, GAO plans to send the report to knowledgeable individuals to solicit their views on the report's conclusions, and to request suggestions on how they might be implemented. If appropriate, GAO will submit further recommendations in a subsequent report.

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

CWO 00001

This report focuses on the problem of low productivity in the U.S. coal industry and identifies causes and possible cures. Recommendations to improve coal industry productivity are made to the Congress and the Departments of Energy, Interior, and Labor.

Copies of this report are being sent to the Secretary of Energy, the Secretary of the Interior, and the Secretary of Labor.

Comptroller General
of the United States

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LOW PRODUCTIVITY IN AMERICAN COAL MINING: CAUSES AND CURES

D I G E S T

National energy policy calls for greater use of coal by the U.S. in order to reduce our reliance on imported oil. Our ability to make this transition to coal, however, depends on the coal industry's ability to meet future coal production needs. Given the importance labor productivity plays in the quantity of coal produced, productivity is crucial to meeting our national energy goals.

The coal industry experienced a remarkable threefold increase in productivity between 1947 and 1969. Substantial increases were realized in both surface and underground mines.

Since 1969, however, overall coal industry productivity has declined 26 percent and a whopping 43 percent in underground mines. Surface mining productivity remained constant up to 1974 when it began to fall; declining 29 percent by 1979.

This report evaluates the major factors determining productivity in the coal industry, identifies those mainly responsible for the decline in labor productivity which has occurred since 1969, and recommends steps to reverse current trends. Throughout this report productivity is defined as tons per worker hour.

The GAO review is based on an analysis of a large coal mine data base, interviews with a wide range of mining personnel at 44 mines, and discussions with numerous Government and private officials.

CONCLUSIONS

The GAO analysis found the decline in underground productivity during the 1970s to be closely tied to the reduced quality of labor-management relations, especially after 1973, and the 1974 union contract requirements calling for helpers on mine-face equipment. While definitive results on the past effect of absenteeism were not obtainable, it seems to have a negative influence on productivity. Other labor management issues frequently thought to be related to productivity such as the age distribution of the work force, labor turnover, and job-bidding, however, have little effect on productivity. Incentive plans seem to be a promising way to improve productivity. (See ch. 2.)

GAO research also indicates that Mine Safety and Health Administration (MSHA) regulation was a primary cause of declining underground productivity between 1970 and 1973, but was less important afterwards. By 1977 it was no longer a factor in the continuing productivity decline. Regulation refers to the impact of enforcement activity and changes in mining practices caused by MSHA regulations. Since the practices required by MSHA causing the initial decline continue, however, some of the initial drop in productivity may be permanent. On the benefit side MSHA regulation has reduced coal mine fatalities and disasters substantially. However, MSHA regulations do not appear to have reduced the frequency of nonfatal disabling injuries caused mainly by human error. (See ch. 3.)

In surface mining the enactment of strict State reclamation laws is largely responsible for the decline in productivity. The majority of coal producing states enacted or strengthened surface mining reclamation requirements after 1968. As more resources were allocated to reclamation activities, productivity suffered. This lost productivity is a price we pay for a restored environment. In addition, due to the start up time needed to reach efficient production, the large number of new surface mines which have been opened since 1974 also has had a negative effect on productivity. This decline has been felt largely in Eastern coal producing States. This report does not address the Federal Surface mining law, since it was recently implemented and its effects are not yet apparent. (See pp. 68 thru 74.)

Although coal mining technology has not caused productivity to decline, mechanization and technological innovation slowed in both underground and surface mines in the late 1960s and has not advanced sufficiently to offset the loss due to other causes. In underground mines, coal cutting machine reliability and haulage from the face are areas where technological improvements could increase productivity substantially. Increased investment in excavation and coal loading equipment will bring the highest productivity improvement in surface mining. (See ch. 4.)

Worsening geological conditions have frequently been cited as a possible cause for declining productivity. GAO found that geological conditions in underground mines have not worsened industrywide nor led to lower productivity. In surface mining, seam thickness and the amount and type of overburden are the principal geological conditions impacting productivity. Low overburden ratios help explain both the higher productivity and increasing production in Western States. (See pp. 90 and 91.)

Labor and Management

Labor-management problems are centered largely in underground coal mining. Surface mining is a more capital intensive process, requiring less labor per ton of coal produced. (See p. 12.)

Since 1969 underground coal mines have experienced worsening labor-management relations as reflected in the explosion in the number of strikes. A close relationship was found between strike activity and productivity. While strikes do not affect productivity directly, they reflect the level of tension between labor and management. A large portion of the decline in productivity after 1972 was due to this increased tension as manifested in the number of work stoppages. (See p. 24.)

The underground mine work force is younger, less experienced, but better educated than their peers of the 1950s and 1960s. The shift to a younger work force and the resulting reduction in experience levels was examined for its impact on productivity. No relationship was found between younger miners and low productivity.

By now young miners hired in the early 1970s have gained needed experience. Young miners are more educated and have other positive attributes which offset the impact of their inexperience. (See pp. 15 and 16.)

Job absenteeism and turnover are important indicators of worker satisfaction or alienation. Coal operators consider absenteeism a significant factor impacting productivity. Due to the limited data available GAO could not determine the change in absenteeism or its overall impact on productivity. The existing level of unexcused absences, however, is substantially higher in coal than other industries. Improvements in this area could raise future productivity. Labor turnover has had little effect on productivity. A higher separation rate has a slight negative effect on productivity, while the accession rate has no effect. However, rates for both separation and accessions were no higher in 1979 than 1968. (See pp. 15 and 19.)

The requirements for helpers on face equipment contained in the 1974 wage agreement was estimated to account for a maximum 5 percent of the 13-percent decline in underground productivity during 1974-75. No support was found for the argument that job bidding was a factor in the decline in productivity. Finally, a well-designed production incentive plan which stresses safety along with realistic production goals can be a useful management tool. Such a plan can lead to improvements in safety, productivity, and overall labor-management relations. (See pp. 26 thru 28.)

Federal Coal Mine Health And Safety Act

The Federal Coal Mine Health and Safety Act of 1969 authorized more stringent health and safety standards and vastly increased Federal enforcement powers and resources. The coal industry attributes low and declining underground productivity primarily to the act. Surface mine operators were less likely to blame low productivity on health and safety regulations. Using the number of inspection days to measure MSHA enforcement, we determined that a direct relationship exists between enforcement activity and productivity. Increased enforcement activity results in lower productivity. MSHA inspections reached a peak in 1973 and then declined slowly. The act had its largest impact on productivity between 1970 and 1973 when the number of inspections was growing. Since 1974, with MSHA and industry adjustment to the enforcement process and the leveling off of inspection activities, the act became less of a factor in the continuing decline in productivity. Although no longer a factor in the continuing decline, some of the initial loss in productivity may be permanent. (See pp. 34 thru 37.)

MSHA regulation reduces mine productivity primarily by requiring that increased labor be spent on nonproduction activities and by reducing available production time.

MSHA regulation reduced fatalities in coal mines dramatically; however, nonfatal injuries have stayed high. MSHA regulation improves mine safety mainly by preventing mine disasters. Fatalities have been reduced by more than half in the 8 years following passage of the act. MSHA regulations requiring increased roof support, ventilation, dust control, methane testing, and protection from machinery and electrical equipment are mainly responsible for the reduction in disasters. These same requirements are most responsible for the lost productivity due to Government regulation. (See pp. 39 thru 43.)

The Bureau of Mines and coal equipment manufacturers have developed safety technologies which could reduce the adverse productivity impacts of some MSHA regulations. MSHA is involved in the selection process for new Bureau of Mines safety technology research projects. However, these technologies have not been adequately transferred to the coal mining industry due to a lack of adequate in-mine testing and continued uncertainty over whether MSHA will modify regulations or grant petitions for modification to operators using new technologies from productivity-reducing regulations. (See pp. 65 thru 67.)

Up to a point a trade-off exists between productivity and safety. In 1977, a direct relationship existed between both the number of lost workday injuries and the number of violations and productivity. An increase in either the number of violations or lost workday injuries resulted in an increase in productivity. However, an increase in the seriousness of violations received by a mine resulted in lower productivity. As a mine pushes to expand production, there may be a tendency to take short cuts, and place less emphasis on safety. The result will be an increase in both production and lost workday injuries. However, those mines which continue to push production beyond this range and are continually guilty of the most serious or dangerous violations pay a substantial penalty in terms of both safety and productivity. (See p. 44.)

Technology

The type of technology employed by a coal mine will have substantial effects on the level of productivity achieved. In underground mines the greatest productivity gains can be achieved by improving the reliability of coal cutting machines and improving haulage from the face. Advances in machine maintenance programs and haulage systems have not kept pace with productivity advances in coal cutting. (See pp. 79 thru 83.)

The potentially more productive continuous mining equipment lost its productive advantage over conventional mining methods after 1969. MSHA regulations and the 1974 union agreement, along with problems in machine reliability have prevented these methods from achieving their productive potential. (See p. 80.)

One indication of the slowness of technological advance in underground mines is the coal industry's reluctance to switch to longwall mining machines. The share of underground coal produced by longwall miners grew to only 5 percent by 1977. Our analyses showed that the coal industry's reluctance to invest in these longwall mining systems was based on a reasonable assessment of their actual productivity versus cost i.e., they improve productivity but at a high cost. However, longwall mines have the benefit of improved worker safety. (See pp. 82 and 83.)

Haulage systems are a main constraint to improving productivity in underground mines. A main bottleneck is the transport from the face to the main haulage line. Adding more shuttle capacity will increase productivity more than adding continuous and longwall mining machines. While shuttle capacity is most important, adding track and conveyor belts to the main haulage will also improve productivity. (See p. 83.)

Surface mining productivity can be increased by improving excavating and coal loading equipment and the efficiency of its use. Increased capacity for loosening coal through the use of more coal drills will significantly increase productivity as will greater use of front-end loaders for coal loading. (See pp. 83 thru 86.)

Coal equipment manufacturers and larger coal companies are doing research on improving the speed and reliability of existing equipment but are doing little research on advanced mining systems. At the same time, the Department of Energy (DOE) is doing substantial research on advanced mining systems that will yield high productivity gains. However, budget cuts have reduced DOE's research efforts. (See pp. 86 thru 90.)

Lessons from European Coal Mining

While still lower than in the U.S., productivity in British and West German coal mines has remained stable or increased slightly without detracting from mine safety. Reasons for lower productivity in European mines include poor geological conditions and more emphasis on safety. European technologies that the U.S. industry could employ to enhance both safety and productivity are longwall mining, computer monitoring of the mining environment, and methane drainage before mining. Greater utilization of these technologies in U.S. mines will require a close examination of current MSHA requirements for longwall mining and methane testing. European miners are given considerably more safety and skill training in more facets of mining. This increases safety and reduces the disruptive effects of absenteeism. Similar levels of training for U.S. miners may be warranted on safety and productivity grounds. European mines have also realized increased productivity through the use of production incentive bonuses. (See pp. 97 thru 105.)

RECOMMENDATIONS

GAO concludes that there are three areas in which changes could render substantial productivity improvements. These areas are: labor-management relations, mining technology, and the relationship between new technology and Federal mine safety and health regulations. (See ch. 6.)

Labor and management must increase their efforts to improve communication and cooperation. Management should emphasize the training of supervisory personnel in labor-management relations, and the union should recognize management's need to have a stable workforce with low absenteeism. To improve the reliability of existing mining equipment, coal operators should increase preventive maintenance programs and training for shift mechanics. Funding of joint labor-management committees by the Federal Mediation and Conciliation Service could lead to improvements in these areas.

The Federal Government's role in improving coal industry labor-management relations has been limited to expediting arbitration procedures and mediating disputes. In recognition of the importance of effective communication and grievance handling, the Labor-Management Services Administration of the Department of Labor recently undertook two experimental training programs on grievance handling. GAO views these actions as promising first steps. Given the national importance of improving productivity and maintaining a steady coal supply, further Federal involvement may be warranted. GAO recommends that:

--The Secretary of Labor should direct the Labor-Management Services Administration to fund coal industry programs to train coal management and labor in effective communication and grievance handling.

Mining Technology

While coal mining technology has not caused productivity to decline, it has not advanced sufficiently in the past decade to offset the loss due to other causes. In underground mines, coal cutting and haulage are examples where technological improvements could increase productivity substantially. Given that expanding coal production is an important national goal, GAO recommends that:

--The Secretary of Energy should direct the Office of Coal Mining to increase research efforts in those areas which have a high potential for improving productivity.

The Bureau of Mines and coal equipment manufacturers have jointly developed safety technologies such as remote movement of line brattice and roof support systems which have the potential to reduce the adverse productivity impacts of MSHA regulations. However, many of these technologies have not been widely adopted by the industry. Two frequently cited reasons for this are the lack of adequate in-mine testing by the Bureau of Mines to demonstrate the benefits of the product and uncertainty over whether the Mine Safety and Health Administration will either grant petitions for modification or change regulations allowing operators to use new safety technology. GAO recommends that:

--Since the weakest link in the commercialization chain is in-mine testing, the Secretary of the Interior should direct the Bureau of Mines to adequately test its products in working coal mines to establish and demonstrate their benefits.

--The Secretary of Labor should direct MSHA to minimize the regulatory lag which now delays introduction of productivity enhancing equipment that does not impair mine safety.

MSHA regulation has not effectively reduced the frequency of nonfatal disabling injuries caused primarily by worker error. Increased effectiveness of on-the-job safety training of both supervisors and workers should help reduce these types of injuries. GAO recommends that:

--The Congress increase the required minimum amount of on-the-job safety training for supervisors and miners.

--The Secretary of Labor should direct MSHA to analyze the impact on industry of increasing training requirements and provide further assistance if warranted.

AGENCY COMMENTS

Comments on a draft of this report were solicited from the Departments of Energy, the Interior, and Labor. The Department of Energy had no official comments. Both Interior and Labor agreed with the major findings of the report. Interior felt that DOE should not become involved in the training of miners and management. GAO agreed and the report's recommendation reflects this. Labor did not agree that MSHA should establish an agency-wide policy on exempting new Bureau of Mines technologies, that can be introduced safely, from productivity reducing regulation. They pointed out that MSHA already grants modifications from health or safety standards on a case-by-case basis and has developed a system for revising standards in cases where a large number of such modifications have been granted. This process, however, was found to be time consuming, and GAO recommends that MSHA take the necessary steps to shorten it. Other technical and editorial comments by Labor and Interior are reflected throughout the report when appropriate.

CONTINUING ANALYSIS

Many of the suggestions and recommendations contained in this report represent potential means of improving productivity. Because higher productivity is so important, GAO plans to send the report to knowledgeable individuals in the United Mine Workers Union, academia, major coal producers, and State governments. GAO will solicit their views on its recommendations and request suggestions on how they might be implemented. GAO will evaluate any suggestions which could require congressional action and, if appropriate, will submit further recommendations in a subsequent report.

Contents

ABBREVIATIONS

MSHA	Mine Safety and Health Administration
DOE	Department of Energy
mt	million tons
T/Wh	tons per worker hour
UMW	United Mine Workers of America
BCOA	Bituminous Coal Operators' Association
ORA	Oak Ridge Associated Universities
NIOSH	National Institute of Occupational Safety and Health
BLS	Bureau of Labor Statistics
NSF	National Science Foundation
OTA	Office of Technology Assessment
Consol	Consolidation Coal Company
mg/m^3	milligram per cubic meter of air

CHAPTER 1

LOW PRODUCTIVITY IN THE COAL INDUSTRY: CAUSES AND CONSEQUENCES

The bituminous coal industry is regaining its position as the keystone of our energy future. Substantial increases in domestic and foreign oil prices and heightened public awareness of nuclear safety problems have placed bituminous coal in its strongest competitive position since the mid-1940s. The main reason for moving to coal, however, is our increasing dependence on foreign oil. In 1972, the Nation imported 29 percent of its oil; in 1979, we imported 44 percent. Both the oil embargo of 1973-74 and the events of 1979 have demonstrated how vulnerable America has become to oil import disruption.

If coal is to be a larger part of our energy diet, the coal industry must be sufficiently productive to meet higher production expectations. The productivity of coal mines will play an important part in future production, as it has in the past.

Unfortunately, the coal industry shares in the current low productivity problem plaguing the U.S. economy. In fact, coal mining has the dubious honor of having nearly continuous productivity decreases. Productivity is defined as tons per worker hour.

This report evaluates the major factors determining productivity in the coal industry, identifies those mainly responsible for the decline in labor productivity which has occurred since 1969, and recommends steps to reverse current trends.

SIGNIFICANCE OF LOW PRODUCTIVITY

Low productivity is the number one concern of coal industry officials. Overall, productivity has declined 26 percent since 1969, and a whopping 43 percent in underground mines. Low productivity may effect labor requirements, safety, and coal prices.

Low and declining productivity may make it difficult to attract the labor needed to achieve ambitious production targets. For example, with productivity at 1974 levels it would take 244,000 miners to produce 1 billion tons of coal in 1985. If productivity continued to decline at the 1969-1978 rate, <u>twice</u> as many miners would be needed to produce 1 billion tons in 1985.

Lower productivity also has implications for safety and health. As labor productivity declines, more workers are needed to produce the same amount of coal and so exposure to mining hazards increases. Because manpower requirements rose, injuries per ton of coal mined underground increased by 90 percent from 1967 to 1977. Ironically, if, as the operators claim, government regulation is responsible for low productivity, government regulations designed to reduce injuries may also increase them by increasing exposure.

Coal must compete with other fuels, especially oil, gas, and uranium. The lower the price, the more willing utilities and industry will be to use coal. In addition, the economic viability of coal liquifaction and gasification will partially depend on the price of coal feedstocks used in these processes. If the price of coal increases, so will government subsidies needed to keep synthetic fuels competitive with alternative energy sources.

Other things remaining the same, low and declining productivity will cause unit labor costs to rise. Since 1968, labor costs have increased nearly 150 percent. While many factors determine coal market prices, a decrease in labor productivity will tend to increase coal prices and possibly other energy costs as well.

ORIGINS OF THE PROBLEM

The American bituminous coal industry has both grown and declined significantly over the past 30 years. At the same time, the industry has changed from labor intensive underground production to mechanized production in both surface and underground operations. Understanding the major factors contributing to low coal mining productivity depends on a clear picture of the economic and institutional forces at work since 1950.

Historically, productivity in coal can be examined in terms of two distinct periods, one of exceptional improvement (1947 to 1969) and the other of rapid decline (1969 to the present). The industry experienced a remarkable increase in productivity between 1947 and 1969. Overall productivity nearly quadrupled from 0.7 to 2.6 tons per worker/hour (T/Wh). Substantial increases were realized in both surface and underground mines. These productivity improvements came from increased mechanization, closing less efficient mines, and improved labor-management relations. 1/

However, table 1 shows that since 1969 productivity in underground coal mining has declined from 2.3 to 1.3 T/Wh in 1979. At the same time, surface mining productivity remained

Table 1

U.S. Coal Production and Productivity (1961 to 1979) (note a)

Year	Underground (note b) Production (million tons)	Underground (note b) Productivity (T/Wh)	Surface (note c) Production (million tons)	Surface (note c) Productivity (T/Wh)	Total Production (million tons)	Total Productivity (T/Wh)
1961	280	1.7	130	3.0	409	1.7
1966	342	2.2	184	4.4	527	2.4
1969	348	2.3	202	4.6	550	2.6
1970	340	2.1	248	4.7	558	2.5
1971	278	1.8	264	4.5	542	2.3
1972	288	1.7	236	4.5	524	2.2
1973	286	1.7	261	4.5	547	2.2
1974	264	1.5	293	4.0	557	2.1
1975	279	1.3	324	3.4	603	1.8
1976	281	1.3	358	3.5	639	1.9
1977	257	1.3	406	3.4	664	1.9
1978	229	1.2	398	3.1	627	1.8
1979	300	1.3	437	3.2	737	1.9

a/Production in million tons. Productivity in tons per worker hour. Excludes employees of mechanical cleaning, preparation plants or brokers.

b/Productivity based on miners working underground only. Surface employees at underground coal mines are excluded.

c/Excludes augers, culm banks, and dredges.

SOURCE: Mine Enforcement and Safety Administration, Information Reports 1961-1975. Mine Safety and Health Administration, Information Reports, 1976-1978.

relatively constant up to 1973, ranging from 4.6 to 4.5 T/Wh. In 1974 surface mining productivity also turned down, dropping to 3.2 T/Wh by 1979, the latest year for which comparable data is available.

The coal industry, 1947 to 1969

In 1947, the industry produced a record 642 million tons (mt) of coal. That year also marked the beginning of declining coal demand. After the war, the railroads began a massive switch from coal to diesel-fueled engines. Railroad coal consumption declined from 125 mt in 1947 to 15 mt by 1955--and to zero by 1960. A similar change began in the residential sector with consumption falling from 119 mt to 29 mt between 1945 and 1960. Manufacturing followed suit. Only electric utilities increased their coal demand and have been largely responsible for overall increases in U.S. coal consumption since 1960.

The decline in coal demand ushered in a period of low prices and profits. Given the competitiveness of the coal industry, only the lowest cost firms survived. As demand and prices fell, marginally efficient mines closed, thus increasing overall productivity.

Officials of both the United Mine Workers of America (UMW) and the remaining coal companies recognized that the industry's survival depended on keeping coal competitive in its remaining growth market--steam coal for electrical generation. In 1950 the industry began an all-out effort to mechanize with the consent and active participation of the UMW. Union officials accepted the resulting unemployment in the coal fields. They realized that increased productivity through mechanization would protect the industry's remaining markets and make wage increases for the remaining work force possible. 2/

During this period UMW leadership worked closely with management to restructure and consolidate production crews into efficient and stable work units.

The period also saw rapid expansion of underground continuous mining which eliminated many of the labor intensive techniques of the past. Continuous mining reduced the number of production steps and cut crew size per mine section from about 9 to 6. By 1969, practically no coal was being cut or loaded by hand.

Low coal prices and profits during the 1950 to 1969 period also encouraged high productivity surface mine production. Production from surface mines increased from

124 mt in 1950 to 202 mt in 1969, rising from 24 percent of total production to 37 percent. Given the relatively higher productivity of surface mining, this shift contributed to higher overall coal industry productivity. Because the size and capacity of stripping and haulage equipment also increased, surface mining labor productivity rose during the period. Productivity of surface mining grew from 2.0 T/Wh in 1950 to 4.6 T/Wh in 1969. This increase in surface mining productivity pushed overall mining productivity up by 21 percent above what it would have been had surface mining productivity remained at its 1950 level.

Coal industry 1969 to 1979

Growing electric utility consumption in the late 1960s forced coal demand up. In 1970, annual coal production topped 600 mt for the first time since 1947. At the same time, coal prices, which had remained relatively constant for the previous 15 years, began to inch up. The 1973 to 1974 increase in world oil prices brought on by OPEC made coal relatively cheap and attractive as a secure domestic energy source. By 1976, annual coal production had reached 648 mt, and the average price per ton at the mine had jumped from $4.99 in 1969 to $19.23.

Declining labor productivity marred this performance. Beginning in 1969, the declining productivity of the work force has been an ever-increasing economic burden on the industry. As noted earlier, productivity began to fall in underground mines first, dropping from 2.3 to 1.3 T/Wh between 1969 and 1979. Surface mining productivity peaked at 4.7 T/Wh in 1970, remained constant until 1973, and then turned downward--dropping to 3.2 T/Wh by 1979.

Although the overall decline in productivity has been steady, it varies among individual States. Most States realized declines of 30 to 50 percent between 1969 and 1978, but a few States were affected less. These are Western States where surface mines with 90- to 100-foot coal seams and productivity from 6.3 to 12.5 T/Wh or more are the norm. For example, Montana had a 52 percent increase, while Wyoming suffered only an 11-percent decline. These changes in productivity reflect the increasing dominance of large surface mines in both States. In Montana, there were five surface and seven underground operations in 1969; in 1976, there were eight surface and no underground operations. In Wyoming, the number of surface mines rose from 8 in 1969 to 17 in 1976 while the number of underground mines remained constant at 4.

Productivity in the six largest underground coal production States declined by 30 to 50 percent between 1969 and

1978. Underground productivity for the industry as a whole declined 45 percent during the period. Productivity started to fall at about the same time in all large coal mining States. The small differences in decline rates among States are due to the local factors (geology, technology, labor force, etc.) which explain differences between State productivity levels before 1969.

The opposite is true of surface mining. Here the data indicate that surface productivity was more sensitive to State-specific factors. Surface mining productivity declined at widely varying rates across States, but more importantly, the year the decline began varies. In Indiana and West Virginia the decline began in 1969, but in Pennsylvania productivity was still rising in 1973. In Wyoming the decline did not begin until 1975. Depending on the State, productivity started to decline as early as 1966 or as late as 1975.

The growing proportion of total production in the higher productivity Western States increased aggregate surface productivity until 1974. In 1968 the combined surface coal production of Wyoming and Montana accounted for only 1 percent of strip-mined coal. This increased to 15 percent by 1974 and to 30 percent in 1978. This expanding proportion of production combined with substantial increases in these States' productivity led to increasing aggregate surface mining productivity even though productivity was declining in most Eastern and Midwestern States. If the shift West had not occurred, combined surface productivity would have been 21 percent lower than it actually was in 1974. In 1978 it would have been 44 percent less.

WHAT DETERMINES PRODUCTIVITY?

In any industry the major determinants of productivity can be divided into those which are part of the production process itself and those which are imposed on the production process from the outside.

For coal mining, the existing resource base, labor force, and production technology are the important factors in the first group; State and Federal laws, union agreements, and industry structure in the second. To make recommendations aimed at increasing productivity, one must determine how these factors currently influence productivity. Such insight also enables better understanding of how changing factors have caused the drop in productivity since 1969.

These factors have been named as possible culprits causing low labor productivity in the coal industry by individuals in industry, labor, government, and academia. The hypothesized causes can be categorized as 1) increased Federal and State regulation, 2) a changing labor force, 3) changing production technology, 4) a deteriorating resource base, and 5) changes in industry structure.

Government regulation

Increasing productivity during 1950-69 greatly reduced labor costs per ton of coal. But as productivity rose, so did the health and safety costs of mining. 3/ In 1969, the Congress passed the Federal Coal Mine Health and Safety Act (P.L. 91-173) in an attempt to reduce these social costs. This law authorized the promulgation of stringent mandatory health and safety standards and their enforcement. Title IV of the act, as amended by the Black Lung Benefits Act of 1972 (P.L. 92-303), created a black lung benefit program. The act was further amended in 1977, authorizing improved standards and enforcement, mandatory health and safety training, and transferring the mine safety and health function to the Department of Labor, Mine Safety and Health Administration (MSHA). This act is the Federal law most frequently cited by industry as causing the decline in underground mining productivity.

However, mine safety and health regulation may also improve mining productivity in that healthy workers will produce more, have less injuries, and spend less time repairing damage caused by accidents or unsafe conditions. In addition, safer and more pleasant working conditions may improve worker attitudes and thus productivity.

Surface mining has also been the target of laws designed to cut social and environmental costs. Since 1966, several States passed tough surface mining reclamation laws. These laws required mine operators to reclaim the land and control water runoff. Many coal operators feel that the additional personnel involved in reclamation work has reduced productivity substantially.

Labor force

Between 1950 and 1969, labor-management relations were stable, and experienced miners were readily available. However, the pool of unemployed labor which existed during the 1950s and 1960s had disappeared by 1969. As the industry expanded, employment increased from 123,000 in 1969 to 207,000 in 1977. At the same time, union-management relations became increasingly strained. This was probably due to increasing awareness of poor safety conditions and a belief by the union membership that they had been "sold out" by their leadership in the late 1950s and early 1960s. As a result, since 1969 the industry has been confronted with an increasing number of inexperienced young miners, numerous strikes and slowdowns, and poor worker morale, all of which have been pointed to by people in the industry as lowering productivity.

In addition, the provisions of the 1974 labor contract between the UMW and the Bituminous Coal Operator's Association (BCOA) added helpers to occupations such as continuous mining machine operators and roof bolters. In some cases, such requirements may have added to the number of workers needed without a proportional increase in production, thus leading to declining productivity.

Production techniques

Many coal experts feel that most of the opportunities for increasing productivity through mechanization of mining techniques employed in underground coal mines were already realized by 1969. Three primary types of mining methods are employed in underground mines: conventional, continuous, and longwall. Many mines employ more than one of these techniques. For surface mining, either drag lines, shovels, or bulldozers are used depending on the geology and topography of the area.

Available data indicate that technical innovation slowed in both underground and surface mines in the late 1960s. Neither underground nor surface technologies have changed significantly in scale or concept. In addition, by 1969 almost 96 percent of underground coal production was mechanically loaded.

Resource base

The physical characteristics of the coal seams being mined help determine overall productivity. Topography, seam thickness and depth, overburden ratio, roof and floor conditions, and the presence of gas or water all influence the amount of production and type of equipment being used. Expanding output may lead to mining less productive seams and a drop in labor productivity. In some cases, the negative influences cannot be compensated for by substituting more advanced technology since the poorer working conditions themselves may be a constraint on the type of equipment used.

Seam quality may have deteriorated during the 1970s either through the expansion of existing mines or the opening of new mines in less favorable seams.

Industry structure

The forces changing the coal industry since 1969 include increases in both demand and prices. Higher prices have enabled new mines or previously inactive mines to enter the industry. These mines may lower productivity in two ways. First, many of the new entries may be small, inefficient operations which could not cover operating costs at lower price levels. As they enter the industry, aggregate productivity will decline. Second, it takes from 3 to 5 years for a surface mine and up to 7 years for an underground mine to reach full production. During the first few years a large portion of available labor may be spent on mine development rather than production and productivity will be low.

OBJECTIVES, SCOPE, AND METHODOLOGY

The possible explanations for declining productivity listed above are based mainly on the opinions of individuals familiar with the coal industry. We decided to analyze productivity at the individual mine level because we felt that the complex factors affecting productivity can best be understood only by examining individual mines.

The quantitative studies conducted in the past have relied mainly on aggregate State data. State level data consists of the summation or averaging of information on all reporting mines within a given State. Using State data hides or dilutes the impact that each individual factor has on productivity because it is averaged across many mines. Therefore, these studies' usefulness in analyzing how individual factors affect productivity is limited.

Our research was divided into two phases--an examination of individual mines by auditors in the field and a quantitative analysis of an extensive mine data base.

We visited 26 underground and 18 surface mines in 7 States. At each mine we interviewed a company representative, mine foreman, union representative, and safety representative if available. In addition, interviews were conducted with officers of six Mine Safety and Health Administration districts and numerous other government and private officials. We obtained information on changes occurring over the last 10 years in the areas of geology, technology, government regulation, and labor force characteristics which may have had an impact on mining productivity. The interviews produced a substantial amount of information on those factors determining productivity levels within a mine. This information is based on individual mine experience and is an important component of our analysis.

The quantitative analysis involved advanced statistical techniques applied to a large computerized data base. The data consisted of specific information on all surface and underground coal mines operating between 1972 and 1977.* They were gathered primarily from the Department of Energy, Mine Safety and Health Administration and the UMW. The data base was constructed with MSHA production and employment data representing the universe of producing mines.** These items were supplemented by data on technology, age of workers, geological conditions, accident and injury experience, and MSHA enforcement activities. The Bureau of Labor Statistics (BLS) also performed an analysis of labor turnover in mines under our direction.

A word of caution must be expressed concerning the quantitative results contained in the report. Although based on accepted economic theory and econometric techniques, the results must be viewed as estimates of the production relationships which exist in coal mines. As with all models, a certain variance from the true value of the variable being estimated may exist. All the quantitative results cited in the report were statistically significant at the 95 percent level or better.

The results of our research are presented in the following order: Chapter 2 is a discussion of labor management relations in the coal industry. Chapter 3 focuses on Federal mine health and safety laws followed by a discussion of State reclamation laws. Chapter 4 examines coal industry technology, geological conditions and industry structure. Chapter 5 is of an examination of the productivity experience in European coal mining. Recommendations are presented in chapter 6.

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*A detailed description of the data and statistical techniques can be found in appendix I.

**The MSHA data is based on mandatory reporting, while the DOE data is based on a voluntary survey. Consequently, DOE data are much less complete than MSHA data.

FOOTNOTES

1/Oak Ridge Associated Universities, Deteminants of Coal Mine Labor Productivity Change (Washington, D.C.: Published for the U.S. Department of Energy and the U.S. of Labor, November 1979), pp. 17-18.

2/Ibid. pp. 17-18.

3/Ibid. pp. 17-18.

CHAPTER 2

LABOR-MANAGMENT RELATIONS

AS A CAUSE OF LOW PRODUCTIVITY

Labor-management relations in underground coal mining during the 1970s can be described as a struggle between two long-time adversaries, neither willing nor able to recognize that the economic well-being of both is closely tied to the degree of cooperation between them. This adversary relationship has arisen through an interaction of many social, economic, institutional, and demographic factors. Completely delineating these interactions would require an analysis beyond the scope of this report. However, the importance labor has in coal productivity necessitates a review of the more important changes in labor management relations over the past 20 years. A statement by Joseph P. Brennan, President of the Bituminous Coal Operator's Association, highlighted this importance--"It is the people of coal who will insure that productivity is a positive rather than a negative input to our future. It (labor) was the pillar upon which the industry was able to withstand the decline of the 1950s and 1960s." 1/

Labor-management problems center largely on underground coal mining. Surface mining is a more capital intensive process, requiring less labor per ton of coal. In many cases surface mining skills and working conditions are similar to those in the construction and excavating industries making for a larger pool of experienced workers to draw from. In addition, the majority of surface mines are not unionized and are less prone to work stoppages. Safer working conditions and high wages have resulted in a more stable work force. Industry officials and surface mine operators agreed that, except for isolated cases, surface mining productivity is not bedeviled by serious labor-management problems. Our analysis of existing data supports this view. For these reasons the remainder of this chapter will focus on labor relations in underground coal mines.

Both the companies we talked to and considerable literature cite deteriorating labor-management relations and work force quality as two of the primary causes of low productivity in underground coal mining. We found that productivity fell as friction between the work force and management increased, and the UMW-BCOA contract agreements changed. Labor turnover and age distribution of the work force has a much less significant impact on productivity. We fully examined one other, often cited cause of declining productivity--absenteeism. Unfortunately, no reliable absenteeism data is available from either the industry or the Government. Until the necessary data are collected we cannot satisfactorily examine the relationship between productivity and absenteeism.

CHANGING LABOR FORCE

Talking about the changes occurring in the 1960s and 1970s in the underground coal mining labor force means talking primarily about the United Mine Workers of America's organized mines located east of the Mississippi River. These mines produce the bulk of U.S. underground coal; in 1975, 87 percent of underground production came from Eastern UMW mines. In 1977, it was 80 percent.

Of the 137,000 underground coal miners in 1976, 132,000 or 96 percent worked east of the Mississippi River and approximately 102,000 were members of the UMW. The greater proportion of underground production by UMW miners means that UMW mines are mainly larger mines. Although the UMW share of coal production dropped from 73 percent in 1968 to 48 percent in 1977, the union still dominates the underground sector with 81 percent of all underground production.

The underground work force of the 1970s, when compared to their peers of the 1960s, are younger, better educated, but less experienced. As discussed earlier, during the 1950s and 1960s the coal industry survived a period of slack demand and low prices through increased mechanization and workforce reductions. The number of underground coal miners dropped from 373,093 in 1950; to 133,302 by 1969. This decline resulted in an older, more experienced, and more productive work force than we have today. The average age of miners remained constant at approximately 46 between 1961 and 1967.

Since 1969, underground employment steadily increased, reaching 141,400 in 1977. Approximately 100,000 new miners have been hired to replace those retiring and to meet additional manpower requirements caused by increased production, the need to comply with new health and safety regulations, and new union contract provisions. This influx led to a drastic change in the age of underground coal miners. In 1967, only 11 percent of all UMW coal miners were under age 30, 33 percent were between 30 and 44, and 56 percent were 45 or older. By 1976, 40 percent were under 30, 32 percent were between 30 and 44, and 28 percent were 45 or older. Not only were these miners younger, but they were better educated. In 1970, the average miner had 8.1 years of schooling. In contrast, 70 percent of new miners entering the industry in 1975 had at least a high school education. 2/

The influx of new miners has also meant a lower overall level of mining experience. By 1970 the pool of experienced unemployed miners created by the layoffs of the early 1960s had disappeared through retirement and occupational change. As mining expanded the industry was forced to hire inexperienced miners. By 1976 the majority of underground coal miners (63 percent) had less than 6 years of experience in the mine. 3/

CHANGING MANAGEMENT CHARACTERISTICS

The U.S. coal industry is a workably competitive industry. 4/ Under these conditions a company's primary concern is to produce coal at lowest cost. This is especially true when demand for the product is declining as coal demand was during the 1950s and 1960s. With declining demand and low prices, only those operators with firm control over the production process could survive. During that period the UMW cooperated with the coal operators and gave them the free hand needed to survive depressed market conditions. 5/

Since 1970, however, these cost minimizing objectives have run counter to union objectives of higher wages, greater health and retirement benefits, job security, and safer working conditions. The coal operators' desire to retain the same degree of control over operations they had in the 1950s and 1960s clashed both with the restrictions imposed on them by the Mine Health and Safety Act and the UMW demands for more safety, job security, and job rights. Management felt that UMW demands and Federal regulations impeded their ability to make the decisions needed for economic coal production. 6/

As demand and prices increased in the 1970s, however, the resulting increase in profits made companies more willing to grant concessions to the UMW. The 1974 contract agreement contained, among other things, unprecedented wage gains, cost of living increases, and paid sick leave along with provisions for training, the right of a miner to leave an area he feels is unsafe, and a revamped grievance procedure. The operators hoped these concessions would return the stability of the workforce that was lost after 1970. 7/

CHANGING LABOR-MANAGEMENT RELATIONS AND THEIR INFLUENCE ON PRODUCTIVITY

As the words imply, "Labor-Management Relations" are an interaction of two distinct parties. The previous section discussed some of the more fundamental changes that have occurred within labor and management over the past decade. In this section we discuss what effects these changes have had on the quality of labor-management relations and productivity.

Age, experience, and education

Experience and education levels are closely tied to the influx of younger miners into the coal industry since 1968. These new miners were better educated than older workers which may be a positive attribute. The average age of miners has declined and so has the level of experience. One would expect that the declining age of miners would have a negative effect on experience and labor productivity.

An examination of those underground mines included in our statistical analysis revealed, however, that mines in which a large portion of the workforce is young do not have lower than average productivity. Those mines with 40 percent or more of their workforce 25 years old or less had an average productivity of 1.4 T/Wh in 1977 as opposed to a national average of 1.3 T/Wh. The productivity of these underground mines ranged from 3.2 T/Wh to .5 T/Wh. Similar productivity levels were achieved by those mines whose workforce had a more even age distribution. This indicates that little if any relationship exists between the age distribution of the workforce and productivity. Our statistical analysis confirmed that no relationship existed between a younger workforce and low productivity.

There are several possible explanations for these results. Young miners have positive characteristics such as more education which may offset their inexperience. Also, several coal officials surveyed noted that although the influx of a large number of miners in the late 1960s and early 1970s caused problems then, they have now gained the experienced needed to be efficient.

A recent study by Oak Ridge Associated Universities for the Departments of Energy and Labor adds support to our findings. They found a slight positive influence from the change in age distribution on productivity. 8/ This indicates that other positive factors such as education may be more important than age or experience.

Work attitudes and motivations

Management has described the younger miners entering the work force as lacking the motivation and work ethic held by older miners. The majority of managers interviewed by us felt this was true for at least some younger miners. Such intangible assessments, however, are hard, if not impossible, to prove or disprove. What may be viewed by management as poor work habits is in turn justified by labor as a rational reaction to unsafe conditions and poor management in underground coal mines.

Job absenteeism and turnover are generally considered to be important indicators of worker satisfaction or alienation. Coal operators point to high rates of absenteeism in their mines as evidence that today's younger miners lack basic work ethics. Absenteeism rates of 17 to 20 percent are often quoted. The underground mines we visited reported absenteeism rates from 15 to 20 percent. Labor and management at surveyed union mines almost always agreed that absenteeism is a serious problem and is more prevalent now than previously.

The main reasons management gave for increased absenteeism were that (1) younger miners do not suffer economically by missing one day per week. Union wages are high enough that a worker can live comfortably by working only four days per week. Therefore, he can "afford" to be absent* and (2) prevailing attitudes of the younger inexperienced miners cause increased absenteeism. Mine officials told us the younger miners are not committed to the rigorous work coal mining requires.

UMW officials we interviewed felt a large part of the absenteeism problem stems from management practices and poor working conditions rather than changes in the views coal miners have toward work. They felt increasing overtime work is directly related to the rate of absenteeism. One UMW official stated that a miner who is forced to work for 5 or 6 days straight in the cramped and wet conditions often found in mines needs a day off for his mental and physical health. They also said the practice of shift rotation, which is followed by some companies, especially in Pennsylvania, is disruptive to a miner's home life. A miner may also miss work, they said, because he feels that mine conditions are unsafe, but does not want to get in trouble with management.

Obviously, the views of labor and management differ on what causes high absenteeism. However, they agree that it is presently a problem. A July 1976 study conducted by the Westinghouse Behavioral Services Center for the National Institute of Occupational Safety and Health (NIOSH) which surveyed a total of 1,061 individuals** from union, management and labor, found that all groups felt that too much absenteeism was a problem in their mine. 9/

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*This is reinforced by the overtime system used in union mines (being paid if an unscheduled day is worked, even if total hours worked are less than 40).

**Individuals included 612 underground miners, 156 surface miners, 54 union officials, 102 foreman, 27 safety directors, and 32 managers.

We found little hard data on the amount of absenteeism in the coal industry, its root causes, or whether it has changed over time. Most absenteeism rates quoted by the coal industry do not give a clear definition of what is included in the rate. For example, one mine we visited claimed an absenteeism rate of 18.4 percent in February of 1977. However, their definition of absenteeism included vacations, holidays, sick leave, and other excused absences. Since excused absences for these reasons should average about 10.8 percent, the rate of unexcused absenteeism equaled 7.6 percent. In 1977, BLS began to publish absenteeism data for the coal industry based on a survey conducted in May of each year. The percent of absences due to illness and other miscellaneous personal reasons as a percent of all workers for the coal industry was 7.9 percent for the month of May 1977. For May 1978, it was 5.3 percent. 10/ Vacations, holidays, labor disputes and weather accounted for 10.2 percent in 1977 and 4.8 percent in 1978. The percent of total workers absent for all reasons was 18.1 percent in May 1977 and 10.1 percent in May 1978. In comparison, all U.S. manufacturing realized a total absenteeism rate of 10.7 percent in May 1977 and 10.3 percent in May 1978 while the rates for all mining sat at 12.8 and 8.7 percent. 11/ The drop in the BLS coal absenteeism figures between 1977 and 1978 is probably due to the fact that in May 1978 the industry had just experienced a long strike and workers were working hard to make up lost wages. Also, the number of work stoppages have dropped off noticeably since the 1978 contract was signed.

The BLS data do not report unexcused absences. A rough estimate can be made for UMW mines, however, if we assume that 240 days are worked per year and that the average underground miner is 35 years old with 12 years' experience.* Using these assumptions the amount of excused absences should be about 10 to 11 percent.** The rate of unexcused absences in May of 1977 would, therefore, have been somewhere around 7 percent.

The conclusion is that the coal industry does in fact have a problem with high absenteeism. This is especially true for unexcused absences which we estimate to average about 6 to 7

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*10 days vacation plus 7 days for 12 years experience.

**Sick Leave	=	5 days
Float Days	=	4 days
Regular Vacation	=	17 days
		26 Total sick and vacation leave
		26/240 = 11 percent.

percent in underground mines. Available data also indicate that absenteeism is more prevalent in the coal industry than in other U.S. industries. We must stress, however, that the data available is quite limited. Given this lack of detailed comparable data over time we could not determine the change in absenteeism or its overall impact on productivity.

The management of those union mines we visited considered absenteeism the most significant factor impacting productivity because unexpected absenteeism forces the mine operator to shuffle his work force to fill vacant positions. The workers who fill these positions may be less experienced in assigned tasks. Also coal production is a team effort. When a new individual replaces a member of the team, there is less cohesiveness and productivity suffers.

In extreme cases, entire sections of a mine must be closed because of absenteeism. At one mine surveyed the superintendent told us he had hired a special 40-man work force to fill positions left vacant by absentees.

The evidence for or against a relationship between the past decline in labor productivity and increasing absenteeism is inconclusive. A strong indication, based on the opinion of the majority of individuals contacted by us, is that high absenteeism presently contributes to low productivity in underground mines. Absenteeism may or may not have contributed to past productivity declines. It is a promising area for possible productivity improvements in the future.

Labor turnover can also be viewed as an indication of worker discontent. Our survey of mines revealed a low level of labor turnover at both union and non-union mines. Very few miners are fired and those that leave do so for the same reasons as people in other industries--advancement, better working conditions, school, etc. Nor has the number of separations in surveyed mines increased during the 1970s. Despite greater labor-management conflict in recent years, the labor turnover rate has remained essentially unchanged. The "separation rate"--the total rate of layoffs, firings, quits, and other separations--was no higher in 1979 than in 1968. The same is true of the "accession rate"--the total rate of new hires, call backs, and other accessions.

The BLS collects labor turnover data on a large number of coal mining establishments. An "establishment" may be a single mine or several mines under central administrative control. BLS combined the productivity figures we supplied with this turnover data for the 1972-77 period and performed statistical analyses of the combined data under our direction.

After separating underground and surface mines, we examined the effects that the accession and separation rates--and their components--had on productivity. We did not find any relationship between productivity and the accession rate in underground mines, but rising separation rates exerted a small negative influence on productivity. More precisely, we found that a 10-percent increase in the separation rate was associated with a 2-percent drop in underground labor productivity. However, the strength of this association was low, so about the most that can be said is that a higher separation rate has a slight negative effect on underground productivity. No other form of turnover had a noticeable effect on underground mining. These statistical results coincide with the opinions of mine operators we questioned. They indicated that labor turnover has not had a noticeable effect on productivity.

Strikes

Both the BCOA and UMW argue that a close association exists between the decreasing age and experience of coal miners and the increased instability in labor-management relations since 1970. The younger miners are more independent and vocal and place more importance on safety. This can be seen through an examination of both the changes which took place within the UMW and the agreements reached between the BCOA and UMW, especially in the 1974 contract.

During the 1950s and 1960s John L. Lewis exercised strong control over the UMW. This authority assured the stability of a shrinking work force while the industry went through a process of mechanization. Strike activity declined sharply in the 1950s, remained at a low level from 1960 until 1967, and then began to increase in 1968. By 1970, rank and file workers had become discontented with their working conditions, wage levels, and lack of influence in UMW matters. Although wages had increased substantially during the 1960s, they failed to keep pace with the wages of workers in comparable industries. Accidents and injuries were unacceptably high, and rising dust levels resulted in thousands of miners being affected with black lung disease. An increasing number of UMW members felt that the price paid for the UMW-BCOA agreement for mechanization and labor stability during the 1960s was too high, and this led to more strikes and a movement to democratize the UMW.

Table 1 contains the most recent data available on work stoppages for the entire bituminous coal mining industry. Individual data on stoppages for underground and surface mines is not available. The number of work stoppages increased substantially from 266 in 1968 to 1,039 in 1973 and remained at high levels through 1977. The number of strikes fell off in 1978; however, man-days idle almost doubled. This is due largely to the long UMWA coal strike which began in December 1977 and ran into March of 1978.

A distinction must be made between those strikes that occur while renegotiating a contract and those that occur during the terms of a contract (wildcat strike). Over 98 percent of all strikes between 1969 and 1976 have been wildcat strikes. This high incidence of mid-contract strikes continued through 1977.

Examining the reasons for wildcat strikes gives a perspective on the conflicts between labor and management. Issues involving general management (job bidding, overtime, vacations, delay of pay, etc.) account for the largest number of wildcat strikes, 32 percent in 1970 and 29 percent in 1974.* Safety issues accounted for 8 percent in 1970 and 13 in 1974. Wildcat strikes over general working conditions increased from 7 percent in 1970 to 10 percent in 1974. Strikes based on discipline or discharge remained constant at around 9 to 10 percent while conflicts over work assignments rose from 6 percent to 8 percent. In contrast, job security related strikes declined from 15 to 7 percent. 12/ The increase in the number of strikes caused by safety and work conditions indicates that the workers were becoming more aware of the hazards associated with coal mining and were pressing operators to make improvements. The proportion of strikes related to discipline and discharge issues may reflect the unrest and youth of the work force; however, no other evidence supports this. Continued dissatisfaction with working conditions, policy differences within the Union's leadership, and difficulties with the new grievance procedure established in the 1974 Union contract have caused many strikes since 1974. A study of strike activity conducted for the National Science Foundation (NSF) gives some additional insight into the causes of wildcat strikes. 13/ The study's main conclusion was that a mine management that fails in human relations--particularly in communicating with employees and in handlng their grievances--will be plagued with wildcat strikes.

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*Comparable data for later years was not available.

Table 1

National Bituminous Coal Mining Work Stoppages 1960-79

Year	No. of Strikes	Workers Involved (note a)	Man-days Idle
1960	120	37,200	137,000
1961	117	25,100	90,700
1962	121	34,300	191,000
1963	131	38,000	234,000
1964	111	56,000	340,000
1965	145	62,600	258,000
1966	160	88,100	629,000
1967	207	62,900	158,000
1968	266	206,400	956,600
1969	457	206,000	900,600
1970	500	198,600	627,000
1971	606	350,700	4,215,100
1972	963	256,000	562,400
1973	1,039	289,800	559,900
1974	996	459,900	3,310,100
1975	1,139	387,200	1,501,300
1976	1,383	506,900	1,980,000
1977	958	649,800	5,628,300
1978	250	108,300	9,946,400
1979	414	138,400	320,100

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics.

a/Workers are counted more than once if involved in more than one work stoppage per year.

Other findings included:

--Mine superintendents at low strike mines spend substantially more time dealing directly with miners and their representatives than did superintendents at high strike mines.

--Miners at high strike mines believed it was necessary to strike to get management to listen to them.

--The miners' biggest (90 percent of those surveyed) complaints focused on excessive delays in the grievance procedure. At high strike mines there was less evidence of serious effort on management's part to resolve grievances short of arbitration.

--Large mines were more susceptible to wildcat strikes than small mines. Dealings between management and labor may be less frequent and more impersonal at large mines and the resolution of grievances may also be delayed.

--There is no evidence that young miners tend to instigate or support strikes more frequently than older miners.

A substantial portion of wildcat strikes stem from disagreements over the provisions contained within the UMW contract such as job bidding and grievance procedures. Contracts were negotiated between the UMW and BCOA in 1974 and 1978.

The UMW came to the 1974 bargaining table with two basic objectives: (1) to make up for ground lost over the past 30 years in the area of wage, medical, and other benefits and (2) to work out new terms for the future handling of grievances. The BCOA on the other hand hoped to achieve greater labor stability through major wage and benefit concessions. On November 12, 1974, the UMW struck and 120,000 miners walked off the job. On December 12, a new contract was signed that included, among other things, the following:

--Increases in wages and vacations,

--Addition of helpers to certain work crews,

--Sick leave and sickness and accident benefits,

--Revisions to job training requirements,

--The right for miners to withdraw from any area they considered unsafe, and

--Revamped grievance procedures.

The union failed to obtain the right to strike over local grievances, including safety matters. 14/

The many strikes after 1974 were an indication that BCOA had failed in its effort to obtain labor stability. At the 1977 contract negotiations, the companies stated they wanted a contract that would promote labor stability, increase productivity and remove what they characterized as restrictive work practices. 15/ Related to this was their concern for greater management control over labor at the minesite, reducing absenteeism, curbing wildcat strikes, and increasing productivity through the use of production incentive programs.

UMW members went on strike December 6, 1977. The strike lasted 109 days. Neither the BCOA or UMW members were satisfied with the final agreement. The 1978 contract contained among other things:

--The right of the employer, based on arbitration review board decisions, to discipline employees who promote or participate in wildcat strikes.

--Revamped grievance procedure. A section foreman now has the authority to settle a dispute at the mine within 24 hours.

--Operator can adopt production incentive plans subject to a majority vote by miners.

--An employee-developed orientation program of not less than 4 days for inexperienced miners and 1 day for experienced miners. The trainee period for new miners was cut from 90 to 45 days.

--Wage increases of an average 31 percent in the first year and a $0.30 maximum per hour raise in the second and third year.

The 1974 contract terms on safety and health remained in force as did the operators right to operate the mine 6 days a week. The BCOA push for a stronger hand by the operator in disciplining wildcat strikes failed in that a miner can appeal to the Arbitration Board. 16/

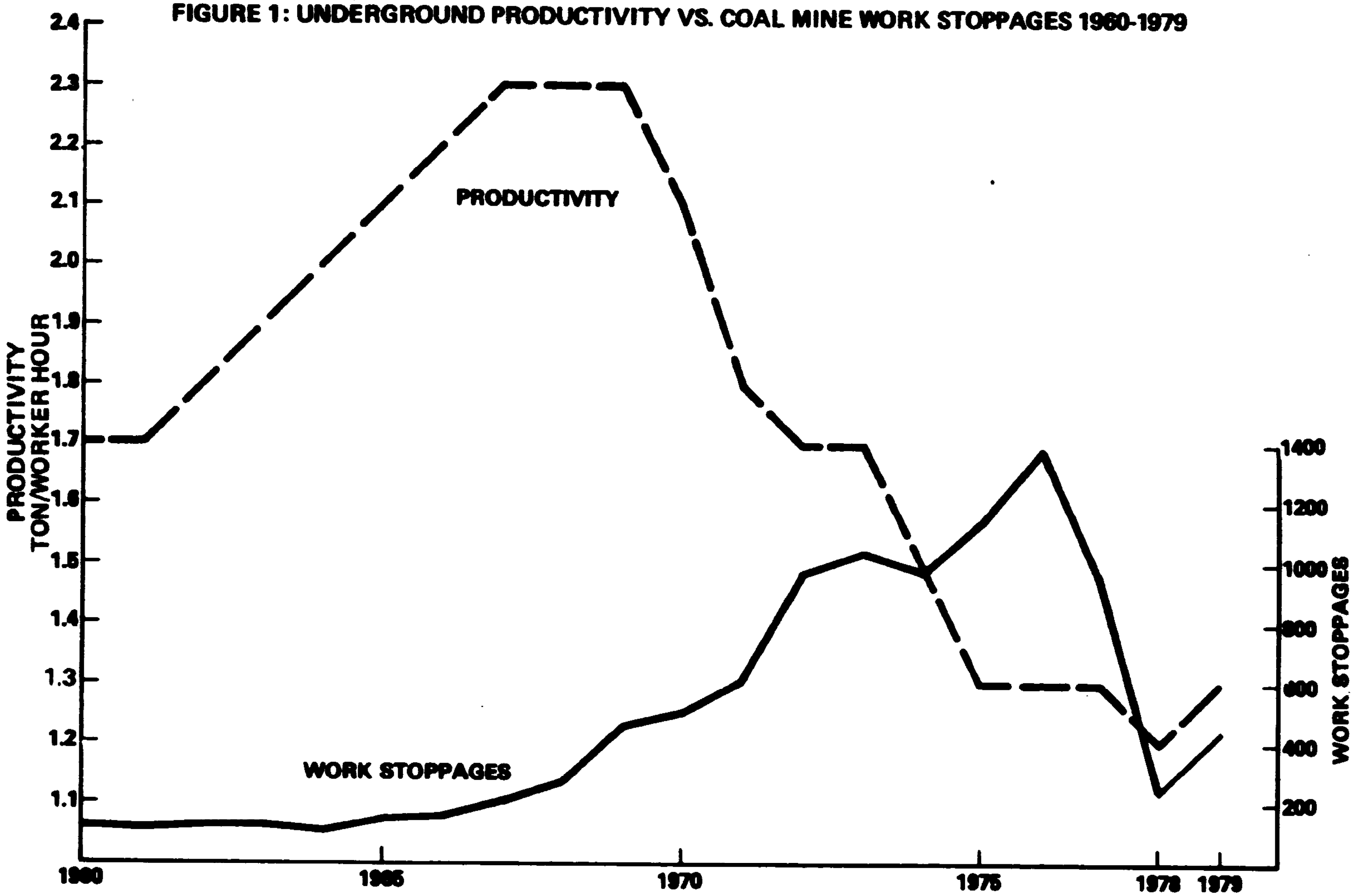
It is difficult to determine the impact of the 1978 contract on long-term labor-management stability. Wildcat strikes have fallen off 90 percent since the signing of the contract, indicating a return to greater stability. In addition, according to the President's Commission on Coal, there are increasing signs of improvement in labor relations. They report significant progress in improving labor relations through joint and separate meetings with officials of the UMWA and BCOA. However, it is questionable if long-term stability has been assured. Much of the decline in strike activity may be due to the fact that the 1977 strike, which lasted 109 days, left most UMW members financially strapped and thus having little desire to lose any additional work time. In addition, almost 20,000 Appalachian miners were laid off during 1978 due to depressed coal demand. Most important, however, is the fact that neither the BCOA or UMWA were satisfied with the last contract. Much of the conflict between the two parties is based on perceptions of one another which have developed through years of hostilities. Long-term stability will require basic changes in the views of management and labor towards each other. The increased communication between the two parties reported by the Coal Commission is a step in the right direction.

Technically, strikes themselves do not cause a loss in productivity. When mines close, both production and manhours are lost, thus productivity is not affected. Our survey of mines also indicated that little production time is lost before or after a strike. This is especially true of short strikes. Thus, strikes themselves do not cause a decline in productivity but rather reflect the underlying degree of discontent between labor and management. The number of wildcat strikes in a mine can, therefore, be used as a indicator of the overall quality of labor-management relations.

Figure I shows the change in underground productivity and the number of work stoppages. As can be seen, productivity since 1969 had an inverse relationship to the number of work stoppages. However, a 4-year gap exists between when work stoppages begin to turn upward in 1965 and the reversal in productivity in 1969, thus the relationship is not exact. It should be noted, however, that 1968 is the first year since 1960 that the coal industry experienced a substantial increase in both the number of workers involved and worker-days idle due to strikes (see table 1). The number of wildcat strikes reached the 400-to 500-per-year range in 1969--the first time since the early 1950s. This indicates that some threshold exists above which poor labor-management relations, as reflected by the number of strikes and miners involved, begins to have a negative effect on labor productivity. The number of strikes dropped from 1383 in 1976, to 958 in 1977, and to 250 in 1978. At the same time underground productivity has remained relatively constant. The decrease in work stoppages may herald at least some moderation in the trend of decline.

While the number of work stoppages can be used as a measure of the overall quality of labor management relations, the data on the number of wildcat strikes is not available on a mine by mine basis and so could not be incorporated directly into our mine level analysis. State level data is available from BLS, however, and was used by Oak Ridge Associated Universities (ORA) in their analysis. 17/ Using the percentage of total miner shifts lost to wildcat strikes in each State in a given year as a measure of labor discontent they found that work stoppages had a strong damaging effect on productivity during the 1970s. ORA found that 25 percent of the productivity lost between 1970 and 1975 was due to conflict between labor and management.

FIGURE 1: UNDERGROUND PRODUCTIVITY VS. COAL MINE WORK STOPPAGES 1960-1979



Union contract provisions

Industry officials and mine operators point to certain provisions of past labor-management contracts as a cause of lower productivity. These include the requirement for helpers on face equipment, job bidding, and lack of production incentive plans.

Helpers

The 1974 UMW contract required helpers on face equipment in underground mines.*

Mine operators claim that the additional workers do not increase production so productivity declines. Union officials on the other hand, feel that the additional helpers add to both the safety and productivity of the mine. They point out that the helper on the continuous miner serves a useful purpose by moving trailing cables and hanging ventilation curtains. Before, the machine operator had to stop cutting coal and perform these tasks. Also, the helper is in effect an apprentice machine operator who is trained during the first 120 days to operate the machine safely. After 120 days the helper becomes a certified operator and continues to work with the more experienced operator until an opening for a machine operator becomes available.

Assessing the productivity impact of additional helpers on underground mining sections is difficult. However, we can get a rough idea of the effect by using aggregate data. In 1978, the Mining Enforcement and Safety Administration (MESA), of the Department of the Interior issued data on employment by occupation in both surface and underground mines from 1972 to 1976. 18/ Applying these data to MSHA production and manhour data, we arrived at an estimated productivity decline due to the helper requirement. In 1974, 8,782 miners were classified by the Department as continuous miner operators and helpers and 8,309 as roofbolter operators and helpers. In 1975, these increased to 10,723 continuous miner operators and helpers and 11,770 roof bolters and helpers. These represent 22 and 42 percent increases. The larger percent increase in the roofbolters and helpers reflects the fact that roof bolting machines are used in both continuous and conventional mining sections. Assuming that an underground miner worked an average of 1,727 hours in 1975, this increase of 1,941 continuous miner operators and helpers equates to an additional 3,352,107

*Exceptions are cases in which a twin-boom roofbolter is employed; or when two roofbolting machines are assigned to work in a single space; or, when a continuous miner is used with a loading machine.

worker hours in 1975. In 1975, miners worked 210,474,994 hours underground and produced 278,649,145 tons of coal resulting in 1.32 T/Wh. If we subtract the additional 3,352,107 hours expended in continuous mining sections from the total hours worked and recalculate productivity, we arrive at a figure of 1.35 T/Wh. The difference in productivity (1.35 vs. 1.32) is 2 percent and represents the estimated maximum decline in productivity caused by the requirement for additional helpers on continuous miners. Applying the same steps to the additional 3,461 roofbolter operators and helpers results in a difference in productivity from 1.36 to 1.32 T/Wh in 1975. This represents an estimated 3-percent decline in productivity caused by the requirement for helpers on roofbolter machines. The maximum overall decline in productivity due to additional helpers on both types of machinery could have been as much as 5 percent.*

Of the 13-percent decline in underground productivity which occurred between 1974 and 1975, a maximum of 5 percent could be due to the 1974 contract requirements for helpers.

Job bidding

The operators we questioned mentioned job bidding as having a negative impact on productivity. All jobs at UMW mines are filled by job-bidding in accordance with the procedures specified in the Wage Agreement. When a position becomes vacant, management posts the job vacancy in a conspicuous location for 7 calendar days or not less than 5 production days. Any employee who believes he has the ability to perform the work described in the vacancy is entitled to bid on the job. Within 5 production days after the end of the posting period, the company must select the senior employee having the ability to perform the work.

Most coal companies indicated that job bidding hurts productivity because the most qualified person may not be awarded the position. Jobs are awarded primarily on the basis of seniority and the ambigious criterion that the worker have the "ability to perform the job." Management has had little success in contesting a miner's ability to perform. Therefore, the person with the most seniority generally receives the job even when he is not as qualified as a miner with less seniority. The result is inefficiency and reduced production during the period the worker is learning his new job. Another

*This estimate represents a maximum assuming that helpers do not increase production. While the UMW argues that helpers do increase production, it is impossible to determine the actual effect on productivity with available data.

impact of job-bidding on productivity was felt to be the "domino" affect created when a job vacancy is filled. When the person to whom the job is awarded moves into the new job, his vacant position must then be posted and filled which in turn leaves another vacant position to be posted and filled. This process may involve filling five or six jobs. Each person moving to a new position must receive on-the-job training or experience before he reaches peak proficiency. The result is decreased production because more time, which otherwise could have been spent producing coal, must be committed to training.

UMW officials disagreed with this. They felt that a new miner entering the industry may bid on two or three different jobs until he finds one he likes and stays there. They did not believe job bidding caused the confusion or decline in productivity noted by management officials.

No data are available on the number of times jobs are filled through job bidding. The union contract states that a worker must work 12 months after his last job change before he can bid on a job that carries the same or lower wage scale; no time limit is set on a job that carries a higher wage rate.

Although the argument that job bidding leads to a decline in productivity has a surface plausibility, no solid evidence exists for or against it. All industries have occupational mobility mechanisms. In addition, the domino affect caused by job bidding would exist even if management were free to pick the candidate. We could find no evidence why job bidding in the coal industry should be more disruptive than occupational changes in other industries.

Incentive plans

Since incentive plans have not been in widespread use they have no direct relationship to the decline in underground productivity.* To be economically beneficial and socially acceptable, they must incorporate elements of both safety and production.

Coal companies were given the right to institute bonus incentive plans under the 1978 wage agreement. These plans must be approved by a majority of voting miners before they are adopted. The contract stipulates that only monetary

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*Incentive plans usually consist of a monetary bonus paid for achieving a certain level of production. Such bonuses may also be tied to other factors such as safety, productivity, absenteeism, etc.

incentives can be used but does not specify what the bonus can be tied to (production, productivity, safety). It does stipulate that the plan "not lessen safety standards as established by applicable laws and regulations." This right to present a bonus incentive plan to the workers was seen as a major industry gain by BCOA. According to a BCOA spokesman "we felt it would help productivity and stability across the board." 19/ The UMW had formerly been opposed to incentive plans mainly because they feared the result would be increased accidents and injuries. Shortcuts in work procedures to earn a bonus could create an unsafe atmosphere.

Since most BCOA companies have just recently begun to experiment with incentive plans, only a limited amount of information on productivity or safety impacts exist. By mid-1979 only six BCOA companies, operating 30 mines, had filed plans with the UMW. In July 1978, Consolidation Coal Co. introduced production incentive plans in four underground mines. The programs included both production and safety bonuses. Under the program a worker could double his annual earnings if he achieved his production target with a perfect safety record. One mine reported a 17-percent increase in production while maintaining a satisfactory safety record. 20/

Even though it is unionized, Amherst Coal Company has been operating a production incentive program at its mines since 1973. Production incentives are set based on the production characteristics of an individual mine. The company reports that when incentive quotas are met, production can be increased 40 percent. Both union and management like the plan which was officially approved after the 1978 wage agreement. According to a company official, safety is not specifically addressed in the plan. The miners know that if a section is shut down because of unsafe conditions which they fail to correct, they can lose their bonus for that period. As a result over the last 6 years, Amhersts' safety record was reported to be as good as, or better than, before the plan was instituted. 21/

The recent experience in British mines can shed some additional light on incentive plans. The British National Coal Board instituted productivity incentive schemes in 1977. Since then they have reported a 10-percent improvement in face worker productivity for the first half of 1978 over the same period in 1977. According to a Board spokesman, "It's the only different factor. Thus, the increase can only be due to the incentive scheme." The bonus payments are set by a joint Board/Union committee at each mine based on a standard weekly output figure for each face team. The standards are reviewed every 6 months. According to the Board no increase in accidents can be tied to the incentive scheme. 22/

Although little data exists on the safety and productivity impacts of incentive plans, it seems that a well-designed incentive program that ties bonus payments to both safety and realistic production performance could reap substantial benefits. Such a plan could also reduce absenteeism and improve labor-management relations.

When designing incentive plans a company must first stress that safety is just as important to the company as increased production. Secondly, it must convince both labor and management that by working together they can both benefit financially from producing coal safely. Finally, the company must set goals that both labor and management feel are reasonable and attainable.

CONCLUSIONS

We found the decline in underground productivity during the 1970s to be tied closely to the reduced quality of labor-management relations and to the 1974 contract requirements calling for helpers on face equipment. While the results proved inconclusive on the past effect of absenteeism, other factors such as age distribution, labor turnover, and job-bidding were found to have little effect on productivity. Incentive plans seem to be a promising way to improve productivity.

Since 1969 underground coal mines have experienced worsening labor-management relations as reflected in the increase in the number of strikes. Work stoppages themselves do not effect productivity directly. Instead, they reflect the level of tension between labor and management. Available evidence suggests a direct relationship between labor-management instability and productivity. A large portion of the decline in productivity after 1973 resulted from this increased tension between labor and management.

We examined the shift to a younger work force and the resulting reduction in experience levels for its impact on productivity. Along with the National Science Foundation we found no correlation between younger miners and low productivity. Also, the large number of young miners hired in the early 1970s have by now gained needed experience.

Because data are lacking, we could not fully analyze the impact of absenteeism on productivity. However, the existing level of unexcused absence is substantially higher in coal than other industries. Thus, improvements in this area could raise future productivity.

Labor turnover in the coal industry has had little effect on productivity during the period. We found that a higher separation rate has a slight negative effect on underground productivity and that no relationship exists between productivity and the accession rate. However, the rates for both separations and accessions were no higher in 1979 than in 1968. Thus, turnover does not seem to be a problem and it need not change in order to improve productivity.

The requirements for helpers on face equipment contained in the 1974 wage agreement was estimated to account for a maximum of 5 percent of the 13-percent decline in underground productivity during 1974-75. No support was found for the argument that job bidding was a factor in the decline in productivity.

Finally, a well-designed incentive plan which stresses safety along with realistic production goals can be a useful management tool. Such a plan could potentially lead to improvements in safety, productivity, and overall labor-management relations.

FOOTNOTES

1/Joseph P. Brennan, "We Must Move Into a New Era," Coal Mining and Processing (1976), p. 65.

2/The President's Commission on Coal, Coal Data Book (Washington, D.C., February 1980), p. 135.

3/United States Office of Technology Assessment, The Direct Use of Coal (Washington, D.C.: Government Printing Office, April 1979), p. 123.

4/United States General Accounting Office, The State of Competition in the Coal Industry, EMD-78-22 (Washington, D.C.: U.S. General Accounting Office, December 1977), p. i.

5/United States Office of Technology Assessment, pp. 129-130.

6/Ibid., p. 135.

7/Ibid., p. 137.

8/Oak Ridge Associated Universities, Determinants of Coal Mine Labor Productivity Change (Washington, D.C.: U.S. Department of Energy and the U.S. Department of Labor, November 1979), p. 25.

9/Westinghouse Behavioral Service Center, Psychological, Behavioral and Organizational Factors Affecting Coal Mines Safety and Health (Washington, D.C.: National Institute for Occupational Safety and Health, July 1976).

10/Based on data provided by the Office of Current Employment Analysis, Bureau of Labor Statistics (Washington, D.C., December 1979).

11/Ibid.

12/Management Engineers, Inc., Preliminary Analysis of the Probable Causes of Decreased Coal Mining Productivity (1969-1976) (Washington, D.C., Department of Energy, November 1977), p. v-31.

13/Jean M. Brett and Stephen B. Goldberg, Wildcat Strikes in the Bituminous Coal Mining Industry: A Preliminary Report (Evanston, Ill.: Northwestern University, 1978), p. 23.

14/U.S. General Accounting Office, U.S. Coal Development--Promises, Uncertainties, EMD-77-43,September 1977, p. 4.30.

15/U.S. Department of Labor, Collective Bargaining in the Bituminous Coal Industry, (Washington, D.C., November 1977).

16/National Bituminous Coal Wage Agreement of 1978, (Washington, D.C.: Allied Printing, March 27, 1978).

17/Oak Ridge, p. 60.

18/U.S. Department of the Interior, Mining Enforcement and Safety Administration, Coal Mine Injury and Employment Experience by Occupation, 1972-75, (Washington, D.C., 1978), tables 8 and 9.

19/Allanna M. Sullivan, "Incentive Plans May Cut Losses in Production," Coal Age (July 1978), p. 82.

20/Allanna M. Sullivan, "Incentives Can't Get Off the Ground," Coal Age (May 1979), p. 91.

21/Ibid., pp. 88-91.

22/Ibid., p. 92.

CHAPTER 3

GOVERNMENT REGULATIONS

AS A CAUSE OF LOW PRODUCTIVITY

Over the past 12 years, increased efforts at the Federal and State level have tried to lessen the social and environmental costs of increased coal production. This increased awareness of the external costs of coal has been manifested through the enactment of strict Federal health and safety regulations and State surface mining reclamation laws. Both have resulted in social benefits and reduced productivity.

In underground coal mining, the Federal Mine Health and Safety Regulations have been a primary cause of declining productivity since 1969. MHSA regulation reduces mine productivity by (1) requiring that additional manhours be spent on non-production activities and (2) reducing available production time. Further, regulatory enforcement disrupts production, thereby lowering productivity. However, mine safety and health regulation was not the only cause of declining productivity and has not been as significant a cause as the coal industry asserts. These regulations had their greatest impact on productivity between 1969 and 1973; their influence leveled off after that year.

State surface reclamation laws have been the primary cause of worsening surface mining productivity. Although overall surface mining productivity did not begin to drop until 1974, the laws' impact was felt as early as 1966 in Eastern States. The switch to Western surface-mined coal, which occurred in the late 1960s and early 1970s, concealed this drop in the East. After Western States enacted strict reclamation laws in 1973, their productivity also began to fall as did the industry total. These reclamation laws continue to have a negative influence on surface mine productivity.

Federal coal mine health and safety regulation has grown greatly since the establishment of the Bureau of Mines in the Department of the Interior by the Organic Act of 1910. In 1941, P.L. 77-49 gave Federal inspectors the right to enter coal mines to obtain information. By virtue of P.L. 80-328, passed in 1947, the first formal code of safety regulations published in the Federal Register became the basis for the previously authorized inspections. Under the Federal Coal Mine Safety Act of 1952, P.L. 82-552, Federal inspectors were empowered to issue notices of violations and orders of withdrawal when imminent dangers were found.

In the wake of the 1968 Farmington, West Virginia, mine explosion in which 78 miners were killed the most dramatic changes in the Federal role came about. The Federal Coal Mine Health and Safety Act of 1969 (P.L. 91-173) authorized stringent health and safety standards and vastly increased Federal enforcement powers and resources. Also, the act increased Federal health and safety research and provided benefits to miners disabled by black lung. The Federal Mine Safety and Health Amendments Act of 1977 (P.L. 95-164) transferred health and safety regulation from the Department of the Interior to MSHA in the Department of Labor. This act also established minimum safety training requirements for coal miners.

The coal industry attributes low and declining underground productivity primarily to the Federal Coal Mine Health and Safety Act of 1969. Both the regulations themselves and the enforcement of this act reduce productivity. While the new mining practices and their enforcement had the greatest impact during the act's implementation, increased enforcement may continue to lower productivity. Our statistical analysis indicates that while the act was one cause, it was certainly not the only cause, and was not as significant as the coal industry asserts. Further, since the major impact on productivity took place during the initial years of implementation, the MSHA Act is not an important cause of continuing productivity decline. However, as long as MSHA-required practices continue, some of the initial drop in productivity will be permanent.

The act is effectively reducing fatalities and disasters, however. In fact, those regulations primarily responsible for the productivity decline are the same ones that have caused safety improvements. Accidents tend to rise with increased employment and production. The Office of Technology Assessment projects that in 1985, between 157 and 187 coal workers are likely to be killed, representing a 13- to 35-percent increase in fatalities over 1977. 1/ Thus, as coal production expands in response to higher oil prices, it is important for the Federal Government and the coal industry to continue efforts to improve mine safety. However, the Federal Government should work to make safety and health regulation less harmful to productivity.

<u>MSHA regulation was a major cause of productivity decline in underground coal mining</u>

Measuring the impacts of Federal health and safety regulation on productivity is difficult. Obtaining data on the act's aspects believed to affect productivity is as problematic as measuring changes in mining methods caused by the act. We estimated the act's impact on productivity in the following two ways: (1) by surveying management and labor at 44 underground and surface mines and by questioning MSHA officials, focusing on specific regulations affecting productivity and 2) statistically examining the relationship between enforcement of the act and productivity.

Our survey results revealed that the act had a substantial effect on productivity in underground coal mines. While the MSHA Act had some impact on strip mine productivity, it was not nearly as severe as in underground mines. Strip mine productivity grew by 5.5 percent annually between 1961 and 1969, remained relatively constant between 1969 and 1973, and fell by 7.2 percent annually between 1973 and 1978. The strip mines we surveyed were less likely to blame MSHA regulation and more likely to cite State reclamation laws as the major cause of productivity decline. Since the impact of the MSHA Act on surface mines was much less severe, most of the discussion focuses on underground mines.

Underground productivity rose by 3.7 percent annually between 1961 and 1969 and declined by 7.1 percent annually between 1969 and 1978, the period following the passage of the MSHA Act. MSHA regulation was the cause of productivity decline most often cited by officials of underground coal mines we surveyed. Coal company officials we interviewed attributed 22 to 40 percent of the productivity decline to MSHA regulation. However, companies had little data to support their claim. The coal industry has attributed a greater percent of the decline to the act than other research indicates. For example, Gordon et al. of Pennsylvania State University determined that the most significant aspects of the MSHA Act caused an average 18-percent decline in productivity, an estimate below industry's range. 2/

While MSHA officials agreed that regulations have affected productivity, they felt that most of the impact occurred during the initial years of enforcement. Our analysis supports MSHA's position that the act no longer causes productivity to decline. While certain practices required by MSHA lowered productivity substantially, their impact was felt largely during MSHA's implementation and should not be a continuing source of decline. However, increased enforcement is a potential source of continued productivity decline.

Using inspections to measure enforcement, our statistical analysis revealed that in 1977 a significant relationship existed between MSHA enforcement activities and productivity. Increased enforcement activity results in lower productivity. For example, increasing the number of inspection days by 10 percent will result in an average 1.5-percent reduction in underground mine productivity. MSHA inspections increased substantially from 1970 to 1973, reached a peak in 1973, and have declined slowly since then. Using State-level data, a joint Department of Energy (DOE)/Department of Labor study prepared by Oak Ridge Associated Universities showed that in the early 1970s, inspections and productivity were negatively related. 3/ (A negative relationship exists when a positive or negative change in a variable has an opposite effect on another variable. For example when inspections increase, productivity decreases.) Thus, it appears that productivity in underground mines was adversely affected by enforcement during the initial years of MSHA regulation, but was not being further depressed by 1977. However, if the number of MSHA inspections increased, productivity might be pushed lower. The Oak Ridge study supports our conclusion that MSHA was the largest cause of the decline between 1970 and 1973 but was less important afterwards. 4/ While MSHA regulation may not be an important cause of a continuing decline in productivity, it may have lowered productivity permanently because the practices required by MSHA regulation causing the decline continue.

Types of mines where MSHA regulations had the smallest and largest effects on productivity

Although MSHA regulation seems to have had a large impact on the productivity of the smallest and largest underground mines using continuous mining machines, the greatest impact has been on the former's (mines producing 25,000 tons per year and less) productivity. This should have a limited effect on industry-wide productivity because these small mines produce only 3 percent of the Nation's coal. However, these small mines represent almost half of all (underground and surface) coal mines, and they tend to be marginal operations which had further to go to achieve acceptable safety conditions. Thus, they probably had to invest relatively more resources to comply with MSHA than larger mines causing them a greater productivity loss. However, the largest mines may also experience a greater productivity loss than the average-sized mines because more time is spent inspecting them. Increased inspection days were found to be a cause of the productivity loss in the early 1970s.

The MSHA Act has affected mines using continuous mining machines more so than conventional mines. In fact, our statistical work showed that between 1972 and 1977, conventional cutting machines had a small productive advantage over continuous mining machines. 5/ The Oak Ridge Associated Universities study determined that in the 1960s, continuous mining was more productive than conventional mining. 5/

The act was probably a major cause of continuous miners losing their productive advantage over conventional miners in mines where additional roofbolting requirements reduced the distance that continuous mining machines were permitted to advance before bolting. Also, additional machine maintenance, electricity supply, and ventilation regulations may have affected mines using continuous and longwall mining more than those using conventional mining methods.

How MSHA regulation reduces productivity

MSHA regulation reduces mine productivity in two major ways:

--Regulatory enforcement may disrupt production.

--The regulations themselves require that additional manhours be spent on nonproduction activities and may reduce available production time.

Coal companies have complained about how disruptive MSHA enforcement is to production. They claim that Federal inspections may disrupt mining operations and managers must spend more time administering MSHA tests, writing reports, obtaining approval of roof-control plan changes, and performing other MSHA-required activities. Thus, managers have less time available to supervise production. Mine superintendents we surveyed claim they spend 30 to 50 percent of their time on MSHA paperwork. A survey of 163 mines for the American Mining Congress by John Straton of Gates Engineering suggests that foremen lose 30 percent of available supervision time due to MSHA compliance. 6/ However, MSHA officials feel that these estimates are too high since many mines have full-time safety engineers to perform this sort of work. They feel that at most mines, superintendents spend less than 5 percent of their time on MSHA paperwork. MSHA also occasionally hinders production by requiring compliance with regulations that are technically difficult to comply with, such as illumination and the use of cabs and canopies on equipment. Some operators must spend a great deal of time experimenting to find an acceptable compliance system.

MSHA regulation also reduces productivity by requiring that additional manhours be spent on nonproduction activities both above and below ground. While the addition of underground rather than office workers is primarily responsible for the decline in productivity, some was due to more office workers being hired. About 5 points of the 45 percentage point drop in productivity between 1969 and 1977 were due to additional office workers. Also, a joint statement submitted by the National Coal Association and Bituminous Coal Operators' Association during congressional hearings claimed that 15 to 20 percent of total payroll in large underground mines is paid to workers performing primarily MSHA-related tasks. 7/ Examples of some specific MSHA regulations requiring additional manhours are: additional roofbolting, mine clean-up, more maintenance, building stoppings for additional entries, and increased testing. In some cases, however, the regulations had been in existence since the Federal Mine Safety Code of 1953 but were not adequately enforced. The number of inspectors has increased thirteen-fold since 1968. Furthermore, prior to the 1969 Act, coal companies were not fined for noncompliance. Thus, sudden compliance with existing regulations may have reduced productivity. Gordon et al estimate that one man must be added per face crew to perform additional required activities. 8/ A major Eastern coal company we surveyed stated that 16 additional workers for the mine and 2 per section crew were required as a result of the act. MSHA officials, however, feel that it was necessary to add one worker per section crew to perform required activities.

Complying with MSHA regulation also hinders productivity by reducing production time available during a shift. For example, machines must be maintained in permissible condition at all times. Since enforcement is now more rigorous, coal companies are less likely to wait until the production shift is over to repair machines. An official of a large underground coal company stated that of the 2 hours per shift lost to required MSHA maintenance, 1 hour could be saved if the maintenance could be done at a more convenient time. Equipment shutdown due to failure of safety devices, more frequent methane tests, and Federal inspection of machines during a production shift are all examples of how MSHA reduces available production time. Straton suggests that MSHA has brought about a 26 percent loss in available production time per shift. 9/

MSHA reduces fatalities substantially

MSHA regulation reduced fatalities in coal mines dramatically, particularly reducing the number of disasters. However, nonfatal injuries have stayed high.

Table 2 shows that since 1970, both the number of fatalities and fatalities per million manhours for underground and strip mines have declined. Before the act was passed, the fatality rate for strip mines was rising, while the underground fatality rate fluctuated. In terms of fatalities per ton produced, the trends are less consistent.

While it is clear from table 2 that the fatality rate for underground mines declined after the act's passage, it is also evident that fatalities had declined for most years before the act was passed. However, the rate of decline increased after the act's passage. Between 1961 and 1969, fatality rates declined by 5.7 percent annually, while between 1969 and 1978 fatalities declined by 10.8 percent annually. The fatality

Table 2

Fatalities Decrease Substantially After the Passage of the MSHA Act of 1969

	Underground mines a/			Strip mines b/		
Year	Number of fatalities	Fatalities per million manhours	Fatalities per million tons	Number of fatalities	Fatalities per million manhours	Fatalities per million tons
1961	256	1.6	0.9	17	0.4	0.13
1963	245	1.5	0.8	22	0.5	0.14
1965	223	1.4	0.7	18	0.4	0.10
1967	174	1.1	0.5	22	0.5	0.12
1968	268	1.8	0.8	24	0.6	0.13
1969	149	1.0	0.4	28	0.6	0.14
1970	206	1.3	0.6	29	0.6	0.12
1971	141	0.9	0.5	23	0.4	0.09
1972	122	0.7	0.4	20	0.4	0.08
1973	99	0.6	0.4	16	0.3	0.06
1974	90	0.5	0.3	24	0.3	0.08
1975	99	0.5	0.4	32	0.3	0.10
1976	104	0.5	0.4	23	0.2	0.06
1977	91	0.4	0.4	27	0.2	0.07
1978	67	0.4	0.3	17	0.1	0.04

a/Includes underground workers only.

b/Includes only strip mines.

Source: U.S. Department of Labor, Mine Stafety and Health Administration, "Injury Experience in Coal Mining," Tables 2 (1978), 7 (1972-77), and 5 (1961-1971).

frequency in 1977 is about half of what it would have been had fatalities continued to decline at the pre-act rate.*

Fatality frequencies in strip mines rose an average of 6.2 percent annually between 1961 and 1969 and declined by an average of 16.1 percent annually between 1969 and 1978. Thus, it appears that the act had a dramatic effect on mine safety. However, the act is probably only one of many reasons why strip mine fatalities have fallen. Another possible explanation is that many large mines with resources available to invest in safety have opened during the time period following the act's passage.

Nonfatal injuries show only limited improvement

Unlike the trend for fatalities, the trend for nonfatal disabilities in underground mines is erratic. Table 3 shows that since the act's passage, the number of disabling injuries has increased. However, injuries would be expected to increase with rising production and employment. The irony is that some of these additional workers were not hired due to expanding production but were hired to perform MSHA-required activities or to maintain production levels after the act reduced productivity. However, the act's effectiveness in improving mine safety is better demonstrated by examining the change in frequency with which all miners are likely to be injured. Table 2 also shows that the nonfatal injury frequency rises and falls throughout the period. Thus, it appears that MSHA was ineffective at reducing nonfatal disabilities. However, changes in reporting nonfatal injuries may help explain the trend. In 1974, and again in 1978, MSHA changed its reporting requirements so that mines had to report more injuries as disabling than they had in the past.**

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*We projected the trend in fatality frequency from the 8 years preceeding the act and compared it with the actual trend in the eight years after the act. In 1977 the projected frequency was 0.90 compared with an actual frequency of 0.44. Thus, had the pre-act trend continued the frequency in 1977 would have been twice as high.

**In 1974, MSHA required that all injuries except those requiring only first aid be reported. Before that, only lost-time injuries had to be reported. In 1978, MSHA regulations clarified the definition of lost-time injuries as those where the worker did not return to his regular job. Before this, injured workers returning to other jobs were not clearly required to be counted as having lost-time injuries.

Table 3

Improvements in Nonfatal Disabilities Since the Passage of the MSHA Act of 1969 Have Been Erratic

	Underground mines a/			Strip mines b/		
Year	Number of disabilities (note c)	Disabilities per million man hours	Disabilities per million tons	Number of disabilities	Disabilities per million manhours	Disabilities per million tons
1961	8,706	53	31	1,052	24	8
1963	8,576	54	28	1,099	24	7
1965	8,651	54	26	1,178	26	7
1967	7,730	50	22	949	22	5
1968	7,339	49	21	1,039	25	5
1969	7,840	52	23	967	22	5
1970	8,906	54	26	1,346	26	5
1971	8,967	58	32	1,564	27	6
1972	9,823	58	34	1,305	25	6
1973	8,818	51	31	1,208	21	5
1974	6,309	36	24	1,229	17	4
1975	8,170	39	29	1,714	18	5
1976	10,658	49	38	2,071	20	6
1977	10,991	53	43	2,246	19	6
1978	10,534	54	46	2,240	17	6

a/Includes underground workers only.

b/Includes only strip mines.

c/A nonfatal disability is any job-related injury resulting in permanent total disability--permanently and totally incapacitates an employee from any gainful occupation or the complete loss of both or any two of the following: hands, arms, legs, feet, or eyes; permanent partial disability--results in loss of any part of the body or any permanent impairment of functions; and temporary total disability--renders the person unable to perform a regularly established job on one or more days.

Source: U.S. Department of Labor, "Mine Safety and Health Administration Injury Experience in Coal Mining," Table 7 1972-1977; Table 5 1961-1971; and Table 2 1978.

MSHA's impact on the frequency of nonfatal disabilities in underground mines is unclear and deserves further study. Table 3 shows that MSHA's impact on the frequency of nonfatal disabilities in strip mines seems marginally greater.

How MSHA improved mine safety

The major way in which MSHA regulation improves safety is by preventing mine disasters. In the 8 years preceeding the act, 12 disasters killed 221 workers. In the 8 years following the act's passage, one half of the number of disasters killed 84 persons. Thus, both the frequency of disasters and the likelihood of fatalities are falling. This is because fewer rooffalls, fires, and explosions occur, and when they do, a smaller area of the mine is affected. Our analysis shows that MSHA regulations requiring increased roof support, ventilation, dust control, methane testing, and protection from machinery and electrical equipment are responsible for most of the reduction in the types of accidents causing disasters. In fact, the Administrator for Coal Mine Safety and Health felt that the five disasters caused by explosions since 1970 could have been avoided if the mines had fully complied with MSHA requirements. Also, deaths from black lung and other lung diseases caused by dust should decrease in the future due to MSHA's stringent ventilation requirements.

In contrast, the frequency of nonfatal injuries has not declined because MSHA cannot easily address the causes of these accidents. For example, in 1977 material handling, haulage, machinery, and slips and falls of miners accounted for 75 percent of all nonfatal disabling injuries in underground mines. Material handling alone accounted for nearly one third of these accidents. These types of accidents are primarily caused by human error. MSHA's Director of Education and Training reports that 85 percent of all industrial accidents are caused by unsafe acts. 10/

Coal companies have reported that less than 20 percent of all disabling injuries have been related to noncompliance with MSHA regulations. Improving supervisors' and workers' safety attitudes and behavior could reduce nonfatal accidents. This implies that MSHA might be more effective at reducing nonfatal disabilities if it spent more resources on educating and training workers. With the passage of the Federal Mine Safety and Health Amendments Act of 1977, Congress set a minimum safety training requirement.

Trade-off between productivity and safety

The results of our statistical analysis suggest a double trade-off between safety and increased productivity. Mines which push production to the point of being dangerous and likely to kill or severely injure workers are less productive. However, mines which make slight tradeoffs between production and safety--taking shortcuts--have a small productivity advantage.

Our results show that mines that incur more fatalities, permanent disabilities, and the most serious violations were less productive. The statistical relationship between fatal and permanently disabling injuries and productivity was not significant, indicating that a mine which has many serious injuries has no output advantage. Further, the statistical relationship between serious violations* and productivity was significant and indicated that dangerous practices actually reduce productivity.

However, our results also show that in 1977 a direct relationship existed between the number of temporarily disabling** injuries and productivity. On the average, a 50-percent reduction in temporarily disabling injuries would cause the output of an underground mine to decline by 6.5 percent. Thus, each additional underground injury avoided would cost 2.8 thousand tons of coal per year. A 50-percent reduction of minor injuries in surface mines would cause a production loss of 22 thousand tons of coal a year. As a mine expends more resources on safety, production suffers. Avoiding minor violations also had a detrimental effect on productivity. In fact, a 10-percent reduction in violations meant a 7.5-percent output loss. A mine that is pushing for higher productivity at the expense of safety would likely receive more violations.

While cutting corners may bring some productivity dividend, mostly at the expense of nonfatal but temporarily disabling injuries, those mines which are badly run kill and permanently disable miners and take a productivity loss.

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*The seriousness of the violation is measured in terms of "gravity points". The higher the number of gravity points, the more dangerous MSHA inspectors deemed the mine's practices.

**An injury which causes a miner to lose one or more days of work.

The MSHA regulations that hurt productivity and increase safety

The MSHA regulations that the coal industry blames for declining productivity are the same ones which are responsible for most safety improvements. Further, as long as mining practices required by these regulations continue, there will be a permanent productivity loss. The major regulatory areas that the coal industry states have caused the productivity decline are: roof support, ventilation and dust control, and mine environment monitoring.

Roof Support

Section 302 of the MSHA Act requires that operators have roof and rib control plans approved for all active underground roadways, travelways, and working places. Plans must be reviewed by MSHA at least semiannually. The most significant change in mining practices resulting from the act was the requirement that no person be allowed to work under an unsupported roof.

Coal operators contend that roof support regulations caused the productivity of continuous mining machines to decline. By forbidding miners to work under an unsupported roof, the continuous miner's advance was reduced to the machine's length, 20 feet. Some mines advanced as much as 90 to 105 feet without roofbolting, a commonly employed method of roof support, before the MSHA Act. Production time is lost when the continuous miner and roofbolting machines move in and out of place more frequently. Since roofbolting tends to be the slowest operation in the production process at the face, the effect on production is magnified. It takes about 2 to 3 minutes to put in an average roofbolt. A MSHA official who did not feel that additional roof control was a large cause of productivity decline pointed out that about 60 percent of all coal mines were roofbolted before the MSHA Act. However, the reduction in feet that can be advanced before bolting hurts productivity. MSHA officials feel that advance is limited primarily in Northern West Virginia and that many mines in other regions can advance mining machines more than 20 feet. However, officials at 75 percent of the underground mines we visited in Kentucky, Illinois, Ohio, and Virginia claimed that roofbolting regulations substantially reduced mining machine advance. MSHA's position is that the adverse effect on productivity is minimized by productivity improvements from fewer roof falls and injuries.

Increased roof support is probably a main cause of reduced fatalities. In 1977, for example, 41 percent of all underground fatalities were caused by roof and face falls, compared with 58 percent in 1967. The frequency of roof falls (per million manhours) has steadily declined from 0.51 in 1969 to 0.18 in 1977. The frequency of disablements due to roof falls has also declined from 9.8 in 1969 to 6.1 in 1977. However, fatalities and disabilities due to roof falls had been declining before the MSHA Act was passed. In the 8 years preceeding the passage of the act, deaths from roof falls declined by 7 percent annually. However, roof fall fatalities fell by 11 percent annually in the 8 years following the MSHA Act's passage. Projecting the trend in roof fall fatalities from the 8-year period preceeding the act and comparing it with actual trend also shows that the MSHA Act accelerated the decline in fatalities.* In all years after the act's passage, the actual roof fall fatalities are lower than what they would have been under the previous trend.

Although roof control regulations have adversely affected productivity, they appear to have accomplished their goal of reducing deaths.

Ventilation and dust control

American ventilation regulations are among the most stringent of any coal mining nation. The reduction of respirable dust to 2 mg./cubic meter of air, the requirement that 9,000 cubic feet of air per minute reach the last open crosscut,** and the requirement that a minimum of 3,000 cubic feet of air per minute pass within 10 feet of each working face*** require expensive main and auxillary fans. Many ventilation and dust control regulations also require labor-intensive activities. The reduction in available production time and the additional personnel hired as a result of these activities reduces productivity. The regulations reputed to cause the largest productivity decrease are: additional use of line brattice and its placement 10 feet from the face, requirements for additional entries, and immediate maintenance of

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*We projected the trend in roof fall fatalities from the 8 years preceeding the act and compared it with the actual trend following the act. In 1977, the projected frequency was 0.33, while the actual frequency was 0.18. The projected frequency was higher than the actual in all years after the act's passage.

**Prior to the act, standard industry practice for nongassy mines was 6,000 cubic feet of air per minute reaching the last open crosscut.

***No requirements for this before the act.

water sprays on mining machines. Other dust control regulations that coal operators felt reduce productivity are requirements for additional mine cleanup and rock dusting. Several mines reported adding one worker per section crew to perform each of these activities. While ventilation and dust control regulations have hindered productivity, the benefits of the regulations in terms of reduced fatalities and disabilities caused by lung diseases, explosions, fires, and suffocation appear to be great.

Line brattice or other equally effective devices are required by section 303(c) of the MSHA Act to be installed and maintained to ventilate working faces and remove dust, gases, and fumes. A brattice is a flame resistant jute or plastic curtain hung from the roof to the mine floor to channel air movement. Line brattice must be placed no more than 10 feet from the working face to ensure proper ventilation. Gassy mines may be required to install brattice even closer to the face.

Coal operators are concerned that using line brattice throughout the mine, and particularly so close to the face, interferes with production. Brattice makes it difficult to maneuver machines and cuts down on visibility. Brattice further reduces the advance of a continuous miner below 20 feet since the curtain must be readjusted for every 10-foot advance. Workers must also stop production immediately to repair a damaged or fallen line brattice. According to Straton, the resulting loss in available production time due to installing and maintaining brattice is 26 minutes, or 7 percent of shift time. 11/ One large Illinois coal mine reported that it employed four additional bratticemen to comply with the MSHA Act. Line brattice also cuts down on the speed and haulage capacity of vehicles that must pass through them.

A MSHA ventilation expert agreed that line brattice hinders production and acknowledged that some nongassy mines did not use brattice at all before the MSHA Act. However, this same official was able to provide us with engineering evidence that it is necessary to place brattice 10 feet from the face to meet ventilation requirements.

Additional entries are required by the MSHA Act. This requirement calls for separate splits of air for each working section and for the conveyor belt to be separate from the intake and return air. Compliance with these regulations often required mines to develop additional entries or air channels.

In addition to hindering mine expansion, additional entries require extra workmen to build and maintain concrete stoppings.* Additional stoppings will be required to extend the entry as the mine expands. Thus, by requiring extra personnel, developing entries reduces productivity. One large Illinois coal mine increased its employment by about 4 percent by hiring additional workers for building stoppings and performing other safety functions. Also, additional entries may increase the amount of time it takes shuttle cars to move between mine faces, thus slowing up production.

According to an MSHA ventilation expert, isolating the conveyor belt from mantrips and escapeways has reduced fatalities from fires to zero since 1970. In fact, during the 9-year period preceeding the passage of MSHA, more than twice as many workers were killed due to mine fires than were killed during the 9 years following the MSHA Act's passage. The conveyor belt was a primary cause of mine fires in the 1960s. Isolating airways from the belt thus prevents the spreading of the fire to other areas of the mine and the resulting fatalities.

While hindering productivity slightly, additional entry requirements have all but eradicated disasters due to fires in the mine.

Watersprays are generally required to comply with section 304(b) of the MSHA Act. Section 304(b) requires the use of water or an effective substitute to wet coal dust on the ribs, roof, and floor, particularly within 40 feet of the face. This reduces dust dispersion and minimizes the risk of coal dust explosions. MSHA may set the velocity of water flow required in mines with excessive respirable dust and require operators to have enough nozzles working to meet that velocity. A frequent coal industry complaint is that nozzles often clog up with dirty water and coal dust. Machine operators are then required to stop production and clean and replace nozzles which reduces productivity. According to Straton, 11 minutes, or 3 percent of available production time, is lost due to repair of water spray nozzles. 12/

MSHA's position is that mine operators can avoid the adverse effects on productivity by having a good maintenance program. A MSHA ventilation expert stated that simple maintenance could keep the required number of nozzles operating at all times. According to MSHA, it takes 10 minutes to clean 3 or 4 sprays and they must be cleaned every 2 to 3 hours

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*Stoppings are permanent airtight masonry walls to direct the flow of air.

or once per shift depending on the type of nozzle. Further, it takes 10 minutes to replace one nozzle and 30 minutes to replace a number of them. It is also MSHA's position that ample downtime is available during a shift to do this. Also, the Bureau of Mines has developed a water spray system that traps dirt particles and can be easily cleaned. As of 1977, the new system became commercially available at a cost of about $800. By mid 1977, coal companies had purchased 75 units.

Increased ventilation and dust control reduce fatalities substantially. The most important benefit of improved ventilation and dust control is that it should substantially reduce the number of black lung victims in the future. The immediate benefits of ventilation and dust contol regulations are that they have helped to reduce the number of disasters and fatalities due to explosions, fires, and suffocation. This is because dust regulations control the spread of dust while ventilation and clean-up requirements prevent dust, methane, and other gases and combustible materials from accumulating. Thus, the risk of dust or methane ignitions and explosions and asphyxiation is reduced.

Between 1970 and 1977, there were one half the number of disasters resulting from explosions than there were in the comparable period before the MSHA Act was passed. The fatality frequency varies widely from year to year, depending on the number of miners that were trapped during an explosion. This means that a smooth trend showing the decline in fatalities caused by explosions is impossible. However, table 4 shows that fatalities and nonfatal disabilities per million manhours due to explosions have steadily decreased since 1969. Since 1973, disabilities due to explosions have practically disappeared.

Fatalities and disabilities due to fires have also declined dramatically to the point where fires are no longer a significant cause of injuries in mines. Ventilation requirements accomplished this by reducing ignitions and preventing fires.

Deaths and disabilities due to suffocation have also decreased since the act's passage. In the 8 years preceding passage, 15 mine workers died from suffocation compared with 2 workers in the 8-year period following passage. Further, twice as many disabilities due to suffocation occurred between 1962 and 1969 than between 1970 and 1977.

Mine environment monitoring

Sections 202 and 303 of the MSHA Act prescribe tests that operators must make for methane, dust, and other hazards. Coal operators have stated that MSHA's testing required hiring additional personnel to test, repair, and maintain testing equipment. Besides more frequent testing, the act requires that certain areas of the mine that were not examined before the act be examined for hazardous conditions. A manager of a large coal company we surveyed stated that it had to hire nine extra workers, or about 8 percent of its work force, to examine parts of the mine not formerly tested. Also, testing and reporting requirements distract foremen from supervising production. Available production time is also reduced by the time required for start-of-shift exams. Straton estimates that start-of-shift exams result in a loss of 13 minutes or 3 percent of available production time per shift. 13/

Methane monitoring is the testing regulation that mine managers felt hurt productivity in underground mining the most. Methane must be tested for at the face before any electrical equipment enters the working place to cut coal, and at least every 20 minutes during the operation of electrical equipment. Methane tests require a certified person (generally supervisors or mining machine operators). An automatic methane monitor must also be installed on all electric face cutting or loading equipment. This de-energizes the equipment if the methane content becomes greater than 2 percent by volume or if the monitor itself fails.

Of perhaps greatest concern to coal operators are the adverse productivity impacts of the automatic methane monitor. When the automatic monitor fails it automatically shuts down the mining machine, a factor which coal operators resent.

MSHA officials stated that methane monitor failure is not nearly as big a problem now as it was when monitors were first required. This device was an outgrowth of MSHA's requirements; removing the "bugs" took several years. The failure rate, which had been once every 4 to 5 shifts, is currently 10 to 20 times less. MSHA also feels that the current problem is primarily limited to d.c.-powered monitors, used mostly in smaller and older mines. Increased maintenance will not reduce failures in these mines because these failures are mostly caused by problems with the power supply.

Table 4

Injuries due to Explosions in Underground Mines Have Generally Declined Since the Passage of MSHA Act of 1969 (note a)

	Number of fatalities from coal and dust explosions	Fatalities from explosions per million manhours	Number of nonfatal disabilities from coal and dust explosions	Nonfatal disabilities per million manhours from explosions
1961	26	0.16	23	0.14
1963	36	0.23	32	0.20
1965	19	0.12	20	0.13
1967	12	0.08	32	0.21
1968	88	0.59	18	0.12
1969	1	0.01	13	0.09
1970	41	0.25	14	0.09
1971	2	0.01	13	0.08
1972	5	0.03	14	0.08
1973	2	0.01	2	0.01
1974	0	0	3	0.02
1975	0	0	4	0.02
1976	23	0.11	3	0.01
1977	4	0.02	1	0.01
1978	0	0	6	0.03

a/Includes underground, shaft, and slope areas for all underground mines.

SOURCE: U.S. Department of Labor, Mine Safety and Health Administration, "Injury Experience in Coal Mining," Tables 13 (1978); 11 (1972-77); and 9 (1961-1971).

Once the monitor fails, MSHA officials pointed out that a loss in available production time of 30 minutes to 1 1/2 hours should occur. However, if a mine does not have spare parts on hand, the loss of production time could be much longer. Thus, management could avoid lengthy delays by keeping spare parts. During the act's initial years, there were occassional shortages of spare parts; however, MSHA feels that this problem has been alleviated.

Operators of "gassy mines" we surveyed generally felt that the testing requirements for methane were fair. However, operators of "nongassy mines" complained about the loss in production and annoyance of frequent methane tests. (In 1976, for example, only 18 percent of all underground coal mines registered any methane.)

Mines were classified as being gassy or nongassy before the act's passage, and different mining practices were employed for both. For example, only gassy mines installed line brattice and maintained explosion-proof equipment. However, the 1969 act declared that all mines were gassy and required compliance with the same stringent methane-testing procedures. Thus, nongassy mines, representing 82 percent of all underground mines, suffered a productivity loss from performing additional safety activities previously required only in gassy mines.

Our statistical results lend some support to this conclusion. We found a very small productivity difference between gassy and nongassy mines in 1977. This indicates that gas testing and other act-related requirements have decreased the productivity differences between gassy and nongassy mines to a very low level. No data were available, however, to demonstrate productivity differences between gassy and nongassy mines before the act. Also, operators of nongassy mines felt that miners stop taking methane monitoring seriously when they test every 20 minutes and never find any gas.

In the past, explosions occurred in mines that were classified as "nongassy," however.* Between 1961 and 1970, 27 people were killed and 37 injured in 30 explosions in those "non gassy" mines. 14/ Thus, it appears that the Congress considered all mines to be gassy and subject to the same stringent testing requirements. However, MSHA will make certain allowances for nongassy mines having methane monitor failures on a case by case basis. MSHA may allow production to continue while the methane monitor is being repaired, but methane has to be tested for by hand every 5 minutes. Methane testing has undoubtedly helped prevent methane accumulation and thus reduced the risk of explosion.

Dust sampling is required by MSHA regulations to be conducted in each working section of underground mines on 10 consecutive production shifts. If in compliance, 5 samples are taken during the following month and thereafter every two months. If the sample exceeds 2.0 mg/m^3, ten additional samples are taken. In addition, individual miner samples were required from all underground miners every 3 to 6 months. MSHA regulations, which became effective on November 1, 1980, replace underground individual sampling with area sampling and reduce samples to five every two months. Proposed regulations

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*Before the 1969 Act, mines were classified as "gassy" or "nongassy" depending on whether they liberated above or below 0.25 percent volume of methane.

might also reduce surface sampling substantially. Surface mines were sampled every 6 or 12 months if in compliance. MSHA also collects samples during its inspections, at least four times a year. MSHA currently collects 50,000 to 60,000 dust samples each year, while the coal industry collects 500,000 to 600,000.

Coal operators raised the point that the volume of dust samples which MSHA requires necessitated hiring additional personnel to do the sampling. MSHA, however, recognized the need for reducing the volume of required samples and is attempting to reduce them by one third for surface and underground mines. MSHA's new area sampling regulations are expected to lower the number of samples operators must collect annually to 350-400,000. Also, MSHA is considering implementing a method of ensuring dust levels are in compliance whereby the frequency of testing could be dramatically reduced. MSHA would set parameters for such items as volume of water spray necessary to meet the required dust level for the mine. If the parameters are met, the dust level would then be assumed to be correct.

The adverse productivity impacts of enforcement are diminishing

Coal companies have repeatedly stated that enforcement of the MSHA Act disrupts production, thereby reducing productivity. Operators have stated that the following aspects of MSHA's enforcement program have disrupted production:

--Inspections.

--Issuance of violation notices unrelated to safety.

--Withdrawal orders .

--Abuse of the safety hotline.

--The requirement that mines comply with regulations that are not presently technically feasible.

During the initial years of enforcement some of the coal industry's complaints were justified. However, as enforcement became more routine, our evidence shows that the complaints became less justified. Further, our research shows that enforcement of the act has significantly improved mine safety.

Inspections

Section 103 of the MSHA Act authorizes frequent inspections of coal mines to locate dangerous conditions, determine compliance with the act, and investigate accidents. Underground coal mines must be completely inspected at least four times a year. Mines may also receive inspections to monitor the abatement of hazardous conditions; special roof control, ventilation, or electrical inspections; and spot inspections. If a mine liberates large amounts of methane or has hazardous conditions, the mine will receive one inspection every 5 to 15 working days. Large mines often have inspectors on their premises daily because of the large numbers of workers exposed to the hazards of underground work and because it takes a long time to inspect a mine. In 1973, an Accident Prevention Program was established for daily inspection of those mines employing over 150 workers and having a high injury rate.

Coal mine operators we surveyed complained that the MSHA inspectors' activities disrupt production. According to Straton's industry survey, the average amount of production time lost per section inspection was 71 minutes. 15/ A superintendent of a large coal mine in Illinois told us while an MSHA inspector is in a section, it loses one half of its production.

Our statistical research shows that while inspections caused productivity decline in the initial years of the act's passage, it is not currently a significant cause of continued productivity decline. This may be partly due to the decline in the number of MSHA inspections after 1973. We found a direct but small relationship between the number of inspection days and productivity in 1977. A 10-percent reduction in the number of inspection days would improve underground productivity by only 1.5 percent. The act had its largest impact on underground productivity between 1970 and 1973--years when the largest growth in inspections occurred. An examination of past MSHA inspections shows that their numbers increased from 9,737 in 1970 to 71,763 in 1973, and then declined slowly to 35,327 by 1977. A similar trend was shown for inspections per mine and per ton of coal produced. Since 1974, however, with the leveling off of enforcement activity, the act became less of a factor in the continuing decline in productivity. By 1974, the majority of underground mines had adjusted to MSHA regulations. Increased enforcement, however, could result in further productivity losses though one would not expect as severe a drop as what occurred in the earlier years. The recent Oak Ridge Associated Universities' study on productivity in coal mining supports these results. Based on State-level data, the Oak Ridge study showed that inspections brought about a decline in productivity, but the impact peaked in 1973. 16/

Coal operators and workers offered many reasons why inspections disrupt production. For example, the inspector may order immediate equipment repair or mine clean-up or idle machines to examine them. MSHA's official response is that inspectors are instructed to avoid shutting down producing equipment if at all possible. This is not always possible due to time limitations.

Coal companies also complained that different inspectors have different operating and maintenance requirements. Thus, they are forced to frequently change procedures, which interferes with production. This may have been a problem during the initial years of enforcement, but MSHA feels it is not a significant problem now. MSHA's Administrator for Coal Mine Safety and Health stated that MSHA rarely receives complaints about this any more. A manual defining precisely what constitutes compliance with regulations is issued to inspectors and made available to mine management and workers. Further, inspectors receive substantial training on the meaning of regulations. In addition to 12 weeks of initial training, inspectors receive 2 weeks of annual retraining to keep them up to date on regulatory changes. Also, although inspectors are supposed to be rotated every 6 months, MSHA has been trying to keep them with a mine for 1 year. During that time, electrical and ventilation specialists may appear at the mine for special inspections, but the mine generally has one main inspector.

Inspections may also disrupt production by removing the foreman and other experienced workers from production. The foreman generally accompanies the inspector on his tour and so cannot supervise production. The act also provides that a miner's representative be allowed to accompany the inspector on his tour. This often removes an experienced worker from production. Finally, workers themselves may slow up or stop producing while an inspector is present out of fear of violating the act.

The disruptive effect of inspections may be substantial, considering their frequency in some mines. MSHA's Administrator for Coal Mine Safety and Health reports that a complete underground inspection can take up to 3 months, while spot inspections can take 8 to 9 hours. Large, hazardous mines usually have an inspector on the premises daily, so these mines may have suffered a large productivity loss. By contrast, surface mine inspections take from 3 days to 3 weeks. Thus, the impact of inspections on productivity in surface mines should be less severe.

However disruptive to production, inspections help reduce mine fatalities. A recent study by Louise Julian concluded that the increase of one inspection for each mine decreases the industry's number of fatalities and nonfatal injuries in a year by 4 and 52 respectively. 17/ Boden's study of 539 underground mines concluded that a 50-percent increase in the Federal inspection rate would reduce fatalities by 11, disabling injuries by 2,400, and nondisabling injuries by 3,800 per year. 18/

We conclude that inspections do disrupt production, particularly during the years the regulations were first implemented. However, inspections are an important tool in improving mine safety. Further, our statistical results show that abolishing all MSHA inspections of underground mines would improve output by only 15 percent.

Violations

In 1977, MSHA issued 95,662 violation notices to underground mines and 34,253 to surface mines. The number of violations issued per inspection has grown every year since 1973. Once a violation notice is issued, the operator is assessed a civil penalty or is subject to criminal sanctions.

Coal operators expressed their concern that MSHA is citing them too often for violations which bear little relation to the causes of accidents. They feel the violation and appeal process distracts management from concentrating on supervising production while not significantly contributing to mine safety. Further, holding corporate representatives criminally responsible for the safety of miners increases the difficulty in hiring experienced mine foremen.

In testimony before the Labor Standards Subcommittee, House Committee on Education and Labor, the National Coal Association and Bituminous Coal Operators Association complained that violations MSHA issues bear little relation to mine safety. They pointed out that 72 percent of all underground safety violations in 1975 were for activities that accounted for less than 10 percent of the total number of fatalities occurring during the previous 7 years. 19/ Other evidence, however, shows a greater relationship between the causes of violations and safety. MSHA's policies improve safety primarily by preventing disasters. The causes of disasters and conditions receiving violation citations are strongly related. Between 1959 and 1977, 90 percent of the disasters which occurred were caused by fires, suffocations, and explosions. MSHA's Administrator for Coal Mine Safety and Health stated that MSHA inspectors are told to concentrate on roof control, ventilation, combustible materials, and fire prevention--all areas directly related to the primary causes of disasters. In 1977, as in the previous 2 years, the most frequently cited violations were for electrical equipment and fire protection, ventilation, combustible materials, roof support, and miscellaneous causes. These categories accounted for 89 percent of all violations in 1977.

The relationship between the causes of nonfatal accidents and violations seems to be, as the coal industry asserts, tenuous. Nonfatal disabilities in underground mines in 1977, as in 1967, were primarily caused by materials handling, haulage, and machinery. These categories accounted for 60 percent of all nonfatal disabilities. Violations in these categories were issued less frequently because most of these accidents are caused by human error, and workers cannot usually be cited for violations. Thus, MSHA's enforcement is more effectively directed to reducing fatalities than nonfatal injuries.

Some coal operators also claimed that MSHA cites them for trivial violations. MSHA's Administrator for Coal Mine Safety and Health stated that complaints of this nature came primarily from small operators who were hurt by payment of fines. Cases of MSHA's enforcing "trivial" violations can undoubtedly be identified. However, differences between the coal industry's and MSHA's positions are primarily caused by differences in trade-offs between acceptable risks of accidents and production. MSHA's mandate is to reduce the risk of injury to miners, while operators are concerned with minimizing production costs. Therefore, MSHA may cite violations where the risk of injury appears small from the operator's viewpoint when compared to the production costs of compliance.

Our research shows that the majority of violations do not now adversely affect productivity. In fact, in 1977 increasing the number of violations would have a positive effect on productivity. As noted earlier, a mine which places more importance on production versus safety will likely have a larger number of violations.

Further, violations may not have been taken seriously enough by coal operators to hurt productivity. Coal companies may have written off fines as a cost of doing business because the fines have been small.* For example, mines were fined only $50 to $100 for violating the dust standard, one of the most important regulations. Our results further indicate, however, that mines which continually have the most serious or dangerous violations pay a productivity price. A strong negative relationship was found between productivity and the number of

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*MSHA revised its fine assessment procedures in 1977 and the level of fines was increased.

gravity points received by a mine.* Those mines which, because of bad management, take greater risks and operate under the resulting hazardous conditions pay a substantial penalty in terms of lost productivity.

We conclude that the majority of violations are viewed by mine management as a cost they must incur for increased production. Violations received for taking less severe chances on short-cuts do not adversely affect productivity. However, those mines which are guilty of the most grave or serious violations suffer a loss in productivity for such unsafe actions.

Withdrawal orders

According to Section 104 and 107 of the act as ammended, an inspector can order miners withdrawn from a mine or any of its sections if he finds: (1) an imminent danger to life or health, (2) failure to rectify a violation within a specified time period, (3) an unwarrantable failure (that the operator knew or should have known about the dangerous condition and did not correct it), and (4) repeated violations. Miners idled by withdrawal orders must be paid regular wages for at least one shift. Mines are reopened when the inspector deems the dangerous condition has been abated. Operators who challenge withdrawal orders before the Federal Mine Safety and Health Review Commission or the U.S. Court of Appeals receive no compensation if the order is reversed.

Withdrawal orders may hurt productivity in two ways. Workers still receive compensation and are thus counted as working, even though production is shut down during the shift. Secondly, withdrawal orders issued for part of a shift reduce available production time.

Coal operators expressed concern that the increasing number of withdrawal orders issued are partly responsible for the decline in productivity. One underground mine in Illinois was closed from 2 hours to 2 weeks for such causes as shuttle car in violation (4 hours), no calcium chloride spread on water (3 hours), and the need to rock dust the conveyor belt (1 day). A study prepared for DOE by Management Engineers, Inc., lends limited support to the industry's contention. The study concluded that there is a relationship between the growing number of withdrawal orders and productivity decline but could not determine whether it was a causal relationship. 20/ We were

*Gravity points are used by MSHA as a measure of the seriousness of a violation when assessing fines.

unable to statistically determine the effect of withdrawal orders on productivity because MSHA is only beginning to computerize withdrawal order data. Table 5 shows the growth in withdrawal orders and the average number of withdrawal orders issued during inspections. The likelihood that mines would receive withdrawal orders during inspections was high during the act's initial implementation, dropped off in 1972, and then gradually rose. The coal industry feels that the growth since 1972 is primarily due to an expanding definition of what constitutes grounds for withdrawal. Coal industry representatives stated that the definitions of imminent danger and unwarrantable failure are overly broad. Since 1969, Administrative Appeal Board decisions have redefined "imminent danger" and "unwarrantable failure" so as to make it easier for inspectors to issue withdrawal orders. 21/ However, these decisions were directed at hazardous mines and mines where management does not show adequate concern for worker safety.

While inspectors are issuing more withdrawal orders, a few mines may be receiving them repeatedly. Although no data is available to support this, MSHA officials agree that withdrawal orders are concentrated in a few "problem" mines in each district. Thus, increasing numbers of withdrawal orders may affect productivity in only a small segment of the coal industry.

The coal industry's other major criticism of MSHA's mine withdrawal policy is the delay in sending inspectors to reexamine mines and terminate the orders. MSHA's Administrator for Coal Mine Safety and Health said that while this probably does happen occasionally, most withdrawal orders last for one shift or less and affect only one section of a mine. No data were available to support this. Conditions involving dust standard violations, however, can take a long time to correct, and mines with inadequate ventilation systems may have to endure lengthy production disruptions.

The withdrawal order is an important enforcement tool since fines are small and can be written off as a cost of doing business. These orders disrupt mine operations but are necessary and effective safety precautions. In 1976, for example, over one quarter of the imminent danger withdrawal orders were issued after explosions in the mine. Further, MSHA asserts that withdrawal orders are concentrated in hazardous mines and those mines continuously failing to comply with MSHA regulations. However, no data exist to corroborate this.

Table 5

Number of Withdrawal Orders Issued Since 1970

Year	Total number of withdrawal orders	Number of withdrawal orders per inspection
1970	1,493	0.15
1971	4,390	0.17
1972	2,804	0.04
1973	3,312	0.04
1974	4,851	0.06
1975	6,147	0.08
1976	5,829	0.09
1977	4,897	0.09

Source: U.S. Department of the Interior, Mining Enforcement and Safety Adminisitration (currently U.S. DOL--MSHA) Annual Report and Achievements Appendices 1970-77, and Dick Rose, U.S. Department of Labor, Mine Safety and Health Administration. (Withdrawal Orders)

Hotline abuses

One tool that MSHA uses to learn of violations is a confidential telephone hotline. Some coal companies have complained that miners are using the hotlines to harass management by making complaints that cause extra inspections. MSHA's Administrator for Coal Mine Safety and Health feels that this is an erroneous criticism because the hotline receives few calls and even fewer that result in actual violations. In 1978, MSHA received only 139 calls, most of which were on matters totally unrelated to the mine's compliance with MSHA regulations. For example, MSHA received many calls about employment opportunities. Further, union members can walk off the job if they feel conditions are unsafe. It is possible that the hotline may have been abused in isolated cases, but this generally does not seem to be a significant problem.

Technically infeasible requirements

Coal operators complain that some MSHA regulations require technology which is exotic or unavailable. Since MSHA enforces these regulations, the resulting inspections, violations, withdrawal orders, machine modifications, and paperwork reduce productivity. The two regulations that mine managers cite most frequently are requirements for cabs and canopies and mine illumination.

Cabs and canopies are steel roofs and sides which protect mining machine operators from collapse of roof, face, or rib. On January 1, 1973, protective cabs and canopies became mandatory on all mobile face equipment used in mines 72 inches and above in height. By 1978, coal mines of all seam heights had to comply with this regulation. Mines with 60 inch or higher seams have generally not had problems in fitting cabs and canopies to their machines. However, 45 percent of production and 41 percent of mines have seams under 60 inches. Low coal and narrow work spaces leave little room to attach these devices. One coal mine official told us that in the last 4 years, his mine experimented with 88 different canopy designs. He also said that the work required to install and test these canopies had substantially reduced productivity.

Other problems with using cabs and canopies in low coal are that they impair the machine operator's vision, restrict movement, and cramp and tire the operator. Thus, some mine managers have had to deal with worker resistance to the cabs and canopies, further hindering productivity.

Recognizing problems with installing cabs and canopies in low coal, MSHA suspended requirements for coal mines with 42-inch seams or less. Further, coal operators have received substantial Federal assistance in complying with cab and canopy regulation. MSHA has provided some technical assistance to mines to help them retrofit machines. For example, during 1973, the first year cabs and canopies were required, the Roof Control Group of MSHA's Pittsburgh Technical Support Center analyzed about 60 cab or canopy designs and 120 redesigns for coal mine operators and equipment manufacturers. The Bureau of Mines has also assisted operators and manufacturers to comply with cab and canopy regulations. The Bureau estimates that 20 percent of the total canopy designs now being used have come from this research.

While requiring cabs and canopies in low coal may have disrupted mining operations, it may also have reduced fatalities and disabilities due to roof collapse. However, an examination of available data suggests that the injury prevention benefits of cabs and canopies require further study.

The 1974 union agreement requirement for helpers on face equipment may have caused an increase in the number of fatalities due to roof falls. One would expect to see a steady decline in injuries due to roof falls since 1975 as lower and lower seam mines were required to comply. However, since 1975, the downward trend in fatalities and disabilities per million manhours due to roof falls has not been steady. MSHA, however, reports that the installation of cabs and canopies saved the lives of at least 114 miners since 1974. 22/

Illumination requirements were also felt by coal operators to be a hindrance to productivity. Final regulations promulgated in 1976 required lights on all face equipment. Difficulties in retrofitting mining equipment and some worker opposition to the lighting distract management from supervising production and may take machines out of production.

Retrofitting machines to contain lights is particularly difficult in low coal. In low coal there is little room to attach lights to the machine's surface, and they are easily smashed if not recessed. Existing machines, however, do not have recesses where lights can be attached. Finally, some miners do not like the lights because they cause glare. This may be especially true in low coal or if management has not placed the lights in their correct positions.

MSHA has, again, provided substantial technical assistance to equipment manufacturers and coal companies to design and install lights. Some of these activities included developing technical papers, exhibits, testing proposed systems, and assisting coal operators and equipment manufacturers in designing and installing lights. The Bureau of Mines also helped develop and test lighting system designs. Further, the United Kingdom has for years required that mines be illuminated without major problems. Thus, it appears likely that the illumination problem will be ameliorated over time.

Lighting the mine may help reduce the disabling and other nonfatal injuries that MSHA has not had much success in preventing thus far. The four major causes of nonfatal disabling accidents in 1977 were material handling, haulage, machinery, and slips of persons, which accounted for nearly 75 percent of these injuries. Unlike roof falls and explosions, those accidents are primarily caused by worker error. Thus, improving workers' ability to see the work environment may eliminate some of these accidents.

Increased safety training might reduce disabling injuries

MSHA's regulatory and enforcement efforts have not reduced disabling injuries because these injuries are mainly caused by unsafe acts. Two ways of combatting unsafe acts are citing workers for violating MSHA regulations and increasing safety training. MSHA has no authority to cite workers for non-compliance with the exception of smoking underground. MSHA and its predecessors have been involved with safety training since the 1950s, and since the 1977 MSHA Act amendments have required operators to provide a minimum amount of safety training.

Increased safety training might improve workers' safety attitudes and behavior, thereby reducing the number of unsafe acts committed. A Westinghouse study prepared for the National Institute for Occupational Safety and Health showed that workers in low-accident coal mines exhibited "safer" behaviors than those in high-accident mines. For example, workers in low-accident mines are more likely to wear safety glasses, report hazards and accidents, and are less likely to bridge circuit breakers when overloading occurs.

While all mines currently engage in safety training, there is evidence that better training may lower accident rates. The Westinghouse study showed that workers in low-accident mines were more likely to rate training as adequate than workers in high accident mines. 23/ Not only the quantity of training but also the subjects taught and the teaching methods used determine its adequacy. Mines with adequate training in how electrical systems work; dealing with hazards such as gases, coal dust, and noise; and how tools and equipment work had significantly fewer accidents than mines with inadequate training in these areas. On-the-job experience, group discussion, and close supervision were found to be the most effective training methods.

Current safety and occupational training appears to be inadequate. A study by Emory Ayers Associates, Inc., revealed that training programs are not working because management lacks commitment to the programs. 24/ The study claims that management does not provide sufficient time, has too few qualified instructors, has inadequate training facilities and equipment, and suspends programs before completion. Another reason why training may be inadequate is that foremen may not supervise workers closely enough. The Westinghouse study found that the most effective kind of training is on-the-job, with close foreman supervision. 25/ Thus, even if sufficient classroom training is provided, workers may still not receive adequate training. Another reason why training programs may fail is that they often do not include supervisors. The Westinghouse study showed that low-accident mines were ones where foremen exhibited "safety-conscious" behaviors such as wearing respirators in dusty conditions and encouraging workers to operate safely and not cut corners. 26/ Thus, training supervisors would improve their ability to instruct workers and would better enable them to promote a more "safety-conscious" attitude among miners.

The Federal Mine Safety and Health Act Amendments of 1977 require that each mine operator have an approved health and safety training program. To be approved, a program must provide the minimum training required by the act. The act required that new underground miners with no experience receive at least 40 hours of training in miners' rights, use of the self-rescue device, hazard recognition, first aid and emergency procedures, basic ventilation and roof control, walk around training, and the health and safety aspects of their assigned task. All miners are required to receive 8 hours of refresher training annually and miners assigned a new task or moving to a new mine must also receive additional training. However, MSHA's Director of Education and Training does not feel that these minimum requirements are adequate. He stated that 1 or 2 weeks a year of on-the-job training would be more appropriate. These suggested amounts are small compared to training required for European miners. For example, a mining machine operator in the United Kingdom will have received 140 days of instruction and 60 days of close supervision. While this is considered to be "occupational" training, it teaches workers to perform their job safely.

Some large operators may train well above the required minimum. Further, MSHA has a State grant program so that it can help provide training to small operators. However, given that a United Mine Workers poll showed that 41 percent of the new workers in the early 1970s received no training, there still may be many mines that stick to the minimum requirements. 27/ The coal industry's provision of more on-the-job safety training for miners and supervisors could significantly lower disabling injuries. Therefore, a change in the statute to strengthen the minimum requirements would be worthwhile.

Transfer of safety technology to industry

Federal coal-mining technology research agencies and coal mining equipment manufacturers are not adequately transferring technologies which would reduce the adverse productivity impact of safety and health regulation to the industry. Coal operators are not adopting these technologies because they are uncertain of MSHA's willingness to alter regulations or grant petitions for modification to companies using the new technology. MSHA is involved in selecting new Bureau of Mines safety technology research projects. Thus, MSHA is likely to accept the technology once it has been developed. However, it is unclear whether MSHA would grant petitions for modification to coal companies from productivity-reducing regulations despite their using the new safety technology. Also, neither equipment manufacturers nor the Bureau of Mines are adequately testing and commercializing the new technologies.

Bureau of mines safety technology

Primary Government responsibility for performing and funding safety technology research and development lies with the Bureau of Mines in the Department of the Interior. Funding for coal mine safety and health research is substantial. The Bureau of Mines spent $29 million in fiscal year 1977, and planned to spend $88 million for fiscal years 1978 and 1979 coal mine health and safety research. Indications are that coal mining equipment manufacturers spend minimal amounts on safety technology research. A study prepared for DOE by Bituminous Coal Research, Inc., reported that in 1978, coal equipment manufacturers spent only about $3 million on health and safety research. 28/

The Bureau of Mines has funded numerous safety projects that might reduce the adverse productivity impacts of MSHA roof control, ventilation and dust control, and mine environment testing regulations. The greatest productivity improvements appear to be from projects that will allow continuous miners to advance more than 20 feet before bolting and will allow remote movement of line brattice. Moving brattice remotely reduces the length of pauses to adjust brattice as the continuous miner advances each 10 feet.

In fiscal year 1977, the Bureau spent $8.4 million on roof control, and planned to spend $9.7 million and $13 million in fiscal years 1978 and 1979, respectively. Some Bureau-funded projects to allow continuous miners to advance more than 20 feet before bolting, include movable roof support systems and remote mining systems which place the worker further back and allow greater machine advance. A Bureau of Mines official reported that remote control systems might place the operator 40 feet back, thereby doubling the distance that continuous miners may advance before bolting. The Bureau is also funding projects to reduce dust generation and promote the use of longwall miners because of their superior roof support systems. In fiscal year 1980, the Bureau expects to spend $4 million for longwall mining health and safety research. The Bureau is also funding research on detecting roof problems, safer designing of mines, and improving roof support technologies. However, unless MSHA allows mining machines to advance more than 20 feet before bolting, these projects will produce only small productivity benefits.

The Bureau of Mines spent about $4 million in fiscal year 1977 on dust and methane control in coal mines. In fiscal year 1979, the Bureau planned on spending $6.2 million for these purposes. While the Bureau has funded projects to improve dust collection from mining machines, most of its research is directed at reducing dust generation. Improved dust control would allow the use of a blower ventilation system, which is a more effective methane control method than the currently used exhaust system. Theoretically, more effective methane control should allow operators to move the line brattice further back from the face. However, if there is uncertainty as to whether or not MSHA will permit this, technologies such as dust collectors are unlikely to improve productivity. The Bureau has also funded projects which would allow remote movement of brattice. Considering Straton's estimate that 7 percent of available production time is lost due to installing and maintaining brattice, this project could significantly improve productivity. However, a Bureau official reported that the coal industry did not adopt this new technology because of maintenance problems and lack of worker acceptance. Given the large potential productivity benefits, the Bureau of Mines should renew its effort in this area.

The Bureau of Mines has also funded research to make dust sampling easier, thus reducing the time supervisors spend away from production. The projects funded would improve present dust-sampling methods, potentially allowing a reduction in sampling frequency, or would make dust sampling more remote. The Bureau has a long-range program to develop a machine-mounted dust monitor. The Bureau has also funded equipment manufacturers to develop a more reliable methane monitor. However, none of these projects should have large productivity benefits, since present dust sampling and automatic monitor failure are not hurting productivity substantially.

Often, coal operators do not use new safety equipment even if it also improves productivity. This may be because its cost exceeds productivity benefits, because uncertainty over whether MSHA will allow them to reap the productivity benefits, and because of worker and management resistance.

Coal operators may not purchase the equipment because they feel that the amount of productivity improvement does not warrant the increased equipment cost. This was probably true for the more reliable methane monitor. One of the equipment manufacturers working on this project reported that the monitor it developed was too expensive to interest coal operators.

Coal operators may also fear that MSHA will not grant them petitions for modification or alter productivity-reducing regulations, such as the reduction of continuous miner advance to 20 feet, in spite of their using better safety technology. Operators should be granted modifications if the alternate method provides the same degree of protection or if complying with the regulation reduces mine safety. However, uncertainty comes from MSHA's case by case determination of whether the mine meets these criteria. This uncertainty is magnified by MSHA's policy to allow each district wide latitude in making modification decisions. In fact, given that each mine has its own roof control and ventilation plans, there is a great deal of uncertainty as to whether any particular mine within a district will be able to benefit from using the technology. Thus, coal operators may avoid purchasing technologies where they may never be allowed to reap the productivity benefits. MSHA is in the process of establishing a system to revise those standards for which a large number of petitions for modifications are granted. Through this system MSHA hopes to create a climate in which new technologies are recognized, further developments are encouraged, and the time and paperwork required in the petition process are reduced. On examination, however, this system was found to be cumbersome and time consuming. Under Federal law the process of revising MSHA standards takes a minimum of one year. In practice however, it takes about 4 years from the time MSHA decides it wants to change a standard until the time it does so. This 4-year period does not include the development time for a new technology or the time needed for in-mine testing. The total time from starting development to final revision of a standard could be as long as 7 years. Given these time periods, the overall impact of this process on reducing coal operators uncertainty is questionable.

Coal operators may also not purchase new safety technologies because workers and management resist them. A Bureau of Mines official reported that this problem is exacerbated by equipment manufacturers not adequately testing machines before introducing them into mines. Thus, the equipment appears to be unreliable and mine management and workers reject it.

Ways to improve technology transfer

The Bureau has a technology transfer program including such activities as special publications, films, seminars, exhibits, demonstrations, and briefings. However, this program does not appear to effectively overcome coal industry resistance to new safety technologies. Further, the Bureau of Mines has limited its efforts primarily to developing and demonstrating new safety technologies. Equipment manufacturers are not effectively advancing the technology from the demonstration to commercialization stages. Secondly, given the present uncertainty over MSHA willingness to allow the use of new technologies, it is important that MSHA make every effort to shorten the period of time needed to change the relevant standards. This would reduce uncertainty about the productivity benefits of new safety technologies and would promote their use. MSHA has already improved this situation by establishing a committee which systematically examines granted petitions for modification to determine the need for altering regulations. Increased efforts to reduce uncertainty about the likelihood operators will be granted modification petitions for using specific safety technologies would be helpful. MSHA should devise ways to minimize the regulatory lag which now delays introduction of productivity enhancing equipment that does not impair mine safety.

STATE SURFACE MINE RECLAMATION LAWS AND LOW PRODUCTIVITY

Responding to the growing public awareness of the undesirable environmental effects of surface mining, many coal mining States enacted or strengthened reclamation laws during the late 1960s and early 1970s. The Federal Government also responded by passing the Surface Mining Control and Reclamation Act of 1977. Prior to the 1977 act, Federal reclamation laws applied only to federally leased coal lands. This report does not address the Federal surface mining law, since it was recently implemented and its effects are not yet apparent.

Coal industry officials often cite these State laws as the factor most responsible for the leveling out and eventual decline in surface mining productivity. Our survey of surface mines and statistical analysis support this view. As more stringent reclamation laws were enacted, surface mines were required to allocate more workers and equipment to reclamation activities. To accomplish this, additional workers were hired, and existing workers switched from production to reclamation and productivity suffered.

Major aspects of State laws

In 1964, only seven States had comprehensive reclamation laws.* In contrast, by 1975, 23 States had enacted reclamation laws. Because a large number of States are involved, our discussion focuses on the laws enacted by the eight top strip mining States. These are Kentucky, Pennsylvania, Wyoming, Ohio, Montana, Indiana, Illinois, and West Virginia, and they accounted for 75 percent of all surface coal production in 1977.

*Kentucky, Illinois, Indiana, Maryland, Ohio, Pennsylvania, and West Virginia.

The following information summarizes the surface mining legislation enacted in each of these States since 1966. 29/

Illinois

Requires that the spoils be graded to a minimum width of 18 feet for pasture reclamation and that visible areas within 660 feet of a public road be graded to a slope of 30 percent or less. All pasture land is to be graded to a slope of 15 percent or less and row crop agricultural areas to within 4 percent of its original grade. For row crop agricultural reclamation, from 8 to 18 inches of darkened surface soil must be removed, segregated from the other spoil, and replaced after spoil grading is completed.

Indiana

Requires that row crop agricultural areas be graded to a maximum slope of 8 percent, pasture and hay land be graded to a maximum slope of 25 percent, and forest or range land be graded to a maximum slope of 33 percent.

Kentucky

Requires surface mine operators to return the land to its original contour. This law also requires certain procedures to prevent erosion from water runoff.

Ohio

Land must be returned to a gently rolling contour. The top soil must be removed, piled separately, and later replaced after the area has been mined and graded. In areas of prime farm land, each horizon or layer of soil must be removed, segregated and later replaced so that land will provide a crop yield equal to or greater than that provided prior to the mining.

Pennsylvania

Requires backfilling to original contour coverage of exposed coal and leveling of peaks or ridges necessary for planting. Requires removal and segregation of topsoil. Twelve inches of topsoil must be replaced, conditions permitting, or all available topsoil. Requires a detailed description of the types of planting which shall be done.

West Virginia

Includes strict grading and backfilling provisions for both area and contour-type mining. Highwalls cannot exceed 30 feet from bench or slopes or 60 feet from horizontal. Detailed standards for revegetation are also included.

Montana

Requires grading to orignial contour, no slopes greater than 20 feet, and elimination of highwall. Topsoil must be separated and replaced. Revegetation with permanent, diverse, and primarily native species required.

Wyoming

Requires separation and return of topsoil. Requires returning land to a condition equal to or greater than "the highest previous use." Requires revegetation where applicable.

Except for Indiana and Kentucky, these States enacted or strengthened surface mining reclamation requirements between 1971 and 1975. The most stringent of new requirements were legislated in West Virginia and Ohio in the East, Illinois in the mid-West, and Wyoming in the West. These additional requirements improve the environment, but these improvements cost something, and part of the price is lower surface mining productivity.

Reclamation impacts on productivity

We interviewed State surface mining officials and surface mine operators in seven of the eight top producing States. A total of 18 surface mines were visited. All mining operators contacted agreed that State reclamation laws have lowered productivity. They pointed to the additional manpower needed for stricter grading, topsoil segregation, and topsoil replacement as having had the greatest negative impact. For example, before 1971, Illinois strip miners were only required to grade the tops of spoils. Since then, however, all spoils had to be graded to a slope of 15 percent or less and agricultural areas had to be returned to within 4 percent of original grade. These requirements are quite similar to reclamation requirements implemented in other States from 1966 to 1977.

Table 7 shows the trend in productivity for the major coal producing States along with the year in which a major reclamation law or amendment was enacted. All these States suffered a decline in productivity within 1 or 2 years of a laws' enactment.* Kentucky and Indiana declined continuously after their laws were enacted in 1966 and 1968. Ohio's and West Virginia's surface productivity remained constant until 1971-72 when, with passage of laws, it too began to fall. In Pennsylvania, where reclamation laws were in effect throughout the period, productivity averaged around 2.7 T/Wh between 1966 and 1978. In contrast, Montana and Wyoming realized substantial increases in surface productivity in the late 1960s and early 1970s. Montana's productivity increased from 12.1 T/Wh in 1968 to 18.0 T/Wh in 1972. A drop to 13.3 T/Wh occurred when reclamation laws were enacted in 1973, with a rebound back to 16.8 T/Wh by 1977. Wyoming showed a similar pattern.

Most strip mines visited did not have data on the specific machinery and personnel acquired to reclaim the land. However, several indicated that machinery and personnel had been added. For example, a small surface mine in Ohio added two scrapers and two workers in 1973. A larger surface mine in Ohio added five men and several pieces of equipment from 1974 to 1977. Several mine superintendents indicated that they had not added workers or equipment to comply with State laws but had allocated a larger portion of existing worker time to reclamation activities.

One indication of the increase in the amount of equipment being used for reclamation work is the increased number of bulldozers and carryall scrapers used at surface mines. These machines are used for overburden removal and reclamation work. In 1969 there were 4.3 bulldozers per million tons of surface coal production in the United States. This rate increased steadily until by 1973, it had almost doubled to 8.2. By 1975, the rate doubled again to 16.1 bulldozers per million tons of surface production. Carryall scrapers showed a similar trend, increasing from 0.3 to 2.1 scrapers per million tons between 1969 and 1976.

Available data on employment by occupation for the years 1972 to 1975 show the impact the increase in the use of bulldozers has had on manpower required. In 1972 there were 3,202 bulldozer operators employed at surface coal mines,

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*A detailed examination of all surface mining states revealed that 15 out of 23 states showed a similar decline.

Table 7

Surface Mining Productivity Versus Enactment of State Reclamation Laws (note a)

State	1966	1968	1969	1971	1972	1973	1974	1975	1976	1977	1978
Kentucky	c/7.6	7.1	6.5	5.8	5.3	c/4.9	3.6	3.1	3.1	3.0	2.3
Pennsylvania (note b)	2.7	2.4	2.7	c/2.9	2.7	3.1	3.1	2.5	2.6	2.7	2.6
Wyoming	7.4	7.5	c/7.1	8.9	7.4	c/8.5	8.6	4.6	6.1	6.3	7.9
Ohio	4.0	4.5	4.6	4.7	c/4.5	4.0	3.6	3.1	2.9	3.0	2.5
Montana	d/	12.1	16.8	18.0	18.0	c/13.3	15.6	16.5	16.2	16.8	12.1
Indiana	6.6	c/6.1	6.4	6.0	5.4	5.3	4.6	3.8	3.4	3.4	2.7
Illinois	6.8	c/6.4	6.0	c/5.6	5.1	4.6	3.9	c/3.9	3.5	2.9	2.5
West Virginia	3.8	3.7	4.0	c/3.5	2.9	3.5	2.8	2.0	2.1	2.2	2.1

SOURCE: Mine Enforcement and Safety Administration, Information Reports, 1966-1975. Mine Safety and Health Administration, Information Reports, 1976-78.

a/Productivity = tons per worker-hour. Excludes auger mines, culm banks, and dredges.

b/Excludes anthracite production.

c/Years in which surface mining laws were enacted or amended to include additional reclamation requirements.

d/Not applicable.

4,815 in 1973, 5,830 in 1974, and 6,261 by 1975.* This represents a 111-percent increase in 4 years, with the largest jump (50 percent) coming between 1972 and 1973. It cannot be determined exactly what portion of these additional workers were being used to increase production. Surface coal production increased only 10 percent between 1972 and 1974, years when the number of bulldozer operators increased 80 percent. This indicates that a large portion of these additional workers were being employed on nonproduction (reclamation) related activities.

Our quantitative analysis revealed that the use of carryall scrapers by the industry had a small dampening effect on productivity. A 10-percent increase in the number of carryall scrapers industry-wide results in only a 0.3-percent average reduction in productivity. This suggests that the positive contribution of scrapers to production is slightly outweighted by their use in reclamation. The opposite was found for bulldozers, where a larger relationship existed. A 10-percent increase, here, results in a 2.3-percent increase in productivity. This indicates that their importance in coal production offsets their role in reclamation. The mines we visited employed bulldozers primarily for production and carryall scrapers primarily for reclamation. A more precise measurement of how additional reclamation by bulldozers and scrapers affect productivity depends on having information on their reclamation work isolated from production work. Such data does not exist. However, a DOE study using different methods found a strong negative influence of reclamation laws on productivity. 30/

CONCLUSIONS

MSHA regulation was a major cause of productivity decline during the initial years of the MSHA Act's implementation. MSHA's enforcement of the act is no longer a significant cause of productivity decline. However, new regulations or increased enforcement efforts may cause temporary productivity problems of a smaller magnitude than what the coal industry experienced in the early 1970s.

Compliance with roof control, ventilation and dust control, and environmental monitoring regulations are also no longer significant causes of productivity decline. However, these requirements have caused a permanent productivity loss.

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*Employment data for scrapers were not available.

This productivity loss is the price the coal industry and consumers are paying for improving mine safety.

MSHA regulation has reduced coal mine fatalities and disasters dramatically, yet, these same regulations have caused the decline in productivity. However, MSHA regulation has not effectively reduced the frequency of nonfatal disabling injuries caused primarily by human error. Increased MSHA and industry safety training of miners and supervisors might help reduce nonfatal accidents.

The Bureau of Mines and coal equipment manufacturers are not adequately transferring technologies to the coal industry that would reduce the adverse productivity impact of safety and health regulation. Greater assurance from MSHA about which safety technologies coal operators can adopt to receive relief from productivity-reducing regulations might increase industry's acceptance of the new technologies. Further, equipment manufacturers and the Bureau of Mines should test and perfect new safety technologies more before attempting to commercialize them.

An examination of trends in individual States' surface mining productivity indicates a close relationship between productivity and the enactment of State reclamation laws. A small negative relationship was found between productivity and carry-all scrapers which are used primarily in reclamation activities. These results support the views expressed by the surface mine operators of the mines we visited. As mines complied with stricter reclamation requirements, added equipment and workers were allocated away from production and productivity suffered. This lost productivity is a cost we pay for a restored environment.

FOOTNOTES

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CHAPTER 4

TECHNOLOGY, GEOLOGY AND INDUSTRY STRUCTURE AS CAUSES OF LOW PRODUCTIVITY

Changes in mining technology, worsening geological conditions, and the entry of new mines into the industry have been pointed to as factors having major impacts on the productivity of both surface and underground mines. In underground mining, for example, the increased use of continuous mining machines was a major factor responsible for the phenomenal growth in productivity which occurred in the 1950s and 1960s. On the other hand, worsening geological conditions due to a slow depletion of the resource base has been hypothesized as a possible reason for lower productivity since 1969. Finally, the entry of a large number of new mines into the industry during the 1970s has been suggested as a possible reason for declining productivity. These new mines may have to allocate additional time and resources to development work, resulting in lower than average productivity during initial production years.

We found that the type of technology employed by a coal mine will have substantial affects on the level of productivity achieved. This is true for both surface and underground mining. Geological conditions, while important in surface mining, were less of a factor leading to lower productivity in underground mining. The entry of a large number of surface mines into the industry, beginning in 1974, lowered productivity. This is due to the long start-up time for new mines before they reach their full productive potential.

TECHNOLOGY

While coal mining technology has not caused productivity to decline, it has not advanced sufficiently to offset productivity losses due to other factors. In underground mines, technological improvements in coal cutting and haulage could increase productivity substantially. Specifically, improving the reliability of coal cutting machines would allow them to realize their productive potential, while faster haulage systems are needed to keep pace with the more productive cutting machines. In surface mines, overburden removal and coal loading are the areas with the greatest potential for productivity improvements.

Large coal companies are engaged in research to improve the reliability of existing equipment, while equipment manufacturers do limited research to advance the state of coal mining technology. Advanced coal research is conducted primarily by the U.S. Government. The Department of Energy conducts advanced coal mining technology research. Current Department of Energy coal technology R&D efforts will not substantially increase productivity in the near term, and a shrinking budget will curb future research.

Underground coal mine technology

The four basic stages of underground coal production are cutting, loading, roof support, and hauling. Our analysis shows that the greatest coal mining productivity gains can be achieved by improving the reliability of coal cutting machines and improving haulage from the face. This is because advances in machine maintenance programs and haulage systems have not kept pace with productivity advances in cutting coal.

Coal cutting machines

There are three coal cutting methods: conventional, continuous, and longwall. Conventional mining consists of mechanically cutting, drilling, blasting, and loading the coal onto cars or a conveyor and out of the mine. About one-quarter of underground bituminous coal production in 1977 was cut by conventional cutting machines.

Continuous miners cut the coal by ripping it off the face with a revolving cutter and loading it without blasting. Because they reduce the number of operations of conventional mining, they should be more productive. In 1977, 64 percent of coal production at underground bituminous mines was cut by continuous miners.

Both conventional and continuous mining methods require miners to be protected by roof supports. Both conventional and continuous miners must be withdrawn from the face to allow the roofbolter to support the roof. Roofbolting is the longest procedure in the production process and production must wait until roofbolting is completed.

Longwall mining greatly reduces the amount of roofbolting. In longwall mining, coal is cut by a blade or revolving cutting head pulled back and forth across the face. The coal falls onto a conveyor belt which removes it. The roof over the area being mined is held up by movable steel supports which advance with the machine and is allowed to collapse behind the machine as it advances. Longwall mining is potentially more productive than conventional and continuous mining because the machine can advance continuously, because there are less haulage delays, and because it allows recovery of more coal than by the room-and-pillar method used with conventional and continous mining. While commonly used in Europe, this method is not used much in the United States due to high costs and inappropriate geological conditions. In 1977 only 5 percent of all underground bituminous coal was produced by longwall miner.

Since 1969 coal cutting technology has not advanced sufficiently to offset productivity decline due to MSHA regulation, labor problems, and other causes. Observers have cited three explanations for the lack of technological advance in coal cutting. They are: 1) the switch to more productive continuous mining has already taken place, 2) continuous mining did not realize its productive advantage over conventional mining, and 3) the switch to more automated techniques such as longwall mining did not materialize.

The 63 percent growth in productivity between 1950 and 1969 was largely attributed to increasing coal mine mechanization. Continuous mining reduces the number of steps in the mining process from five in conventional to three and reduced crew size per mine section from an average of 9 to 6. In 1959, 1 percent of underground coal was produced by continuous miners compared to 50 percent in 1969 and 63 percent in 1976. Secondly, the amount of coal loaded by hand decreased from 30 percent to 3 percent between 1950 and 1969, and by 1973 it was less than 1 percent. Between 1960 and 1969 the share of underground coal produced by continuous miners grew by an average of 7 percent annually, while between 1969 and 1977, the annual rate of growth was 3 percent.

A second reason why coal mining productivity has not advanced during the 1970s is that more productive continuous mining equipment did not realize its productive advantage over conventional mining. MSHA regulation and the 1974 union agreement, along with problems in machine reliability have prevented these methods from achieving their productive potential. Our statistical analysis measures the contribution to productivity of individual pieces of equipment employed by mines operating throughout the industry under differing conditions from 1972 to 1977. These results represent statistical estimates of the mean or average productiveness of each equipment type. In an actual operation the productivity of individual pieces of equipment will vary above and below these estimates. Statistically it is possible to calculate a range or interval in which we can say, with a high degree of confidence, the actual level of productivity will fall. Table 8 presents our estimates of the impact on industry-wide productivity of a 10-percent increase in different types of mining equipment. The data is presented in terms of a 95 percent confidence interval--we are 95 percent confident that the resulting change in industry-wide productivity will be within the ranges given. Of greatest interest is the relative ranking of equipment types rather than the absolute level of productivity achieved. As such, the results should be viewed more as identifying areas within the industry where technological improvement would have the largest productivity benefits rather than as an exact formula for designing the most efficient production process within an individual mine. Based on our estimates we would not, for example, make the statement that all underground mines increase their use of certain equipment by some fixed percentage since other constraints may not warrant such an increase. As the table shows our analysis of mining machines operating during the 1972 thru 1977 period revealed that conventional cutting machines were actually more productive than continuous miners. A 10-percent increase in the number of cutting machines would result in an average 2.4-percent increase in productivity as compared to 1.3-percent increase for continuous miners. A study by Oak Ridge Associated Universities also agrees with our finding that continuous mining lost its advantage after passage of the MSHA Act. 1/ MSHA regulations which limit the advance of continuous miners to 20 feet and stringent MSHA standards for the permissibility and maintenance of electrical equipment are major reasons why continuous miners lost their productive advantage in the 1970s. In addition, the National Bituminous Coal Wage Agreement of 1974 required two additional workers per continuous section and only one additional worker per conventional section. This helped to give conventional mining a productive advantage over continuous mining.

Table 8

Industry-Wide Productivity Impact of a 10-Percent Increase in Production Equipment (underground mines) (note a)

Equipment type	Percent increase in productivity (95 Percent Confidence)		
	Lower Limit	Most Likely Effect	Upper Limit
Cutting machines	+1.6	+2.4	+3.2
Shuttle car capacity	+1.5	+2.1	+2.7
Continuous mining machines	+0.5	+1.3	+2.1
Longwall machines	+0.1	+1.2	+2.2
Track length	+0.1	+0.6	+1.1
Belt length	+0.04	+0.2	+0.3

a/Equipment types listed are those found to be statistically significant at the 0.05 level. A more complete discussion of the results can be found in appendix I.

More sophisticated mining methods may also be less productive in practice than their potential suggests due to their unreliability. More complicated machines require more maintenance and break down more often. The Office of Technology

Assessment (OTA) reports that continuous miners only produce 20 to 30 percent of the time. 2/ The Bureau of Mines reports a loss of one third of available production time due to continuous mining machine failure. 3/ Emory Ayers Associates, Inc., found that an increase of equipment availability of just 5 percent could increase production by 25 percent. 4/ Given the environment they must operate in, mining machines are inevitably less reliable than other modern machines. However, a study by J.J. Davis Associates concluded that the real problem of mining machines is inadequate maintenance. 5/ Maintenance programs have not kept pace with the growing machine complexity. The J.J. Davis study further states that the lack of preventive maintenance and insufficient training of shift mechanics are the primary reasons for mining machine failure. 6/ Coal operators we surveyed reported that increased maintenance of MSHA-required safety equipment exacerbates this problem. Emory Ayers reports that productivity is higher in mines that have scheduled maintenance shifts and practice preventive maintenance. 7/ In fact, they found that higher productivity mines often spent up to five times the time on preventive maintenance than lower productivity mines. Besides unreliability, more complex machines are more likely to shut down section production entirely when they fail since they combine several mining steps and their cost may prohibit operators from owning spare machines. Conventional cutting machines are the least complex and expensive cutting machines and so are more reliable and less likely to shut production down entirely.

A popular explanation for slow technological advance in coal is the industry's slow acceptance of the longwall miner. In 1977, only 73 longwall machines were operating in the United States. The share of underground coal produced by longwall miners only grew from about 1 percent to 5 percent between 1967 and 1977. Growing use of longwall miners has been slow because increased production has not offset the high cost of longwall mine operations. It may cost as much as $10 million to initiate longwall operations.

As in the case of continuous miners, longwall miners may not achieve their high potential productivity. In addition to reliability problems, longwall miners lose the 2 to 3 weeks production time it takes to move them from section to section. In addition, the U.S. has better mining conditions and thicker seams than Europe. Thus, the high recovery rate of longwall systems as opposed to room and pillar is not as important an advantage as in Europe where longwall mining is the primary method utilized. In addition, since American mines are generally not as deep as European mines, our roofs do not break easily as required by the longwall process. A final reason why coal operators have been slow to adopt longwall mining is that they have to purchase a whole new haulage system to accommodate the large amount of production coming off the face.

Our analysis shows that the coal industry's present reluctance to invest in longwall mining systems is based on a reasonable assessment of their actual cost versus productivity improvement. Referring back to table 8, of the three underground mining methods--conventional, continuous, and longwall--our results indicated that longwall machines were the least productive. However, longwall miners have the benefit of improving worker safety. Their movable roof support system and the reduction of workers at the face make longwall mining safer than other mining methods.

Coal haulage systems

Coal is generally first loaded onto shuttle cars or gathering conveyor belts and hauled out of the mine by rail or conveyor belt. The most common main haulage method is by conveyor belt. The most common track haulage vehicles are mine cars pulled by locomotives. Both conveyor belts and mine cars are used as a means to transport workers. Rubber-tired tractors and trailers are also occasionally used to haul coal out of the mine.

Our coal industry survey, an OTA study, and discussions with DOE officials revealed that haulage systems are a main bottleneck in the production process. Technical developments in coal cutting equipment have overwhelmed mine haulage systems, especially the transport from the face to the main haulage line. As shown in table 8, our statistical results show that adding more shuttle capacity will increase productivity more than adding continuous and longwall mining machines. In fact, except for conventional cutting machines, the largest productivity gains could be achieved through increases in shuttle car capacity. This indicates that substantial improvements in productivity can be had through improvements in face haulage capacity. J.J. Davis Associates, Inc., reports that 25 percent of the available cutting time of a continuous miner is lost due to face haulage delays. 8/ Thus, the addition of transport capacity from the face should improve productivity more than additions to main haulage equipment such as track or conveyor belts, a point confirmed in our findings.

Surface mine technology

Surface mining generally involves the following procedures: 1) overburden removal using bulldozers, shovels, bucketwheel excavators, or draglines; 2) blasting using coal drills to make holes to place explosives; 3) coal loading using shovels or front-end loaders; 4) coal hauling using trucks; and 5) reclamation using bulldozers, motor graders, or scrapers. Unlike underground mines, the types and combinations of surface mining equipment vary greatly with changes in geographic location and mining method employed. The four basic types of surface mining methods are area, open-pit, contour, and auger.

Area mining is the main strip mining method used in the Midwest and parts of the West. Large open pits in a series of long narrow strips are developed. Bulldozers, scrapers, or draglines are used to cut a trench across one end of a strip. After blasting to loosen the coal, a loading shovel lifts the coal onto trucks. Overburden from each new trench is used to fill the mined-out trenches.

Open-pit mining is used primarily for the thick Western seams which are too deep to use draglines. Front-end loaders and trucks remove the overburden and take the coal.

Contour strip mining is often used in hilly areas such as Appalachia. In this mining method, benches are created in the hillside. Smaller scale bulldozers, shovels, front-end loaders, and trucks than found in Western mines are the primary pieces of equipment used in this process.

Auger mining is sometimes used in hilly terrain, often in conjunction with contour mining. However, since only 1 percent of all surface-mined coal in 1978 was mined by this method, we did not include auger mining in our study.

Excavation and coal loading equipment

Surface mining productivity can be improved by increasing the coal mine's overburden removal, and coal loosening and loading capacities. Table 9 contains the results of our statistical analysis of the productiveness of different types of equipment employed from 1972 to 1977 at surface mines throughout the United States. As in table 8 they are presented in terms of an assumed 10-percent increase in the number or capacity of each type of equipment and represent 95-percent confidence intervals. Also, as in table 8, the productivity of individual pieces of equipment will vary above and below the estimated limits for the average productivity impact. As indicated in table 9, increasing the number of wheel excavators, bulldozers, and dragline capacity will increase productivity. These machines are largely used for removing overburden. However, our results showed that of the three, wheel excavators are by far the most productive. A 10-percent increase in wheel excavators is associated with an average 3-percent increase in productivity, while 10-percent increases in bulldozers and dragline capacity increase productivity by an average 1.3 percent and 0.4 percent respectively. A major reason for wheel excavators' superior productivity is that they are often

Table 9

Industry-Wide Productivity Impact of a 10 Percent Increase in Production Equipment (surface) (note a)

Equipment type	Percent increase in productivity (95-Percent Confidence) Lower Limit	Most Likely Effect	Upper Limit
Wheel excavators	+1.2	+ 3.0	+4.8
Front-end loaders	+1.8	+ 2.9	+3.9
Coal drills	+0.9	+ 2.4	+3.9
Bulldozers	+0.1	+ 1.3	+2.5
Dragline capacity	-0.2	+ 0.4	+0.9

a/Equipment types listed are those found to be statistically significant at the 0.05 level. A more complete discussion of the results can be found in appendix I.

used to remove soft overburden. Soft overburden is easier to remove and thus one should expect to find a higher productivity associated with equipment that removes it. Bulldozers are also highly productive, although not nearly as much as wheel excavators. Bulldozers are often used for overburden removal in smaller mines in the Midwest and Appalachia. However, they are also used for reclamation, a nonproduction activity. This explains their lower productivity benefits.

Increased capacity for loosening coal should increase productivity significantly. Our results in table 9 show that increasing the number of coal drills by 10 percent will increase productivity by an average of 2.4 percent. Coal drills make the holes needed for blasting the coal to loosen it for removal.

Increasing coal loading capacity will also increase productivity. Our analysis shows that increasing the number of front-end loaders will bring substantial productivity improvements. Increasing the number of front-end loaders will improve productivity more than will increasing the number of power-shovels. This may be because power shovels are also used for overburden removal. Front-end loaders bring substantial productivity benefits because they are fast, flexible, and, unlike shovels, are used almost exclusively for loading coal. Front-end loaders are most common in open-pit mining in the West, although they are also used in the Midwest. However, the fact that they bring such large productivity benefits may signify that not enough of them are being used in mining thick Western seams. However, it is unclear whether front-end loader capacity can be increased in the West. Production limitations due to lack of sufficient rail transportation may constrain increasing coal loading capacity.

Unlike underground mining equipment, where reliability is the greatest constraint to productivity improvement, surface mining productivity could be best improved by increasing the capacity of excavating and coal loading equipment and the efficiency of their use. Further, increasing the amount of mining of thick seams in the West could improve productivity.

Industry and government research and development efforts

Our analysis shows the greatest room for technological improvements in underground mining are in improving the reliability of coal cutting equipment, finding ways to offset the impacts of MSHA regulation, improving longwall mining techniques, and improving haulage. Coal equipment manufacturers and large coal companies are doing research on improving the speed and reliability of existing equipment but are doing little research on advanced mining systems. The Department of Energy is doing substantial research on advanced mining techniques that would offset some of MSHA's adverse productivity impacts, improve longwall mining, and improve haulage. However, DOE is decreasing its advanced technology research.

Industry research

Coal producing companies and equipment manufacturers have focused on technology research that reduces the cost of operating existing equipment. A recent National Academy of Sciences study explains why the coal industry shies away from advanced technology research. 9/ The study cites difficulties in adjusting to supply and demand forces, the large investment required in existing productive capacity, and uncertainties in government policies, laws, and regulations necessitate that only research with low risk and immediate benefits be undertaken.

Because equipment breakdown and failure are major causes of high costs and production interruptions, coal companies are pursuing ways of improving the reliability and speed of existing machinery. Consolidation Coal Company (Consol), for example, aims to increase productivity by improving the availability of existing equipment. Consol is developing a computerized accounting system for reporting equipment performance and down time to analyze and reduce problems in these areas. The system is meant to identify components that require redesign, improve maintenance, and change equipment usage patterns.

Another coal company pursuing similar efforts is Peabody Coal Company. Peabody is attempting to improve machine availability and the speed of slower machinery at the face. The system that Peabody is developing gives management the ability to monitor face equipment to determine if certain machines consistently malfunction or work slower than other equipment in the mining cycle. In this way, Peabody believes it can improve slower machines and productivity. Neither Consol nor Peabody are doing substantial research in technologically advanced equipment.

Coal equipment manufacturers do limited research to develop advanced mining systems. A DOE study prepared by Bituminous Coal Research, Inc., showed that in 1978 equipment manufacturers spent $36 million on coal mining R&D.* 10/ Coal equipment manufacturers do research on advanced techniques that have a clear and immediate pay-off. This research will help offset the adverse productivity impacts of MSHA roof support regulations, improve longwall mining techniques, and improve haulage. For example, Joy Manufacturing is presently commercializing a continuous miner/bolter developed partly from DOE funds. By the end of 1980, 12 to 15 percent of its total mining machine production will be from these machines. Joy is also redesigning longwall mining machines to make them more appropriate for American mining conditions. The machine should be commercialized in 5 to 10 years. Joy Manufacturing will also commercialize an underground continuous haulage system this year.

Government Research

The Department of Energy's Mining Research and Development Program's purpose is to "increase the efficiency of labor and capital for the entire mine operation." 11/ DOE appears to focus its research efforts on projects that will increase productivity substantially. However, these efforts will not substantially increase coal productivity until the late 1980s. Further, future technological advances to improve productivity will be curbed by a shrinking coal mining research and development budget. Given the importance to national energy goals of improving coal mine productivity, DOE should maintain or speed up advanced technology research projects bearing large productivity increases.

DOE's Mining Research and Development Program had a budget of $76 million in fiscal year 1979.* Underground

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*Coal mining R&D includes expenditures for reclamation, underground and surface equipment, mine systems design, materials handling, electrical, and materials and supplies.

mining R&D receives DOE's primary emphasis, receiving 70 percent of the mining R&D budget in 1979. This is consistent with our finding that underground mining has far greater productivity problems than surface mining. DOE is researching underground advanced mining technologies that will help offset adverse productivity impacts of MSHA's roof support requirements, improve longwall mining, and improve haulage within the mine. Our statistical analysis identified these areas as having the potential for improving productivity.

DOE's major effort in underground mining R&D is the development of a fully integrated miner-bolter system. At present, a substantial portion of production time is lost while roof supports are put into place. This has been especially true since MSHA regulation reduced the advance of the continuous miner before bolting to 20 feet. A miner-bolter would allow miners to extract coal continuously by cutting coal and roof bolting without losing production time. However, this system, which seems to have considerable promise in terms of alleviating a major face production bottleneck (i.e., stopping the continuous miner while roof supports are put into place) is probably at least 6 to 8 years from commercialization. Less automated miner-bolter machines have been available for the industry since the 1950s.

Another area receiving considerable attention in DOE's underground mine R&D efforts is developing an automated longwall system. This system would automate shearing and face advancement operations which are currently controlled by manually activated hydraulic control valves. Each component can be introduced separately for commercialization but this will take at least 3 years.

DOE has also given considerable attention to developing haulage systems which will reduce face production bottlenecks. Both rail and belt haulage systems are being developed for face and main line haulage. The capacity and flexibility of these systems are the major goals of the R&D efforts in this area. The primary benefits expected from an automated haulage system would be lower overall haulage costs per ton, increased production through minimizing delays, greater equipment utilization and reduced down time. Although DOE is placing substantial emphasis on these automated haulage systems they expect few, if any to be commercially available before 1985.

DOE had budget authority for $12.6 million in fiscal year 1979 for surface coal mining research. The lower funding for surface reflects DOE's assessment that the largest technological constraints to improving productivity are presently in underground mining. Unlike underground mining projects, DOE's surface mining projects are already commercially available or will be so shortly. DOE contracts emphasize improvements in extraction and reclamation systems that allow for higher rates of production with improving the performance of present systems. DOE is also allocating considerable resources to develop new techniques and equipment for excavation, continuous haulage, and environmentally acceptable reclamation. Two DOE projects that should bring substantial productivity improvements are the computerized dragline and low wall haulage. The computerized dragline consists of an on-board computer which helps optimize normal tasks on a cycle-by-cycle basis. A computerized dragline should increase productivity by 5 to 10 percent and is already commercially available. DOE has also developed a low wall haulage system which would use conveyors to replace trucks in handling overburden. This would alleviate pit congestion and production hindrances common in surface mining. DOE expects this $1 million system to be commercially available by next year.

DOE's Director of the Office of Coal Mining, Fossil Energy Division felt that substantial productivity benefits could be gained by increasing funding of both underground and surface advance technology research. The primary underground mining projects that would produce these benefits are expanding miner-bolter research, improving face and main haulage, and further research on adapting longwall mining to American conditions.

Miner-bolters could be developed for use in seams lower than the present 6 to 8 feet, and for different types of continuous mining machines. Both face and main haulage can be improved through increased research in hydraulic and pneumatic transport and improving the reliability and flexibility of belts for continuous haulage.

The DOE Office of Coal Mining official also felt that surface mining productivity could be increased by about 40 percent within 10 years. However, he felt that this would require increasing surface mining research funds by four to five times. Projects that would improve productivity in Eastern contour mines would improve materials handling and excavation. Productivity improvements in area mines in the West and Midwest could best be achieved by improving the efficiency of the dragline and developing a cross-pit conveyor system. A cross-pit conveyor would move overburden and coal from the highwall to the reclamation side of the pit, thereby avoiding the use of trucks in the pit.

While we have not done an independent analysis of the productivity gains likely to be achieved through increasing funding for the above-mentioned projects, it is evident that technological advances can increase productivity substantially in both underground and surface mines. However, DOE has decreased its underground and surface mining R&D budget from $60 million in fiscal year 1979 to $34 million in fiscal year 1981. Further, fiscal year 1980 spending for underground and surface coal mining R&D was cut by 23 percent due to a budget recision. Given the large productivity benefits these projects are capable of achieving, we feel that DOE should try to allocate sufficient resources to projects that will increase productivity substantially. Further, DOE should find ways to speed up current projects so that productivity benefits can be achieved sooner than 1985.

GEOLOGY

Geological conditions affect productivity in both underground and surface mines. Factors such as seam thickness and depth, overburden, roof and floor conditions, the presence of gas or water, will influence production and the equipment used. Theoretically, as output expands seams with poorer working conditions, greater distance from working face to mine entrance or at greater depths come into production and labor productivity may fall. In some cases, these negative influences cannot be compensated for by substituting more advanced technology since the poorer working conditions may themselves be a constraint on the type of equipment used.

We assessed the impact of geological conditions on productivity at each mine we visited and by statistical analysis. We concluded that, although geological conditions are important to an individual mine's productivity, they have not worsened to the point of being a major cause of the overall decline in either surface or underground mining productivity.

Surface mines

Geological conditions have a substantial impact on the productivity of individual surface mines. Most surface mine operators we visited stated that the thickness and composition of overburden--and to a lesser extent excess water--reduce productivity. Officials at one mine complained that the overburden was very hard, causing dragline bucket teeth and scraper blades to wear out faster than normal, increasing machine downtime. At another mine, water softened the pit floor and bogged the equipment down.

Surface mine operators could not quantify the impact these conditions had on productivity. Several operators stated that they had encountered more water and increasing overburden in recent years. Both of these conditions would decrease productivity.

In surface mining the proportion of overburden thickness to seam thickness (overburden ratio) is used to measure the economic potential of a mine. As the overburden thickness increases, more cover must be removed per ton of coal. Given a constant seam thickness, increasing overburden removed per ton of coal recovered eventually makes the mine unprofitable.

We found a strong relationship between the overburden ratio and productivity. Assuming nothing else changed, a 1-percent increase in the overburden ratio leads to a 1.3-percent decrease in productivity. Productivity for a surface mine is, therefore, closely related to overburden and seam thickness.

These results shed additional light on why strip mining has been moving West despite strict reclamation laws, lower coal BTU content, and significant transportation problems. DOE data show that the overburden ratio declines substantially as one moves West. In the Appalachian region the ratio ranged from 10.4 to 28.0; in the Midwest from 8 to 25.7; and in the Western region from 2.1 to 6.7. Because a lower ratio leads to higher productivity, one would expect a move to the more geologically favorable Western States. This is exactly what happened. Between 1968 and 1977 Montana and Wyoming's share of U.S. surface production increased from 1 to 30 percent. With increased coal demand this shift to western production should continue.

Underground mines

Poor geological conditions in underground mines require time and effort to overcome, and therefore, decrease the total time available for coal production. These conditions may characterize a mining section for its entire life or may only be occasionally present. In addition, the geology of individual sections within a mine will vary from excellent to very poor. The important question is whether underground mining conditions overall have worsened since 1969. Our results indicate that they have not.

Poor roof conditions require more roof support while poor floor conditions impede equipment movement. Poor floor conditions may also require lighter equipment to be used when heavier machines would be more efficient and productive. Excessive water contributes to poor floor conditions, affects worker morale and the operation of equipment, and may require extra effort to pump it out of the mine. Lower coal seams require longer machine operation to produce the same quantity of coal. While poor geological conditions obviously hurt the productivity of individual mines, only 2 of 25 underground mines visited indicated that geological conditions had worsened in recent years.

Little quantitative information exists on geological conditions in underground mines. In fact, the only data available is on seam thickness. This data revealed that seam thickness in mines varies greatly but has not changed over time.

Our quantitative analysis showed no significant relationship between productivity and seam thickness. There are several possible explanations for this. Other favorable geological conditions may compensate for a narrow seam. For example, thin-seam mines tend to have better roof conditions. If it is a minable coal seam, mining equipment and practices can be adjusted. Mines or sections with unminable seams simply do not produce.

Our results shed additional light on the process of adjusting to an individual mine's working environment. We found a strong positive relationship between a mine's cumulative production over time and productivity. This suggests that "learning by doing" is an important contribution to the level of productivity achieved by an individual mine. As time passes, mining personnel learn better ways of coping with the mine's geology and productivity improves accordingly.

NEW MINES

The entry of new mines into the industry has been pointed to as a possible factor in the decline in both surface and underground productivity. As coal demand and prices increased during the mid-1970s, many mines opened. The productivity of these mines could have been lower due either to development time needed to reach top efficiency or their opening in economically marginal seams. For surface mines our results indicated this to be true.

Beginning in 1974, the entry of new surface mines into the industry had a detrimental impact on productivity. This decline was felt primarily in Eastern States. Given the small production of these new mines, however, the overall effect on productivity was minimal. No evidence showed that the entry of new underground mines into the industry lowered productivity.

In our quantitative analysis we tested the relationship between productivity and a mine being in its first full year of coal production. We found a strong relationship between new surface mines and productivity, i.e. new surface mines tend to have lower productivity. Underground mines, on the other hand, showed no significant correlation between productivity and newness. An examination of the average productivity of new underground and surface mines included in our analysis support these findings. In 1977, the average productivity of these new surface mines equaled 3.0 T/Wh compared to an industry average of 3.4 T/Wh. For new underground mines, the average productivity equals 1.4 T/Wh compared to 1.3 T/Wh for the industry. Thus, new surface mines had slightly lower than average productivity and new underground mines slightly higher than average productivity.

An examination of MSHA data on the number of active surface mines revealed a substantial increase occurred beginning in 1974 in the East. The number of active surface mines declined from 1,490 in 1968 to 1,112 in 1973 and then exploded to 3,176 by 1978. Over 98 percent of these new mines were located in Eastern coal producing States. More important, however, 85 percent of these new mines produced less than 100 thousand tons per year and 70 percent less than 50 thousand tons annually. Mines producing 50 thousand tons or less accounted for less than 7 percent of 1977 total suface coal production.

The small production of the majority of new mines indicates that their impact on overall industry productivity between 1974-77 was small. However, the impact on the productivity in some Eastern States was substantial. Kentucky and Pennsylvania alone account for over 50 percent of the increase in surface mines. The number of Kentucky surface mines increased from 157 in 1973 to 676 in 1978. During this same period, Kentucky's productivity declined 16 percent. Part of the decline in the productivity of both States during any given year can be attributed to the entry of these new surface mines.

CAPTIVE PRODUCTION

Captive coal production* has increased in importance since 1970. In that year 85 mt or 14 percent of production was captive. By 1977 this had increased to 121 mt or 18 percent of production. Increasing captive production came from growing consumption by electric utilities. Captive coal consumption by electric utilities grew from 19 to 69 mt between 1970 and 1977.

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*Defined by DOE as that portion of mine production for consumption by a parent or subsidiary company.

Some individuals in the coal industry stated that the increase in the proportion of captive production has had a depressing effect on productivity in the coal industry. The relationship between the parent company and coal mining subsidiary could result in less incentive on the part of the coal company to produce coal in the most efficient and cost effective way.

To test this contention, we took the percent of a mine's total production not sold on the open market and examined the relationship between captive mines and productivity. Our results revealed that underground mines with a large portion of captive production are slightly more productive than noncaptive mines. In surface mining, no relationship was found between productivity and captive production.

Although our results suggest that captive mines are more productive, they do not confirm that these mines produce at lowest cost. Captive mines may for example, allocate a larger amount of financial resources into better equipment or training which would increase both production and costs.

CONCLUSIONS

A major reason why productivity is currently declining is that technological advance has not been sufficient to offset the decline due to MSHA regulation, labor problems, and other causes. This is particularly true in underground mines where the switch to continuous mining already took place during the 1950s and 1960s, and where MSHA regulation reduced continuous mining's productive advantage over conventional mining. Improving the reliability of mechanized mining machines such as continuous and longwall miners, offsetting some of MSHA regulation's adverse productivity effects, and improving haulage systems will bring the highest productivity gains in underground mining. Increased preventive maintenance programs and training for mechanics would greatly improve the reliability of existing machinery.

Coal companies are engaged in research to improve the speed and reliability of existing equipment, while coal mining equipment manufacturers do advanced technology research only if the productivity benefits are clear and immediate.

The Department of Energy is doing substantial research on advanced mining systems and is currently funding projects that will yield high productivity gains. However, budget cuts have reduced DOE's research efforts. Given the importance of promoting coal production to our national energy goals, DOE should try to find the resources to maintain and speed up current projects with high productivity gains. Further, funds should be provided for new projects with high potential productivity gains.

In underground mines, geological conditions may improve or worsen as the mine progresses. For example, production may progress into sections where poor roof conditions exist that require additional roof support. As the operation continues, however, it may progress through this area and into another area with good roof conditions. Therefore, the effect of geological conditions on productivity in underground mines normally fluctuates during the life of the mine. We found no evidence that conditions have been worsening industry-wide. Our statistical analysis of seam thickness revealed it has not been a factor in the overall industry decline in productivity.

In surface mines, seam thickness and the amount and type of overburden are the primary geological conditions impacting productivity. We found a strong relationship between the overburden ratio and productivity. Low overburden ratios help explain both the higher productivity and increasing production in Western States.

We found that the entry of new surface mines into the industry beginning in 1974 had a detrimental effect on surface mining productivity. However, the effect on overall industry productivity was small.

Finally, we found no evidence that captive mines are less technically productive. We found that captive production has a small positive effect on productivity in underground mines but none in surface mines. Since captive mines may expend greater resources on equipment and training, however, this does not prove that they are less costly coal producers.

FOOTNOTES

1/Oak Ridge Associated Universities. Determinants of Coal Mine Labor Productivity Change (Washington, D.C.: U.S. Department of Labor and U.S. Department of Energy, November 1979), p. 22.

2/United States Office of Technology Assessment. The Direct Use of Coal (Washington, D.C.: Government Printing Office, April 1979), p. 73.

3/U.S. Department of Interior, Bureau of Mines, Division of Minerals Health and Safety Technology. Unpublished data.

4/Peter B. Lilly. "Improving Productivity Through Effective Maintenance Management," How to Improve Productivity in Underground Coal Mining (New York, New York: Emory Ayers Associates, Inc., 1979), p. 2.

5/J. J. Davis Associates. Survey of Equipment Manufacturing Research and Development Needs (McLean, Va.: J. J. Davis Associates, Inc., 1975), pp. II-35-36.

6/Ibid., p. II-36.

7/Lilly, Exhibits IV and V.

8/J. J. Davis Associates, p. II-17.

9/National Research Council, Technological Innovation and Forces for Change in the Mineral Industry (Washington, D.C.: National Academy of Sciences, 1978), pp. 2, 42, 43.

10/Bituminous Coal Research, Inc., Assessment of Research Projects and the Coal Industry. (Monroeville, Penn.: Bituminous Coal Research, Inc., 1980), Table 4, p. 5.

11/U.S. Department of Energy. "Fossil Energy Research and Development, Fossil Energy Construction, Coal," FY1980 Congressional Budget Request (Washington, D.C.: U.S. Department of Energy, 1979), p. 7.

CHAPTER 5

LESSONS FROM THE EUROPEAN EXPERIENCE*

West Germany and the United Kingdom are two European countries with substantial coal production that have not shared our recent decline in productivity. While still lower than in the United States, productivity in British and West German coal mines has remained fairly constant or increased slightly without detracting from mine safety. In fact, despite poorer mining conditions, United Kingdom coal mines are as safe or safer than ours.** These facts suggest that analyzing United Kingdom and West German mining operations and safety and health regulations might indicate ways to improve U.S. productivity without detracting from mine safety.

U.S. LABOR PRODUCTIVITY IS HIGHER THAN THE UNITED KINGDOM AND WEST GERMANY'S

Table 10 compares productivity in underground coal mining in the United States, United Kingdom, and West Germany. U.S. productivity is far above that of the other countries in all years in spite of greater use of highly productive longwall mining machines in European mines.

The primary reason for lower productivity in British and West German mines seems to be their poorer geological conditions. Mines are deeper and thus likely to produce more methane, floors and roofs are more difficult to maintain, and workers may be exposed to intense heat. Seams are also thinner, steeper, and are close together, making mining more difficult. 1/ Adverse mining conditions reduce not only each worker's productivity but require extra workers for mine maintenance.

Another explanation of why British and West German mines have lower productivity than the United States mines is that their operators invest more resources in safety than their U.S. counterparts. For example, greater resources must be devoted to roof and floor control such as using ringed arch supports and spending more manhours maintaining supports. This greater "safety consciousness" may be due to higher risk of injuries and production disruptions caused by poorer mining conditions.

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*Discussion is limited to underground mines. Nearly 90 percent of British coal production in 1977 came from underground mines.

**As measured by fatality frequency.

A final explanation for United Kingdom and West Germany's lower productivity is that their mines are older than ours, so that faces farther away from the mine mouth are being mined.

United Kingdom and West German productivity is not declining

Table 10 shows that U.S. productivity has declined while British and West German productivity has generally remained constant or increased slightly. U.K. and West German productivity has not declined for the following reasons: new workers receive greater training, absenteeism seems to be less disruptive to production, mine mechanization continues to increase, safety regulations were instituted earlier, government safety and health regulation may be less disruptive to mining operations, and workers are given production incentives.

The number of new workers entering the U.K.'s coal mining industry has generally been declining since 1961, while those entering into the U.S. coal mines have been increasing. 2/ British training requirements for new miners are more rigorous than ours.* Thus, fewer new workers are being added to Britain's coal mining work force, and they are better trained.

Secondly, unlike the United States, high absenteeism rates 3/ in the United Kingdom do not seem to reduce productivity. British miners are trained to perform several jobs so that absent members of a work team may be more easily replaced. Since workers are not trained to perform a range of jobs in the United States, workers are less interchangeable in U.S. mines. Thus, absenteeism may be more disruptive to production in U.S. mines.

A third reason productivity is not declining in the United Kingdom is that operations are still being mechanized. While the percent of coal produced with power loading machines in the United Kingdom has increased almost every year since 1969, the U.S. percentage has remained at about 99 percent since 1966. 4/ Thus, the United Kingdom's mining industry has greater room for increasing productivity-improving technologies than does the American industry.

British and West German mine safety and health regulations apparently hinder productivity less than U.S. regulation. For example, there appears to be no relationship between the introduction of major coal mine health and safety amendments and

*A mine machine operator will have received a minimum of 140 days of formal instruction and 60 days of continued close supervision.

Table 10

U.S. Underground Productivity is Higher Than British and West German But is Declining (1968-78)

	U.S.	U.K.	West Germany
	(Metric tons per manhour)		
1968	2.10	0.36	-
1969	2.08	0.38	-
1970	1.87	0.38	0.52
1971	1.64	0.30	-
1972	1.53	0.37	-
1973	1.51	0.40	-
1974	1.38	0.34	-
1975	1.20	0.43	0.53
1976	1.17	0.44	0.55
1977	1.13	0.42	0.55
1978	1.07	0.37	0.53

SOURCES: U.S. - U.S. Department of Labor, Mine Safety and Health Administration, "Injury Experience in Coal Mining" 1968-78 (Denver, Colorado: U.S. Department of Labor 1968-78), table on "Worktime, Production, and Productivity Data at Coal Mines in the U.S. by Kind of Coal and General Work Location." (1968-71: table 2, 1972-77: table 4, 1978: table 2), p. 13.

U.K. - U.K. Department of Energy, Report of H.M. Chief Inspector of Mines and Quarries (London, England: Her Majesty's Stationary Office, 1971, 1974), tables 3 and 5 (1968-74 manhours).

United Nations, Annual Bulletin of Coal Statistics for Europe (New York, New York: United Nations; 1979), table 2, pp. 60-62 (1975-78 man-hours).

National Coal Board, Statistical Tables 1977-78 (London, England: N.C.B., 1979), pp. 3-4 (1968-78 Production).

W. Germany - United Nations, Annual Bulletin of Coal Statistics for Europe (New York, New York: United Nations, 1979), table 2, p. 60 (all data).

productivity in the United Kingdom as demonstrated in figure 2. This may be because the most time consuming and costly health and safety practices were already required or practiced by industry before the new laws and amendments were enacted. Also, the regulations may not be as restrictive as in the United States. For example, the respirable dust level at the face in the United States cannot exceed 2 milligrams per cubic meter of air, about half the acceptable level at a United Kingdom longwall face.* 5/

The West German approach to dust regulation emphasizes flexibility. Instead of requiring the same ventilation in all mines, West Germany classifies work locations by their dust levels and sets restrictions on which miners can work, where, and how often. Work by lung-impaired miners in high-dust areas is restricted, and no worker may work more than 500 shifts during 5 consecutive years in the highest dust areas. Production is not allowed in mines with dust levels exceeding 12 mg/m^3. 6/

Methane monitoring and dust sampling are not required as frequently in British and West German mines. In the United States, the face must be tested for methane every 20 minutes. In the United Kingdom testing occurs every 4 hours and in West Germany every 2 hours. Testing is more frequent in West German mines if methane levels are high. Further, U.S. mining machines must have automatic methane monitors which will shut the machine down if the methane level is too high or if the monitor itself fails. Automatic methane monitors are only required in British mines where the methane level exceeds 0.5 percent in volume for six consecutive readings. 7/ Thus, unlike the United States, most British mines do not encounter production shutdowns from methane monitor failure.

British and West German mines utilize area dust sampling, while American mines use testers carried by individual miners. Miners in the United States have complained about being loaded down with dust samplers in addition to the other equipment they must carry. This is especially true in low coal. Further, more miners must be used to sample an environment than if an area sampling were used. However, MSHA is now moving towards area dust sampling in United States mines. Interestingly, it appears that both the United Kingdom and West Germany are moving toward individual sampling, as they consider it a more effective measure of dust exposure.

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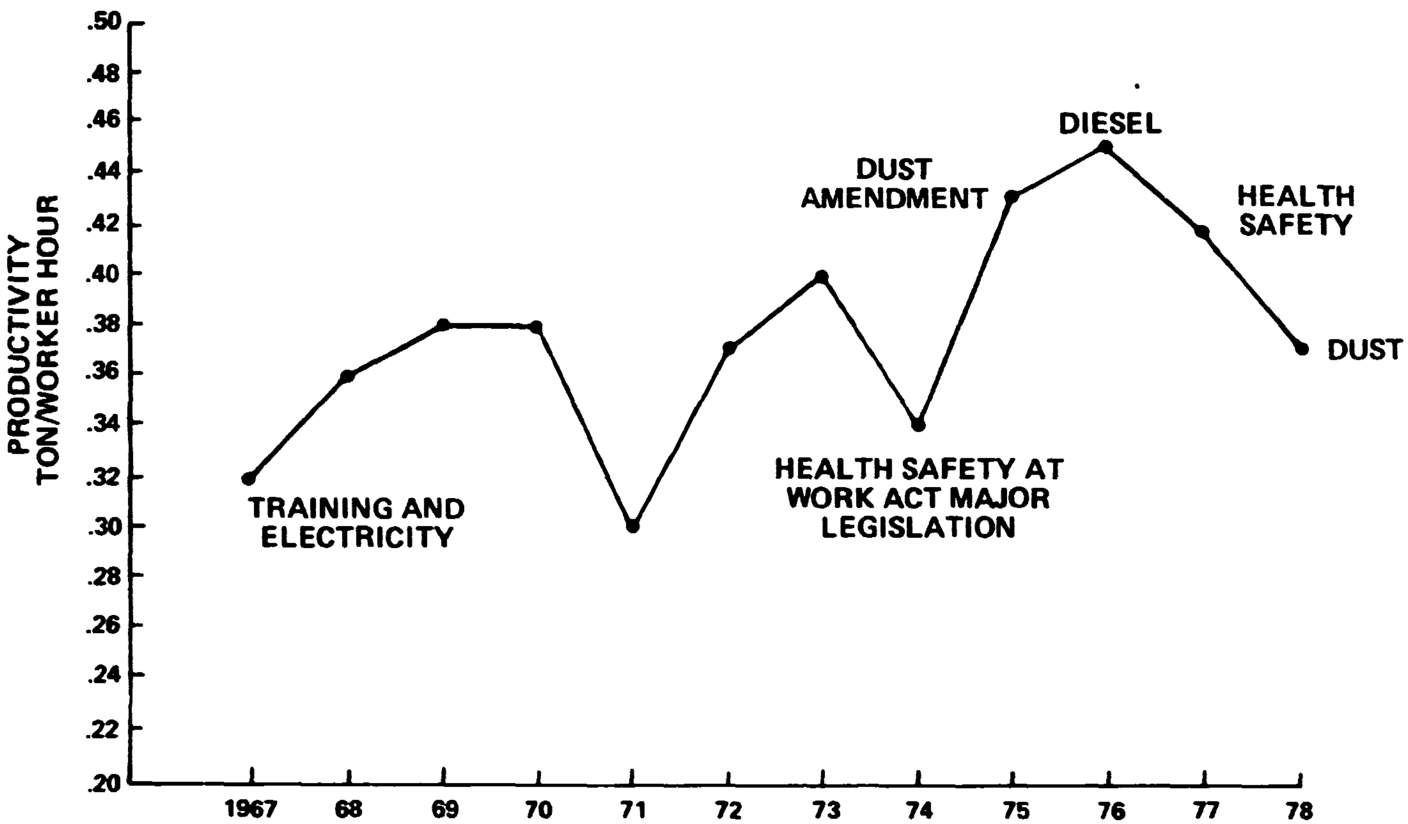
*It is difficult to compare U.S. and U.K. respirable dust levels since they are measured differently. Further, the U.K. standard was recently lowered.

FIGURE 2: UNDERGROUND PRODUCTIVITY VS. THE INTRODUCTION OF MINE SAFETY AND HEALTH REGULATION IN THE UNITED KINGDOM 1967-1978



Another reason safety and health regulation are less disruptive in the United Kingdom and West Germany than in the United States is that United Kingdom and West German mining industries appear to accept regulation more easily than their U.S. counterpart. One would expect the nationalized industry in the United Kingdom to accept regulation easily. In West Germany, regulations are established with direct cooperation and not just input from employee associations and the industry. Thus, industry and worker acceptance of the regulations is high.

British and West German mine operators also appear to have adjusted to regulation in ways that minimize its effect on productivity. For example, many British and West German mines have a central computer monitoring environmental changes in the mine. This removes the need to use labor for environmental monitoring and testing. A few U.S. companies such as Eastern Associated Coal Corporation and Consolidation Coal Company are already developing this type of system.

Finally, the United Kingdom and West Germany may have prevented a decline in productivity by giving miners production incentive bonuses. A production incentive bonus was introduced in the United Kingdom at the end of 1977. After 1 year of operation, productivity at the face rose by nearly 8 percent. 8/ In West Germany, both the government and the mining industry provide workers with incentive bonuses. Further, wages are partially determined by a piecework rate, encouraging production. While one concern with incentive programs is possible adverse effects on safety, the National Coal Board claimed that no appreciable increase in injuries occurred when these programs were instituted. National Coal Board data show that underground accident rates in the United Kingdom fell during 1977 and 1978. 9/ However, the fatality rate increased over this period. 10/ While the National Coal Board noted that rooffalls increased over the period, these occurred in mines which were not included in the production incentive plan. 11/ Thus, not enough evidence is available to prove whether or not the incentive plan had a detrimental effect on mine safety.

UNITED KINGDOM MINES ARE AS SAFE OR SAFER THAN U.S. MINES

Despite poorer geological conditions, British miners are less likely to be killed during each hour on the job than U.S. miners. U.S. mines are more or less safe than West German mines depending on whether safety is measured in terms of hours of worker exposure or tonnage produced. Table 11 shows fatality rates for underground coal mines using both measures. It was impossible to examine injury rates for these countries due to a lack of comparable data. In terms of man-hours worked, British mines are substantially safer than West

German mines, and U.S. mines are the least safe. However, since the 1969 Mine Health and Safety Act passed, the U.S. fatality rate has declined to a level comparable to West Germany. In terms of fatalities per ton produced, British mines are roughly equal to U.S. mines. However, due to the higher productivity in U.S. mines, the U.S. compares favorably with West Germany in this measure. Thus, British mines are as safe or safer than U.S. coal mines while the comparison with West German mines remains ambiguous.

It is surprising that U.S. mines have a higher rate of fatalities per million manhours than British and West German mines which are deeper than U.S. mines, generating more methane and pressure on roofs and floors. One would, therefore, expect that fatalities due to roof and ground falls and gas explosions would be greater in the U.K. and West Germany than in the U.S. However, the number of falls per million manhours of exposure in both countries is substantially lower than the United States rate over the past 15 years. 12/ In 1976, for example, the number of fatalities due to roof and ground falls per million manhours was .17 in the United States compared with .05 and .06 in the United Kindgom and West Germany respectively. Data also suggest that ignitions and explosions of coal dust and gas are more likely to kill American than British and West German workers. 13/ British and West German coal mines may have fewer fatalities per million manhours of exposure than U.S. mines largely because of their greater safety efforts and because longwall mining calls for fewer workers at the face.

The British and West German coal mining industries may be more safety conscious than the U.S. industry because the adverse geological conditions make mining more risky. More safety measures must be taken routinely such as methane drainage before mining, reinforcing underground facilities with concrete, and using ringed arch supports for roof and floor control. In West Germany, the mining industry is composed of a few large mines that can afford to make large capital investments in permanent supports and other safety items. 14/ The risky conditions also promote safety consciousness among both management and workers. British coal mines are probably the safest because they are managed by the National Coal Board, an arm of the British government. The government has greater financial resources at its disposal to modernize and improve conditions in the mines.

Both the British and West German governments have subsidized their coal mines, enabling more resources to be devoted to safety. Direct government subsidies to the coal mining industry in 1976 were \$0.20 and \$2.50 per metric ton for United Kingdom and West Germany respectively. 15/ If indirect and capital-related subsidies are included, the totals per metric ton are \$19.00 for the United Kingdom and \$14.10 for West

Table 11

Estimated Fatality Frequencies for U.S., British and West German Underground Coal Mines (1968-1976)

	Per million manhours			Per million metric tons		
	U.S.	U.K.	W. Germany	U.S.	U.K.	W. Germany
1968	1.80	0.23	0.51	1.09	0.65	-
1970	1.25	0.22	0.41	0.67	0.59	0.94
1972	0.72	0.19	0.46	0.47	0.52	
1974	0.52	0.14	0.34	0.38	0.34	-
1975	0.47	0.18	0.41	0.39	0.43	0.99
1976	0.48	0.16	0.38	0.41	0.37	0.90

SOURCES: U.S. Department of Labor, Mine Safety and Health Administration, "Injury Experience in Coal Mining," 1967-76 (Denver, Colorado: U.S. Department of Labor, 1968-76), tables 4 and 7 (1972-76), tables 2 and 5 (1967-71).

National Coal Board, Statistical Tables, 1977-78, (London, England: N.C.B. 1979), p. 4 (U.K. 1967-69) United Nations, Annual Bulletin of Coal Statistics for Europe, 1978. (New York, New York: United Nations, 1979), table 2, p. 162 (U.K. 1970).

United Kingdom Department of Energy, Report of H.M. Chief Inspector of Mines and Quarries for 1971 and 1974 (London, England: Her Majesty's Stationary Office, 1971, 1974), tables 3 and 5 (U.K. 1971, 1972).

Commission of the European Communities, 14th Report of the Mines Safety and Health Commission for the year 1976 (Luxembourg: Office for Official Pubications of the European Communities, 1978), table B and D (West Germany and United Kingdom), 1973-76.

Germany. 16/ These subsidies amount to about 40 percent of production cost. 17/ Further, by limiting coal imports and by taxing oil consumption, the government enables the coal industry to charge more for coal and thus have more to spend on mine safety.

The West German coal mining industry also receives an economic incentive to encourage safe mining operations. Each firm must contribute funds to an accident insurance program which are returned if there are no accidents or illnesses during the year.

The British and West German industries may also be more safety conscious. In the United Kingdom, workers are actually searched for smoking materials before entering the mine. Workers are also required to participate in an ongoing mandatory medical program to monitor coal-dust/related lung diseases. 18/ In West Germany, miners employed for longer than 1 month must have a health examination for lung conditions and other job related physical problems. Followup exams are required at least every 3 years. 19/ This allows the West German government to keep susceptible workers out of occupations and mines where they will be exposed to excessive dust.

Finally, miners in the United Kingdom and West Germany may be less likely to be killed on the job because they receive better training than their U.S. counterparts. In the United Kingdom, a coal mining machine operator receives at least 140 days of instruction and is supervised closely for at least his first 20 days in the mine. Workers must receive 40 additional days of close supervision to qualify in a specific mining occupation. 20/ West Germany has a 3-year apprenticeship program with special government-supported schools. 21/ In the United States, new underground miners are only required to receive 40 hours of safety training and no occupational training, while all miners must receive a minimum of 8-hours annual refresher training and retraining when moving to a new mine or task. 22/ However, MSHA's Director of Education and Training feels that large operators already train far beyond these minimums.

In addition to the greater safety efforts, the extensive use of longwall mining also reduces the likelihood that British and West German miners will be killed because less workers are at the mine face--the most dangerous area of the mine. The increased mechanization of longwall mining may also free workers to maintain roadways and perform other safety-oriented functions in the mine. Finally, the use of a longwall mining machine and continuous belt haulage from the face reduces the need for trailing electrical cables. The most frequent cause of fires in U.S. mines are failures with electrical equipment and more specifically problems with electrical cables.

PRODUCTIVITY AND SAFETY LESSONS LEARNED FROM EUROPEAN COAL MINING

British and West German mining regulations and practices suggest ways that the U.S. Government and industry may be able to improve productivity without reducing--and possibly improving--mine safety. Major areas for improvements in the U.S. mining industry are: mining technology, miners' training, industry acceptance of regulation, and the more extensive use of production incentive bonuses.

Switching to longwall mining, computer monitoring of the mining environment and methane drainage before mining are all technological changes that the U.S. industry could employ to enhance mine safety and productivity. One reason the U.S. coal industry has not found it economical to switch to longwall mining is that safety regulation sometimes requires that two or three entries be on each side of the longwall panel. In Europe, only one entry needs to be on each side. Further examination of the need for three entries in longwall mines may indicate whether our requirements are necessary.

Computer monitoring could provide mine management with instantaneous and continuous data on ventilation, methane, and dust in the mine. It can also be used to better organize the production process. However, if Federal regulation still requires the same hand testing or there is sufficient uncertainty as to what modifications MSHA will allow, there will be little real or perceived economic advantage in switching to the computerized system.

Methane drainage can be accomplished by drilling small holes into a seam and forcing steel pipes into the holes. Thus, methane is drained prior to mining the coal. It has already been practiced experimentally in this country and is used at about one-third of West German coal faces. A Battelle study concluded that the sale of the gas generally offset the cost of extracting it. 23/ Here again, there is presently little incentive for the U.S. coal mining industry to utilize this technique if ventilation and methane testing requirements remain the same.

Miners could also be given considerably more safety and skill training. Miners might also be trained in more facets of mining operations to reduce the disruptive effects of absenteeism.

Finally, both the Federal Government and industry might further explore the merits of production incentive bonuses and ways of using them without detracting from mine safety. The United States outlook for such bonuses is encouraging and is discussed in chapter 2.

FOOTNOTES

1/J. J. Breslin and R. J. Anderson, Observations on Current American, British, and West German Underground Coal-Mining Practices (Columbus, Ohio: Battelle Memorial Institute, 1976), pp. 18-46.

2/Management Engineers, Inc., Preliminary Analysis of the Probable Causes of Decreased Coal Mining Productivity (1969-1976), (Washington, D.C.: U.S. Department of Energy, Division of Solid Fuels, Mining and Preparation. VA: 1977), p. V-19,20; and National Coal Board, Statistical Tables 1977/8 (London: N.C.B., 1979), Table 2.

3/National Coal Board, p. 4; and unpublished data, U.S. Department of Labor, Bureau of Labor Statistics, Office of Current Employment Analysis.

4/National Coal Board, p. 4; National Coal Association. Coal Data (Washington, D.C.: NCA, 1979), p. 57.

5/U.S. Code of Federal Regulations 30 CFR 70. 100(b)(U.S.); U.S. Library of Congress, "Coal Mining Health Standards in Great Britian" (Washington, D.C.: Library of Congress, 1977), p. 4; and Murry Jacobson, U.S. Department of Labor, Mine Safety and Health Administration.

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8/National Coal Board. Reports and Accounts 78/9. (London, England: NCB, 1979), pp. 11, 18.

9/Ibid., p. 14.

10/Ibid., p. 14.

11/Ibid., p. 18.

12/U.K. Department of Energy, Report of H.M. Chief Inspector of Mines and Quarries, (London: Her Majesty's Stationary Office, 1971, 1974), Table 3; Commission of the European Communities, 13th and 14th Report of the Mines Safety and Health Communities, (Luxembourg: Office for Official Publications of the European Communities, 1977, 1978), Tables A, B, and la; and U.S. Department of Labor, Mine Safety and Health Administration, Injury Experience in Coal Mining (Denver, Colorado: U.S. Department of Labor, 1961-1977), Table II (9).

13/Commission of the European Communities, Table lb; and U.S. Department of Labor, Mine Safety and Health Administration, Table 11(9).

14/International Energy Agency, Steam Coal Prospects to 2000, (Paris: IEA, 1978), p. 67; and National Coal Board, Reports and Accounts 78/79, p. 11.

15/ICF, Inc., Technical Analysis of Steam Coal Prices in Six OECD Countries prepared for U.S. Department of Energy, Assistant Secretary for International Affairs, Office of Resource Trade (Washington, D.C.: ICF, Inc., 1978); pp. II-31, II-43.

16/Ibid., pp. II-34, II-48.

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19/U.S. Library of Congress, "Coal Mining Health Standards in the Federal Republic of Germany," p. 42.

20/National Coal Board, Deputy's Handbook, 1977, Chapter 13, pp. 101-109.

21/Breslin and Anderson, p. 57.

22/U.S. Congress. The Federal Mine Safety and Health Amendments Act of 1977, P.L. 95-164, Title I, Section 115(a) of the 1969 act as amended.

23/Breslin and Anderson, p. 113.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

PRODUCTIVITY DECLINE: A CONTINUING PROBLEM

The coal industry experienced more than a threefold increase in productivity between 1947 and 1969. Since 1969, however, productivity has declined by 26 percent. The decline has been more severe in underground mines than in surface mines. Since 1969, productivity in underground mines declined by 43 percent compared with a 29-percent decline in surface mines. In addition, underground mine productivity began to decline in 1969, while surface mine productivity leveled off until 1973 and then fell.

Differences between underground and surface mine productivity trends are due to differing causes of decline. Between 1970 and 1973, a major cause of underground productivity decline was the implementation of the Federal Mine Safety and Health regulations, while deteriorating labor-management relations was the primary cause of decline after 1973. Most underground mines followed similar productivity trends. In contrast, surface mining productivity decline was largely caused by the implementation of State reclamation laws. A secondary cause of declining surface mining productivity was the addition of less productive new mines between 1974 and 1977, a period of rapidly expanding coal production. New mines tend to be less productive because a greater percent of workers' time is spent on mine development work, a necessary but nonproductive activity. However, given the small production of the majority of these new mines, the overall impact on productivity would have been small. Finally, both underground and surface mine productivity are declining because mining technologies have not advanced sufficiently to offset losses due to other causes.

Some of the drop in productivity observed in both underground and surface mines may be permanent. In underground mines, MSHA regulation may have lowered productivity permanently. In surface mines, the implementation of State reclamation laws may also have caused a permanent productivity drop, while the implementation of the Federal Surface Mining Control and Reclamation Act of 1977 might continue to reduce productivity. However detrimental to productivity, Government regulation has served the important function of protecting miners' health and safety and the environment. Government regulation may be viewed as a method for internalizing safety and environmental costs of coal production.

Future productivity decline will not be offset by an increasing switch to surface mine production to the extent that it was between 1969 and 1978. Overall coal industry productivity decline between 1969 and 1978 would have been far greater had it not been for the increasing share of coal produced by surface mining. In 1969, 63 percent of coal was produced by underground mining and 37 percent by surface mining. In 1978, the percent shares were reversed. Surface mining is more than twice as productive than underground mining. Thus, increasing surface mining's share of production improved overall industry productivity. In addition, the switch to mining coal from thick Western seams also lessened the decline. In 1977, for example, 18 percent of all surface production came from Montana and Wyoming compared with 5 percent in 1971. Growth in surface mine production cannot continue at the rapid rate that occurred between 1969 and 1978. Thus, less of a positive productivity effect of switching to surface mining will be available in the future to offset productivity decline elsewhere.

Coal mining productivity decline is a problem of national concern. Low productivity increases our coal mining costs and manpower requirements. If productivity continues its present decline, the manpower required to reach the Federal coal production goal of 1 billion tons in 1985 would double. Further, rising labor costs due to low productivity hurts the ability of coal and coal based synthetic fuels to compete with oil and gas. Thus, low productivity is a deterrent to meeting national energy goals of converting users of scarce oil and gas to coal so as to reduce oil and gas import dependence.

Low productivity: causes and cures

Given the importance of reducing oil and gas import dependence, we examined ways in which coal industry management and workers and the Federal Government could ameliorate the causes of productivity decline and improve productivity. The areas amenable to change that could render substantial productivity improvements are labor-management relations and mining technology and the interface between new technology and Federal mine safety and health regulation.

Labor and management

We found that an adversary relationship has existed between management and labor in underground coal mining. This relationship is rooted in past hostilities and basic changes which have occurred in both parties since the 1960s. This increased strain was reflected in the growing number of work stoppages since 1968. Closely related to this is the high level of absenteeism which presently exists in the industry. Increased stress between management and labor has been costly in terms of declining productivity. Solutions to this situation center mainly with the United Mine Workers and management itself. Both must come to recognize that their futures are tied closely to the economic well being of the coal industry. Our examination of this aspect of the productivity problem has led us to conclude that the following actions, if pursued vigorously by labor and management, would make for both higher productivity and greater labor peace:

--Labor and management should increase their efforts to improve communication and cooperation at all levels.

--Management should convey a willingness to listen and respond to labor's problems and emphasize training of supervisory personnel in labor-management relations.

--The union should recognize management's need to have a stable work force by maintaining a low level of work stoppages and effectively addressing the issue of absenteeism within its membership.

--Labor and management at individual mines working together should design realistic production incentive plans which encourage increased safety and productivity.

--Labor and management should increase their efforts to resolve local issues at the local level.

--To improve the reliability of existing mining equipment, coal operators should increase preventive maintenance programs and training for shift mechanics.

Federal support for joint labor-management committees is one vehicle through which such actions could be pursued. The Federal Mediation and Conciliation Service has the authority, under the Labor Management Cooperation Act of 1978, to fund joint labor-management committees. These committees can help to stabilize the labor relations climate in a particular industry or area and thus contribute to the process of regional economic development. The Federal Mediation and Conciliation Service expects to begin funding committees in 1981.

The Federal Government's role in improving coal industry labor-management relations has been limited to expediting arbitration procedures and mediating disputes. Given the national importance of improving productivity and maintaining a steady coal supply, further Federal involvement is warranted. While assistance in resolving conflicts is a valuable contribution, it would be fruitful to address the causes of poor labor-management relations. Issues involving general management (e.g., overtime, vacations, etc.,) are the largest causes of wildcat strikes. The failure of labor and management to communicate effectively in handling grievance procedures has been found to be the single largest cause of disputes. Improvements in human relations are needed to address the entrenched causes of poor labor-management relations. Managers should receive supervisory training, while labor representatives and managers alike could benefit from training in effective communication and grievance handling. We recommend that

--the Congress authorize the Department of Labor to fund coal industry programs to train coal management and labor in effective communication and grievance handling.

<u>Federal Mine Safety and Health Regulation</u>

Federal coal mine safety and health regulation was a primary cause of declining underground productivity between 1970 and 1973 but was less important afterwards. Since the practices required by MSHA that caused the decline in the early 1970s continue, some of the productivity drop will be permanent. The Bureau of Mines and coal equipment manufacturers have developed safety technologies which potentially could reduce the adverse productivity impacts of MSHA regulations. However, these technologies have not been adequately transferred to the coal mining industry due to a lack of adequate in-mine testing and uncertainty over MSHA's willingness to grant petitions for modification to operators using new technologies from productivity-reducing regulations.

<u>Recommendations</u>:

--Since the weakest link in the commercialization chain is in-mine testing, the Bureau should ensure that its products are adequately tested in working coal mines to establish and demonstrate their benefits.

--MSHA should devise ways to minimize the regulatory lag which now delays introduction of productivity enhancing equipment that does not impair mine safety.

MSHA regulation has reduced coal mine fatalities and disasters dramatically. In fact, regulations that have caused productivity decline are the same ones responsible for reducing fatalities and disasters. However, MSHA regulation has not effectively reduced the frequency of nonfatal disabling injuries caused primarily by worker error. Increased on-the-job safety training of both supervisors and workers should help reduce these types of injuries.

Recommendation:

--The Congress should increase the required minimum amount of on-the-job safety training for supervisors and miners.

--The Secretary of Labor should direct MSHA to analyze the impact on industry of increasing training requirements and provide further assistance if warranted.

Technology

While coal mining technology has not caused productivity to decline, it has not advanced sufficiently to offset the loss due to other causes. In underground mines, coal cutting and haulage are areas where technological improvements could increase productivity substantially. Two reasons why underground coal cutting technology has not advanced substantially are that continuous mining did not realize its productive advantage over conventional mining and the expected switch to highly productive longwall mining did not materialize. Improving the reliability of continuous miners, offsetting some of MSHA regulation's adverse productivity effects on continuous miners, and improving longwall mining techniques should improve coal cutting productivity substantially. Improving haulage from the face will allow sophisticated cutting machines to reach their full productive potential. The Department of Energy is engaged in research on advanced mining systems that should yield high productivity gains, but their coal mining R&D budget is shrinking.

Recommendation:

--Given that expanding coal production is an important national energy goal, the Secretary of Energy should direct the Office of Coal Mining to increase efforts in those areas which have high potential for productivity gains. Those projects that should receive special attention are ones which reduce MSHA regulation's adverse productivity impacts, improve longwall mining techniques, and improve face haulage.

AGENCY COMMENTS

Comments on a draft of this report were solicited from the Departments of Energy, the Interior, and Labor. Their formal responses are reprinted in appendixes II and III to this report.

The Department of Energy provided numerous informal editorial comments which we considered in this final report but had no official comments.

The Department of the Interior concurred with the major findings and recommendations of our report. They did raise the point that the Department of Energy has no significant expertise in dealing with training in labor management relations and should therefore not become involved in the training of miners and management. They further noted that the Department of Labor has already developed expertise in these areas. We agree our recommendation reflects this. Interior also provided numerous technical and editorial comments which they stated "may help strengthen the report." We have made changes in the report reflecting these suggestions when appropriate.

The Department of Labor stated that "GAO has presented an objective and detailed report which clearly illustrates the problems facing the coal industry." Labor concurred with our recommendations for increased training of labor and management in the areas of safety and effective communciation and grievance handling. However, they did not agree that MSHA should establish an agency-wide policy on exempting new Bureau of Mines safety technology from productivity reducing regulations. They pointed out that MSHA can only grant modifications not exemptions to safety standards and it can do so only on an individual mine basis.

In addition, MSHA is in the process of establishing a system for revision of standards for which a large number of petitions for modifications are granted. Through this system MSHA hopes to create a climate in which new technologies are recognized and further developments are encouraged.

We recognize MSHA efforts in developing a system for reviewing standards. Our concern, however, is on how to reduce the uncertainty surrounding MSHA acceptance of new technologies so that industry will more quickly adopt them. On examination, MSHA's present system for revising standards was found to be cumbersome and time consuming. In practice, it usually takes about 4 years from the time MSHA decides it wants to change a standard until the time it actually becomes law. This 4-year period does not include the development time for a new technology or the time needed for in-mine testing. Given the positive benefits possible through greater acceptance by the industry of new BOM technology, it is important that MSHA make every effort to shorten the period of time needed to change the relevant standard. The report therefore recommends that MSHA devise ways to minimize the regulatory lag which now delays introduction of productivity enhancing equipment that does not impair mine safety.

ECONOMETRIC METHODS,

DATA, AND RESULTS

This appendix describes estimated microeconomic production functions for underground and surface coal mines on the basis of individual mine data for the years 1972-77. The estimated production functions were used to test a variety of hypotheses concerning the sources of productivity decline in U.S. coal mining. It also reports on an analysis of the effect of labor turnover on coal mine labor productivity.

Most production function studies are done at some aggregate level of data such as States, all manufacturing, two-digit industries, etc. 1/ Those studies that use individual firm data use capital aggregates constructed from fire insurance valuations or book values of capital stocks. 2/ The difficulties involved in creating a capital aggregate are well known. This study avoided aggregation error by using individual mine data and avoided the errors in variables that can arise from using capital aggregates by using physical measures of capital inputs. Thus, the estimated function is very close to the textbook microeconomic production function.

METHODOLOGY

The basic postulated production function for each mine has the standard form for such functions based on micro data:

$$q = f(x_1, \ldots, x_n) \qquad (1)$$

where q is the output of a given mine and the x_j represent the variable inputs, measured as flows per unit time. Mining production is a function of various kinds and qualities of capital, labor, energy, and materials as well as certain geological inputs that are peculiar to mining (e.g., seam thickness, depth, water conditions, gas conditions, floor conditions, etc.) In addition, some occupational hazards can be considered shifters on the production function in the sense that reduction of these hazards may reduce output and productivity for given levels of capital and labor input. There can be technical progress in mining that shifts the production function and allows a greater amount of ore extraction for given input levels and geological conditions.

Following Herfindahl and Kneese we assumed that depletion takes the form of changes in the geological conditions of the mine. 4/ The most obvious example is that the seam may become progressively thinner as extraction proceeds. Similarly, the mine may have to go progressively deeper or it may encounter adverse gas, water, roof, or floor conditons as production continues. Thus, the production function can show constant returns to scale as long as the geological conditions are unchanged.

To estimate equation (1) we used a Cobb-Douglas form. 5/ The Cobb-Douglas can be considered a linear approximation to any production function expressed in logarithms and may therefore be a reasonable starting point. 6/ We postulated the following production function which is presumed to hold for all mines:

$$q_{it} = A_{it} \prod_{j=1}^{J} K_{jit}^{\alpha_j} L_{it}^{\beta} \qquad (2)$$

where q_{it} is the output of mine i in year t, K_{jit} and L_{it} are the corresponding inputs of capital of type j and labor, respectively, and A_{it} is a shift or productivity variable which incorporates the effects of geological conditions, capital and labor quality, management, technical change, and depletion effects of cumulative production. In an effort to specify the shift variable more concretely, we hypothesized that:

$$A_{it} = \exp \{\gamma_i + \delta_t + \sum_{k=1}^{K} \theta_k X_{kit} + U_{it}\} \qquad (3)$$

where the X_k are shift variables incorporating the effects of geological conditions, input quality, and other measurable variables, γ_i is an intercept that is unique to mine i and captures the effects of any mine specific omitted variables, γ_i is the year intercept that incorporates omitted time effects such as neutral technological change and depletion not measured by other included variables, and U_{it} is a random error term which is assumed to be normally and independently distributed with zero mean and constant variance.

The final form of the estimating equation is:

$$\ln q_{it} = \sum_{j=1}^{J} \alpha_j \ln K_{jit} + \beta \ln L_{it} + \sum_{k=1}^{K} \theta_k X_{kit} + \sum_{i=1}^{N} \gamma_i D_i + \sum_{t=1}^{T} \delta_t D_t + U_{it} \qquad (4)$$

where D_i is a dummy variable for each mine and δ_i is a dummy variable for each year. The γ_i coefficients, which estimate individual mine productivity, are of interest in a second stage regression utilizing cross section data that are not available in time series:

$$\hat{\gamma}_i = \hat{\gamma}(z_i) \tag{5}$$

where $\hat{\gamma}_i$ is the estimated individual mine intercept and z_i is a vector of cross section variables which were omitted from the first stage regression for lack of data on further geological conditions, regulatory effects, and other determinants of individual mine productivity.

THE DATA BASE

The unique advantage of this study is its use of individual mine data, requested by us from the Department of Energy (DOE), the Coal Mine Safety and Health Administration (MSHA), and the United Mine Workers of America (UMW). Output is measured in physical units (tons) while capital inputs are measured as capacities or numbers of machines of a given type. 7/ Labor input is measured in manhours.

We utilized six data bases in the analysis. These were: underground and surface mines which produced each year between 1972 and 1977, underground and surface mines whose first full year of production was in 1977 ("new mines"), and a special sample of Kentucky underground and surface mines in operation during 1972-74.

These data bases were assembled using a master list of all mines reporting production and manhour data to the MSHA. All other data are matched to the mines on this list. The reasons for preferring the MSHA production and manhour data were (1) all mines are required to report such data to MSHA, but not to DOE; and (2) the UMW uses these data to determine employer contributions to its pension fund. Given that MSHA data collection has the force of law, and that the UMW is willing to trust the pensions of its members to this data, we felt it to be the most reliable. Later, when we found numerous errors in the DOE data, our confidence in the superiority of MSHA data was confirmed.

Starting with a universe of 604 underground and 569 surface mines which produced coal every year between 1972 and 1977, we eliminated those mines which were missing data on one or more of the needed variables. This screening process reduced the number of underground mines with all needed data to 177, and the number of surface mines to 120. The great majority of missing data turned out to be DOE technology (capital equipment) data.

The same process was used to winnow out mines for our analysis of "new" mines. Here, of the 383 underground mines whose first full year of production was 1977, we wound up with 56, of 538 surface mines we kept 173.

The 177 underground and 120 surface mines were satisfactory in all but one respect--they included only 4 underground and 1 surface mine in Kentucky. Here, the problem was that practically no mines had fully responded to DOE's (previously BOM's) 1975 survey. To increase Kentucky mine representation, we assembled surface and underground data bases for Kentucky for 1972-74, years of active MSHA implementation. We were able to retrieve 48 underground and 22 surface Kentucky mines with all needed data for the 1972-74 period.

Both underground and surface mine functions were estimated. The capital variables in the underground production function are mine car capacity, trailer capacity, shuttle car and shuttle buggy capacity, track length, conveyor belt length, and numbers of: cutting machines, roof drills, mobile loaders, longwall mining machines, and continuous mining machines. The geology of the mine is characterized by seam thickness which is the only available data. The shift variables in the production function include two types of injuries to capture the injury-productivity tradeoff (INJ1, temporarily disabling injuries, and INJ2, permanently disabling injuries and deaths). We also include the proportion of miners in three age groups (18-24, 25-34, and 35-44, leaving 45-65 as the excluded category) in an attempt to include the productivity effects of experience. 4/ Finally, we include the ratio of coal not sold on the open market to total coal production, this "captive ratio," indicates the extent to which administrative controls have supplanted market forces in enforcing efficiency.

For surface mines the capital inputs are power shovel capacity, carryall scrapers (used primarily for reclamation), bulldozers, front-end loaders, wheel excavators, and coal drills. As this list of inputs indicates, we conceive the process of mining to be uncovering the ore and separating the coal from the ore body. Transporting coal from the mine is considered a separate process.

The geology of the mine is assumed to be summarized by the stripping ratio, the ratio is overburden to seam thickness. Exhaustion would take the form of declining seam thickness, while increasing depth will increase the overburden. In either case, the stripping ratio will rise. Therefore, we expect a negative coefficient on this variable. We also include dummy variable for reclamation laws which takes the unit value for mines in States in years that were enforcing reclamation laws. 8/ Also included in the regression are the same labor and labor quality variables (manhours and three age categories) as in the underground equation and the same injury variables. We also include the captive ratio, although most surface mines sell entirely on the open market. The variable names, definitions, and means for underground and surface mines are presented in tables 1 and 2.

The age variables were derived by a complex process. First, we obtained the records of MSHA's dust sampling program, where all miners are tested for exposure to excessive coal dust. These records gave us a complete list of social security numbers of miners working in each mine. Second, we identified all miners who were injured in any year (1972-77) by social security number. Age data are kept on all injured miners, so by matching the dust sample and injury files we were able to place all injured miners in whatever mine they worked during the entire period. This technique identified 78,400 miners.

We then took the remaining Dust Sample social security numbers and matched them against age records of United Mine Workers of America members for 1976. This identified 109,292 more miners who were in turn traced to all mines in which they worked between 1972 and 1977. These two matching exercises "found" most miners. In 1976, of a grand total of 193,695 active miners, we were able to locate 138,292 and assign them appropriate ages.

Table 1

Underground Mines
Variable Definitions, Means
and Sources of Data

Variable	Definition	Mean	Source
Q	Production per year (thousand tons)	596.9	MSHA
K1	Mine car capacity (tons)	1087.5	DOE
K2	Track length (miles)	7.5	DOE
K3	Trailer capacity (tons)	7.5	DOE
K4	Shuttle car capacity (tons)	76.8	DOE
K5	Shuttle buggy capacity (tons)	0.1	DOE
K6	Belt conveyor length (thousand feet)	21.4	DOE
K7	Cutting machines	1.1	DOE
K8	Roof drills	7.5	DOE
K9	Mobile loading machines	1.5	DOE
K10	Longwall machines	0.2	DOE
K11	Continuous mining machines	4.8	DOE
L	Manhours (thousands)	396.6	MSHA
Th	Seam thickness (inches)	60.9	MSHA/DOE
A1	Percent miners between 18-24	0.28	MSHA/UMW
A2	" " " 25-34	0.28	MSHA/UMW
A3	" " " 35-44	0.16	MSHA/UMW
I1	Permanently disabling and fatal injuries	0.5	MSHA
I2	Temporarily disabling injuries	25.5	MSHA
C	Captive ratio (percent not sold on open market)	0.21	DOE

 APPENDIX I

Table 2

Surface Mines
Variable Definitions, Means and Sources of Data

Variable	Definition	Mean	Source
Q	Production per year (thousand tons)	691.4	MSHA
K1	Power shovel capacity (tons)	21.7	DOE
K2	Dragline capacity	24.4	DOE
K3	Carryall scrapers	1.1	DOE
K4	Bulldozers	5.9	DOE
K5	Front-end loaders	3.2	DOE
K6	Wheel excavators	0.1	DOE
K7	Coal drills	0.3	DOE
L	Manhours (thousands)	58.4	MSHA
SR	Stripping ratio	1.1	MSHA/DOE
A1	Percent miners between 18-24	0.19	MSHA/UMW
A2	" " " 25-34	0.28	MSHA/UMW
A3	" " " 35-44	0.20	MSHA/UMW
I1	Permanently disabling and fatal injuries	0.2	MSHA
I2	Temporarily disabling injuries	2.6	MSHA
C	Captive ratio (percent not sold on open market)	0.05	DOE

ECONOMETRIC TECHNIQUE

The estimation technique, least squares dummy variables (LSDV), uses dummy variables created for each mine and each year. We chose this method over two other pooling techniques (ordinary least squares and variance-components) because both these alternatives are biased in the presence of omitted variables. Although the information on inputs is unusually complete, there are several omitted variables (e.g., regulation effects, geological conditions other than seam thickness and overburden, management efficiency, and other mine specific attributes). Estimating productivity change using dummy variables avoids postulating a constant trend, does not require the assumption of producer equilibrium, and does not collect random errors into the productivity series. Thus, we use LSDV both because of its attractive econometric properties and also because the estimated dummy variable coefficients are interesting in their own right.

One problem is possible simultaneous equation bias that could occur if the production function is only one equation in a simultaneous equation model of firm behavior. We can sidestep this problem in the Cobb-Douglas context by assuming that the firm maximizes expected profits and relies on the theorem by Zellner, Kmenta, and Dreze which states that under these conditions inputs are independent of the error term in the production function. 9/

Pooling cross section and time series data raises the possibility that our estimates will suffer from the twin horrors of autocorrelation and heteroskedasticity. However, the effects of both autocorrelation and heteroskedasticity are reduced in LSDV due to the presence of mine dummy variables, which reduce some of the cross section variation, and time dummy variables, which reduce the time effects. These considerations, along with the absence of any compelling reason to suppose severe heteroskedasticity in these data, led us to conclude that we could ignore heteroskedasticity as a problem. However, since almost all economic time series data show some autocorrelation, we attempted an autocorrelation correction. The most reasonable starting place seemed to be that each cross section should be allowed to have its own autocorrelation coeeficient, computed as $\hat{\rho}_i = \sum_t e_{it}e_{it-1}/\sum_t e_{it}^2$ for each mine. However, with only 6 years of data, the estimates of the autocorrelation coefficients were very inefficient and extremely variable, with estimates ranging from less than negative one to greater than one. As a result, we concluded that we were adding more noise than information with this correction. In an attempt to derive a more efficient estimate, we constrained the autocorrelation coefficient to be equal across mines and equal to the mean $\hat{\rho}_i$. This procedure resulted in estimated autocorrelation coefficient so close to zero that it made virtually no difference in the LSDV estimates. We decided to make no autocorrelation correction, and to report the original LSDV results.

Thus, we believe our results to be free of serious autocorrelation or heteroskedasticity, omitted variable bias, or simultaneous equation bias. Examination of the matrix of correlation coefficients among the independent variables revealed the expected low correlations for microdata, so that multicollinearity is apparently not a problem. Finally, since we have observations on individual mines which avoids aggregation error and capital inputs measured in physical units, we are fairly certain that there are no serious errors in variables. In light of these considerations, we expect clean estimates from our regressions based on the LSDV technique and previously unavailable microdata.

RESULTS

Underground mines. 1972-77

The estimates of the underground mine production function coefficients are presented in table 3. The production function is constrained to constant returns to scale for the reasons discussed in section III. It is customary to test for constant returns to scale by testing if the sum of the coefficients of the Cobb-Douglas production function is different from 1. We performed this test, the t-statistic testing the null hypothesis of constant returns to scale was 1.54 which is not significant at the .05 level. Coefficients on six of the capital variables (railroad track length, shuttle cars, conveyor belt length, cutting machines, longwall machines, and continuous mining machines) are positive and significant at the .05 level. The rest of the capital inputs have estimated coefficients which are not significantly different from zero (mine cars, trailer capacity, shuttle buggies, roof drills, and mobile loaders). These insignificant coefficients could be due to some overinvestment in these kinds of capital, either because of mandated safety requirements (e.g., roof bolting), or because of some indivisibilities not captured by the Cobb-Douglas specification. The coefficient on manhours is positive and significant.

Of the various mining methods, cutting machines, representing the conventional mining technique, has the highest elasticity. Both longwall and continuous mining machines, representing more advanced technology, have lower elasticities than the conventional method. This is consistent with Baker's finding that MSHA regulations have reduced the advantage of continuous mining techniques relative to conventional methods. 10/

With respect to the poor showing of longwall machines, this may be due to the fact that we only have the number of longwall machines rather than their actual input in machine-hours. A common problem with longwall machines is their downtime due to frequent breakdowns and the long time it takes to move them from one coal face to another as mining proceeds.

The coefficient on seam thickness is insignificant. This could be because seam thickness is only relevant in combination with other geological factors (slope, depth, roof conditions, gas conditions, etc.) which are better captured by the individual mine dummy variables. The coefficients on the age distribution variables are not significant at the .05 level (two-tailed). We take this as evidence that the influx of young miners during the early 1970s was not responsible for a significant amount of the productivity decline. The injury variables attempt to capture the injury-productivity tradeoff inherent in coal mining and other risky occupations. The coefficient on the number of permanently disabling and fatal injuries (INJ1) is not significantly different from zero, indicating that reducing these very serious injuries does not lower output. 11/ The coefficient on temporarily disabling injuries (lnJ2) is positive and significant, indicating a tradeoff between output and these less serious injuries. Evaluated at the means, the elasticity of output with respect to temporarily disabling injuries is 0.13.

The captive ratio (percent of output not sold on the open market) is included to measure the effect of administrative controls as opposed to market forces on coal mine productivity. The coefficient on the captive ratio is positive and significant, indicating that administrative controls increase productivity. This could be due to a reduction in risk that may allow a more efficient allocation of resources and better timing of investment and production decisions. It may also be "gold plating," i.e., buying more productive equipment than is justified on cost grounds alone. Since management of a captive mine is judged on reliability of deliveries relatively more than on costs that can often be passed forward, higher physical productivity may go hand in hand with high production costs.

The last coefficients listed in table 3 are those associated with the year dummy variables which estimate pure time effects not captured elsewhere. This measures total factor productivity change overtime and is significantly negative from 1972-77. If these estimates are correct there has been, taking 1977 as the base, an incredible 45-percent decline in underground coal mine productivity, holding capital, labor, seam thickness, injuries, and the age distribution of the work force constant. Thus, while total factor productivity

Table 3

Restricted LSDV Underground Mine Production Function

Dependent variable: lnQ

	Independent variable	Coefficient	t-ratio
lnK1	Mine car capacity	.012	1.20
lnK2	Track length	.064	2.25
lnK3	Trailer capacity	-.012	-1.16
lnK4	Shuttle car capacity	.211	7.32
lnK5	Shuttle buggy capacity	-.0003	-0.01
lnK6	Belt length	.018	2.45
lnK7	Cutting machines	.238	5.90
lnK8	Roof drills	.026	1.26
lnK9	Mobile loaders	-.022	-0.90
lnK10	Longwall machines	.115	2.07
lnK11	Continuous mining machines	.132	3.42
lnL	Manhours	.217	11.19
Th	Seam thickness	-.001	-0.94
A1	Age 1 (18-24)	.033	0.35
A2	Age 2 (25-34)	-.014	-1.49
A3	Age 3 (35-44)	-.232	-1.90
INJ1	Permanent injuries	-.006	-0.52
INJ2	Temporary injuries	.005	6.76
C	Captive ratio	.192	3.59
	D1972	0.454	11.53
	D1973	0.477	13.09
	D1974	0.330	9.86

Table 3 (continued)

D1975	0.304	9.72
D1976	0.206	6.83
INTERCEPT	8.328	32.22

RSQ = .94 F = 62.65 N = 1062 DF = 862 DW = 1.89

is a measure of ignorance, we can say that we must look beyond the factors listed above for the causes of this productivity decline of almost 12 percent per year. In section VI we use the estimated individual mine coefficients, which measure differential mine productivity, to help identify possible sources of this productivity change.

Surface mines. 1972-77

The restricted LSDV estimates of the Cobb-Douglas production function for surface mines are reported in table 4. The test statistic for the hypothesis of constant returns to scale is t = 0.55 which is not significantly different from zero at the .05 level. We therefore cannot reject the null hypothesis of constant returns to scale in surface mining. Of the capital variables, draglines, bulldozers, front-end loaders, wheel excavators, and coal drills are significant and positive at the .05 level. The remaining capital inputs (power shovels and carryall scrapers) are not significant. The coefficient on power shovel capacity is positive as expected while the coefficient on carryall scrapers, which are used primarily for land reclamation, is appropriately negative. Of the available technologies wheel excavators have the highest output elasticity. However, while wheel excavators are very productive for both coal production and overburden removal, they can only be used on relatively soft material. The other highly productive technique is the combination of coal drills and front-end loaders. The coal drills are used to plant explosives, and the freed coal is scooped up by the loaders. This is the standard technique of open pit mining in the West. Manhours are also significant, although the estimated elasticity is low.

The geological conditions of the mine are summarized by the stripping ratio, the ratio of overburden to seam thickness. This variable is highly significant, with the expected negative sign. The age distribution of the work force is not significant. This indicates that, as in underground mining, the changing age distribution of miners has had no significant effect on mine productivity. The findings with respect to the injury variables are also similar to underground mining, namely that risking very serious injury does not significantly increase output, but there does seem to be a tradeoff between temporarily disabling injuries and output. The elasticity of output with respect to INJ2 is even smaller for surface mines than it is for underground mines at .07.

Unlike the regression for underground mines, the captive ratio is insignificant for surface mines. This is reasonable, since less than 1 percent of surface mined coal was sold on the open market in 1977.

Table 4

Restricted LSDV Surface Mine Production Function

Dependent variable: lnQ

	Independent variable	Coefficient	t-ratio
lnK1	Power Shovel capacity	.028	1.33
lnK2	Dragline capacity	.044	1.87
lnK3	Carryall scrapers	-.059	-1.46
lnK4	Bulldozers	.132	2.15
lnK5	Front-end loaders	.287	5.30
lnK6	Wheel excavators	.300	3.22
lnK7	Coal drills	.242	3.10
lnL	Manhours	.025	2.20
SR	Stripping ratio	-.135	-3.31
A1	Age 1 (18-24)	.034	0.55
A2	Age 2 (25-34)	.043	0.77
A3	Age 3 (35-44)	.063	0.96
INJ1	Permanent injuries	.034	1.03
INJ2	Temporarily disabling injuries	.025	4.15
C	Captive ratio	.018	0.11
D1972		.033	0.54
D1973		.120	2.09
D1974		.148	2.92
D1975		.066	1.38
D1976		.026	0.55
INTERCEPT		12.261	45.80

RSQ = .94 F = 62.47 N = 720 DF = 580 DW = 1.83

The year dummy variables again capture the time effect on productivity, controlling for the variables included in the regression. The coefficients on the year dummy variables are a measure of neutral productivity change that does not impose a constant trend or collect random errors. Unlike underground mines, productivity in surface mining actually rose between 1972 and 1974. However, there has been a 15-percent decline in productivity from 1974-77. While this is one-third the rate of decline of productivity in underground mining, it does indicate that productivity is being affected in both surface and underground mining by factors other than those included in the regression equation.

ANALYSIS OF DIFFERENTIAL MINE PRODUCTIVITY

The LSDV regressions require a dummy variable for each mine to capture the effects of mine-specific omitted variables. These coefficients measure productivity differentials across mines in that they act as shifters on the production function. For example, geological conditions peculiar to a given mine could make the extraction of coal harder or easier than for mines which use the same extraction techniques but face different geological conditions. Similarly, management is an omitted variable in almost all production function studies, but obviously management experience and expertise will vary across mines and cause productivity to vary. Also, regulatory enforcement could vary across mines. For example, MSHA inspectors could concentrate on large mines, possibly reducing their productivity relative to smaller mines. Finally, mines may "learn by doing" if mines producing the largest cumulative output also gain experience which can result in higher productivity. 12/ The estimated individual mine intercepts from the LSDV regressions allow us to investigate some of these possible sources of mine productivity. We therefore estimated a cross section regression of the form of equation (5) above for underground and surface mines utilizing data that is available only in cross sections.

Underground mines

The variables, definitions, and means for the underground cross section regression are presented in table 5. The only additional geological variable is METH, the methane level of the mine, measured as a categorical variable taking the values 0-4 with 4 being the highest methane level. We expect higher methane levels to lower mine productivity.

Table 5

Variables for Cross Section Underground Mine Regression

Variable	Definition	Mean	Source
DI	Productivity	8.35	
METH	Methane level	1.43	MSHA
CP	Cumulated production (million tons)	3.58	MSHA
CP^2	Cumulated production (squared)	23.21	MSHA
G	Gravity points	1203.7	MSHA
INSP	Number of inspection days	253.22	MSHA
VIOL	Number of violations	148.97	MSHA

We consider ore body exhaustion to be captured by seam thickness. Nevertheless, there are additional geological factors concerned with resource exhaustion (depth, ore quality, etc.,) not measured directly and whose influence is collected by the mine dummy variables. Thus, some additional effects of exhaustion could be captured by production cumulated over the years in our sample. However, while cumulated production may represent ore exhaustion it also represents the learning by doing which accompanies the operation of a given mine. This is a source of productivity differentials across mines. Thus, both the negative effects of ore exhaustion and the positive effects of learning by doing are captured by cumulative output. We therefore have no hypothesis concerning the sign of the coefficient on cumulated production. However, we also include cumulated production squared (CP^2) to allow for the possibility that the effect of cumulated production is not constant. For example, the learning by doing effect may dominate initially but eventually be overtaken by the negative effects of resource exhaustion. Our priors are that the coefficient on CP^2 will be negative.

We obtained data on three variables which measure aspects of the health and safety regulation of underground mining. These are gravity points (G), inspection-days (INSP), and violations (VIOL). Gravity points are awarded by MSHA inspectors on the basis of the seriousness of a given violation. The higher the number of gravity points the more dangerous are the mine's practices in the opinion of MSHA inspectors. Since it is unclear just what influence serious injuries have, we have no prior belief concerning the sign of this coefficient.

Baker reports that the industry feels that enforcement of, rather than compliance with, MSHA regulations is an important source of productivity decline. We tested this hypothesis with the number of MSHA inspection-days. We expect a negative coefficient on inspection-days. The final regulation variable is the number of violations (VIOL). These are not weighted by severity as is the gravity points variable, and therfore, represents both more and less serious hazards. Since we hypothesize a safety-efficiency tradeoff, at least for less serious injuries, we expect a non-negative coefficient on the number of violations.

The regression results are presented in table 6. The coefficient on methane level is negative and significant at the .05 level (one-tailed), as expected. The coefficient on cumulated production is positive and highly significant, indicating that the effects of learning by doing outweigh any effects of ore body exhaustion, at least initially. However, the coefficient on cumulated production is negative and also highly significant, indicating that the gains from learning by doing are finite, presumably because the effects of ore body exhaustion eventually dominate the learning effects. In fact, given our estimates, the point at which the exhaustion effects become dominant occurs at 20.4 million tons of cumulative output for the typical mine in our sample. This is five standard deviations above the average for our mines where mean cumulated production is 3.58 million tons; however, the largest mine in our sample has cumulated production of 23.2 million tons, and therefore, should be feeling some of the detrimental effect of resource exhaustion.

The coefficient on gravity points (G) is negative and significant indicating that dangerous practices tend to reduce productivity. The coefficient on inspection-days (INSP) is also negative and significant, supporting the industry's contention that enforcement of MSHA regulations has a detrimental effect on mine productivity. However, the coefficient on inspection-days is small, with an implied elasticity of 0.15. The last regulation variable, violations (VIOL), has a positive and significant effect on productivity, a further indication of the safety-efficiency tradeoff.

Table 6

Cross Section Underground Mine Regression

Dependent variable: Individual Mine Intercepts

Independent variable	Coefficient	T-Ratio
METH	-0.042	- 1.74
CP	0.245	10.15
CP2	-0.006	- 4.98
G	-0.0005	- 2.08
INSP	-0.0006	- 2.28
VIOL	0.005	2.23
INTERCEPT	8.06	39.45

RSQ = .63 F = 41.39 N = 177 DF = 169

Surface mines

A regression of the form of equation (5) was run on the estimated individual mine intercepts for surface mines. We do not have MSHA regulation data for surface mines, but since most of MSHA's efforts have been directed toward underground mines, we did not expect any significant effects. We regressed the individual mine intercepts on cumulated production (CP) and cumulated production squared.

The results of the surface mine cross section regression are presented in table 7. The coefficient on cumulated production and cumulated production squared have the same signs and virtually the same magnitudes in this regression as they had in the corresponding underground mine regression. As a result, the estimated cumulative production at which resource exhaustion effects overcome learning effects is almost the same, 23.3 million tons for surface mines. This is 3.9 standard deviations above the average cumulated output of surface mines (4.15 million tons). However, the largest mine in the surface mine sample has cumulative output of 40.7 million tons, well into the range of detrimental resource exhaustion effects. This leads us to the quite reasonable conclusion that resource exhaustion effects will be felt first in surface mines since their production rates are higher than the production rates of underground mines. This could mean that some of the optimism with respect to the potential output and productivity of surface mines should be tempered.

Table 7

Cross Section Surface Mine Regression

Dependent variable: Individual Mine Intercepts

Independent variable	Coefficient	T-ratio
CP	0.282	17.44
CP^2	- 0.006	- 10.66
INTERCEPT	11.000	78.30

RSQ = .81 F = 125.07 N= 120 DF = 115

"New" Mines (1977)

For this study, a "new" mine was defined as one having produced coal for a full year for the first time in 1977. This definition was adopted to avoid confusion caused by mines which were in operation for only part of 1976. These new mines were then pooled with the 1977 data for "old" (1972-77) mines.

The same econometric technique and variable definitions were used. A dummy variable was added to collect the effects of newness. Tables 8 and 9 compare the results for old and new mines.

These results show that newness has a significantly negative effect on productivity for surface but not for underground mines. This is reasonable since surface mines can begin production before mine construction is completed much earlier than underground mines can.

Table 8

Underground Production Function Coefficients for "old" and "new" Mines

		"Old"	"New"
NEW	New mine dummy	a/	.106
lnK1	Mine car capacity	.012	-.026
lnK2	Track length	b/.064	.053
lnK3	Trailer capacity	-.012	.115
lnK4	Shuttle car capacity	b/.211	b/.352
lnK5	Belt length	b/.018	.004
lnK6	Cutting machines	b/.238	b/.207
lnK7	Roof drills	.026	-.003
lnK8	Mobile loaders	-.022	b/.190
lnK9	Continuous mining machines	b/.132	b/.373
L	Labor	b/.217	b/.324
Th	Seam thickness	-.001	-.016
A1	Age 1 (18-24)	.033	.053
A2	Age 2 (25-34)	-.014	.362
A3	Age 3 (35-44)	.232	.844
I1	Permanent injuries	.006	b/.128
I2	Temporary injuries	b/.005	.003
C	Captive ratio	b/.192	.007
INTERCEPT		8.330	5.550
R		.94	.76
RSQ		1.890	1.740

a/Dummy variable not included.

b/Statistically significant .05 level.

Table 9

Surface Production Function Coefficients for "old" And "new" Mines

		"Old"	"New"
NEW	New mine dummy	a/	b/-.514
lnK1	Power shovel capacity	.028	.062
lnK2	Dragline capacity	b/.044	b/.185
lnK3	Carryall scrapers	-.059	b/.274
lnK4	Bulldozers	b/.132	b/.673
lnK5	Front-end loaders	b/.287	b/.234
lnK6	Wheel excavators	b/.300	.182
lnK7	Coal drills	b/.242	.189
lnL	Manhours	b/.025	b/.032
SR	Stripping ratio	b/- .135	b/-.142
A1	Age 1 (18-24)	.034	.186
A2	Age 2 (25-34)	.043	.118
A3	Age 3 (35-44)	.063	-.012
I1	Permanent injuries	.034	.199
I2	Temporary injuries	b/.025	b/.064
C	Captive ratio	.018	b/1.097
INTERCEPT		12.261	9.771
RSQ		.940	.650
DW		1.830	1.810

a/Dummy variables not included.

b/Statistically significant .05 level.

ANALYSIS OF THE EFFECTS OF LABOR TURNOVER ON PRODUCTIVITY

This analysis was carried out by the Bureau of Labor Statistics under our direction. We supplied production and manhour data for individual mines which were matched to coal mining "establishments" surveyed by BLS. An "establishment" may be a single mine or several mines administered from a central office. While many MSHA mines could be matched unambiguously, a number of cases arose where an "establishment" covered more than one mine. In these cases, matches were made only if they seemed sensible, that is, if addresses and mine sizes were consistent. Completely unambiguous matches were made for 56 percent of underground and 71 percent of surface mines.

Data

Besides the production and manhour data, overall rates of accessions and separations, along with their components, were used. The variables are listed in table 11 and all refer to the 1972-77 period.

Table 11

Variables Used in Turnover Analysis

Variable	Definition	Underground mean	Surface mean
TS	Total separation rate	20.2	22.1
Q	Quits	9.7	10.1
DIS	Discharges	.5	.9
LO	Layoffs	3.8	8.9
OS	Other separations	6.1	2.7
TA	Total accession rate	21.6	25.7
NH	New hires	16.9	19.6
RC	Recalls	.8	2.6
OA	Other accessions	4.0	3.6

Econometric technique

Pooled time series/cross section regression analysis was used. One set of estimates were made of the influence of total separations and accessions on productivity and another set using the components of the totals. The functional forms tested were quadratic and linear in order to assess non-linearities. Since the quadratic forms gave generally better results, they are reported here. The general form of the function was:

$$PR_{it} = A_t TS_t + B_t TS^2{}_t + C_t TA_t + D_t TA^2{}_t$$

where PR_{it} is the labor productivity of mine i in year t and TS and TA are total separation and accession rates for those mines and years. A second quadratic function using the components of TA and TS was also estimated.

Results for surface and underground mines

Tables 12 and 13 summarize the regression results. Labor turnover obviously has little influence on productivity. In the case of underground mines, only separation variables proved to be significant. Furthermore, as separation rates rise the effects on productivity increase less than linearly. In summary, underground mining productivity is not affected by varying accession rates; increasing separation rates have a depressing influence on productivity but in the case of discharges and other separations, the effect rises less than linearly with these rates.

In the case of surface mines the results are less consistent. In this case, discharges are barely significant (at the .10 level) and negative while, the new hire rate has a positive effect on productivity. This influence is also moderated by the negative sign on the NH^2 term. None of the signs on the significant variables were contrary to expectations.

Table 12

Underground Labor Turnover Regressions

Total accessions and separation rates

Dependent variable: PR

Independent variable	Coefficient	t-ratio
TS	-.1015	-2.92
TS^2	.0003	1.34
TA	-.0085	-0.25
TA^2	.00007	0.39
INTERCEPT	16.339	26.42

RSQ = .06 F = 5.87 DF = 385

Components of rates

Dependent variable: PR

Independent variable (note a)	Coefficient	t-ratio
Q	.0896	1.00
Q^2	-.0042	-1.87
DIS	-.8546	-1.99
DIS^2	-.0812	2.24
LO	-.0899	-1.91
LO^2	.0003	.88
OS	-.2522	-3.37
OS^2	.0019	2.72
INTERCEPT		

RSQ = .10 F = 4.16 DF = 379

a/all accessions components were insignificant.

APPENDIX I

Table 13

Surface Labor Turnover Regressions

Total accession and separation rates

Dependent variable: PR

Independent variable	Coefficient	t-ratio
TS	-.1712	-0.55
TS^2	.0003	0.22
TA	.9304	1.88
TA^2	-.0085	-2.09
INTERCEPT	46.5086	5.71
RSQ = .03	F = 1.39	DF = 212

Components of rates

Dependent variable: PR

Independent variable	Coefficient	t-ratio
Q	.2465	0.33
Q^2	.0009	0.08
DIS	-6.3832	-1.63
DIS^2	.2182	0.87
LO	-.0952	-0.26
LO^2	-.0007	-.27
OS	.0102	0.01
OS^2	-.0295	-0.61
NH	1.4118	2.44
NH^2	-.0148	-2.63
RC	-.0877	-0.85
RC^2	.0051	.41

Table 13 (continued:) Surface Labor Turnover Regressions

OA	.1052	.10
OA^2	- 0.0060	.34
INTERCEPT	45.0861	5.40
RSQ = .06	F = 1.17	DF = 204

Footnotes

1/However, there is a production function literature using individual firm data in agriculture [see, e.g., Mundlak (1961)] and in electricity production [see, e.g., Nerlove (1963)].

2/V. Corbo and P. Meller, "The Translog Production Function: Some Evidence from Establishment Data," Journal of Econometrics, Vol. 10, 1979, pp. 193-199.

Z. Griliches and V. Ringstad, Economies of Scale and the Form of the Production Function (Amsterdam: North Holland, 1971).

V. Ringstad, "Economies of Scale and the Form of the Production Function. Some New Estimates," Scandinavian Journal of Economics, Vol. 80, no. 3, pp. 251-264.

3/R.G.D. Allen, Mathematical Analysis for Economists (New York: St. Martin's Press. 1938), p. 234.

4/O.C. Herfindahl and A.V. Kneese, Economic Theory of Natural Resources (Columbus: Charles E. Merrill, 1974).

5/Similar procedures can be found in:

M. Goldstein and R.S. Smith, "The Predicted Impact of the Black Lung Benefits Program on the Coal Industry," in Evaluating the Labor Market Effects of Social Programs, O. Ashenfelter and J. Blum, (Princeton, N.J.: Industrial Relations Section, Department of Economics, Princeton University, 1976), pp. 133-182.

G.S. Maddala, "Productivity and Technological Change in the Bituminous Coal Industry, 1919-1954," Journal of Political Economy, Vol. 73, August, 1965, pp. 352-365.

6/We also experimented with the translog production function, Corbo and Meller (1979), and a generalized Leontief production function, Diewert (1971). We found we could not estimate these functions using the preferred econometric technique (least squares dummy variables, LSDV) because of perfect collinearity between some of the quadratic terms and the mine dummy variables. Persisting with generalized inversion methods Statistical Analysis System (1979) yielded LSDV estimates of the translog and generalized Leontief functions which were not unique and which had larger residual sums of squares than the corresponding Cobb-Douglas form. We decided to retain the simpler Cobb-Douglas specification.

7/We do not have any measure of the utilization of the various types of capital nor of their vintage. To this extent our capital inputs are less than ideal.

8/The decision as to whether a State was actually enforcing its reclamation laws was made only after telephone interviews with mining officials in the relevant States.

9/A. Zellner, J. Kmenta and J. Dreze, "Specification and Estimation of Cobb-Douglas Production Function Models," Econometrica, Vol. 34, October 1966, pp. 784-795.

10/J.G. Baker, with W.L. Stevenson, November 1979. "Determinants of Coal Mine Labor Productivity Change." Prepared for U.S. Department of Energy and U.S. Department of Labor. Washington, D.C.,: U.S. Government Printing Office.

11/The data are from 1972-77, years when MSHA regulations were already in effect. There may have been a payoff to risking very serious injury before these regulations went into effect, but this is a hypothesis we cannot test without pre-MSHA data.

12/This is nothing more than a restatement of the assumption underlying a learning curve or progress function. For an early econometric analysis of learning by doing, see Hirsch (1956).

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

OCT 21

Mr. J. Dexter Peach
Director of Energy and
Minerals Division
U. S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Peach:

We have reviewed the draft copy of the GAO report entitled "Low Productivity in American Coal Mining: Causes and Cures." We concur with the major thrusts of their assessment. Improvements in the areas of labor management, Federal Mine Safety and Health regulations, and mining technology can have a favorable influence on coal productivity.

More specifically, we strongly agree with the conclusion that proper training can positively impact coal productivity. Bureau of Mines extensive research on mining education, training, and organizational development substantiates this conclusion. Concurrently, we feel proper training produces significant gains in the health and safety welfare of miners. Further, we feel the analysis of the effects of the Coal Act of 1969 properly reflects that the major impact of this act occurred before 1974. We agree that the downward trend in productivity lessened as a result of the experience gained by the coal mining industry and MSHA (MESA) with regulations. Your recommendation that the Bureau of Mines should expand and improve efforts to commercialize new safety technology is appropriate. We are presently focusing on this need and in 1979 created a new Branch of Technology Transfer with expanded responsibilities in this area. Finally, we agree that the Federal Government should emphasize research projects which have a high potential for improved coal mining productivity. However, we believe this must be interactive with the Bureau of Mines programs on coal mine health and safety, and environmental research.

Although the report does address the subject of open pit mining and some causes of productivity loss, it only provides a low level treatment of reclamation and environmental requirements as they relate to MSHA and EPA requirements. The coal mining industry, to meet the requirements, must divert capital and manpower from production. The Bureau of Mines, within the Department of the Interior, under Section 302, Public Law 95-91, is charged with coal mine reclamation and has an extensive ongoing research program in this area. While we agree with the major determinations, for your consideration, we offer the following comments on each recommendation:

1. Congress consider authorizing the Departments of Labor and Energy to jointly fund coal industry programs to train coal management and labor in effective communication and grievance handling.

Comments:

We take exception to this statement. We would like to point out that the Department of Labor has already developed expertise and facilities in the training of both miners and managers. In addition, the Bureau of Mines in the Department of the Interior has also developed salient expertise in both the development of education and training programs and in organizational development which largely addresses labor-management relations. These agencies have established a high degree of cooperation between themselves and labor, industry and academia in developing and implementing training programs. For example, during the past year several training packages have been developed by the Bureau of Mines at the request of MSHA and delivered to them for use throughout the industry. As provided in the Federal Mine Safety and Health Amendments Act of 1977 (Public Law 95-164), responsibility for training is delegated to the Department of Labor, and training media development is the responsibility of the Department of the Interior. We believe that the 1977 Act, in greatly expanding training required of the industry, has provided sufficient opportunity to attain the stated needs.

In response to a request from Congress, a recent contract report done for the Bureau of Mines entitled, "A Study to Determine the Manpower and Training Needs of the Coal Mining Industry," has analyzed the future training needs of the industry and has determined that quality and not quantity is of concern; this report is in agreement with your statement on p. 3-45. The study further outlined a number of means by which the quality issue could be addressed. The primary suggestion entailed the formation of a Mining Extension Service which was to be created within existing agencies. Finally, the Department of Energy has no significant programs of expertise in dealing with training of labor management relations in the mining industry. Therefore, it would seem logical to continue and expand existing programs within the Departments of Labor and the Interior instead of creating a new program and organization within the Department of Energy.

2. The Bureau of Mines should assume a greater role in commercializing new safety technologies which would reduce the adverse productivity impacts of MSHA regulations. Specifically, the Bureau should insure that its products are adequately tested before deployment in mines.

Comments:

Although we agree with the intent of this statement, we feel it is necessary to clarify "adequately tested." Laboratory testing is now, for many purposes, adequate and serves an important function in reducing new product downtime. The final and most important phase of any development, however, is that of in-mine evaluation where products are deployed in mines with some uncertainty as to their reliability and performance characteristics in actual mine service. Improvements are certainly needed in capital intensive in-mine large-scale evaluation efforts of both government and industry research and development. Large-scale in-mine efforts are especially needed if the diverse mining environment in the U.S. is to be addressed. This is in contrast to the situation where a European coal nation may be concerned with a much more homogeneous environment.

Another constraint on improving mine technology in the U. S., and specifically the transfer of new technology into mines, is the recent change in liability rulings. Many companies with hardware-oriented technology are reluctant to introduce their improvements because they will face difficult (and expensive) new liability problems. Possibly the formation of the Mining Extension Service previously mentioned would provide the mine-by-mine attention that would be necessary to minimize liability problems. In addition, such an organization would also tend to institutionalize both Bureau of Mines and industry generated training and technical development, and provide additional guidance to government minerals industry research efforts. Therefore, we believe that this concept should be considered.

3. The Department of Energy put more emphasis on research projects which have a high potential for improving productivity.

Comments:

We are in strong agreement with this recommendation. DOE efforts should be directed toward this objective. However, there is an important variable which must be considered in complying with this recommendation.

It is our belief that, in mining, productivity research cannot be conducted without full consideration for the health and safety of miners. Department of Energy research should be critiqued to insure that known health and safety considerations are included in new technology at the earliest design stage.

We have generated a number of additional comments throughout the report as a result of our technical review which we believe may help to strengthen the report. We appreciate the opportunity to review this document and we hope that you find our attached comments helpful.

Sincerely,

Larry E. Meierotto

Assistant Secretary of the Interior

Enclosure

GAO Note: Technical comments that were contained in the enclosure to this appendix were incorporated throughout the report when appropriate.

U. S. Department of Labor
Inspector General

OCT 2 2 1980

Mr. Gregory J. Ahart
Director
Human Resources Division
U. S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Ahart:

This is in reply to your letter to Secretary of Labor Ray Marshall requesting comments on the draft GAO report entitled, "Low Productivity In American Coal Mining: Causes and Cures." The Department's response is enclosed.

The Department appreciates the opportunity to comment on this report.

Sincerely,

Ronald Goldstock
Acting Inspector General

Enclosure

U. S. Department of Labor's Response To
The Draft General Accounting Office Report
Entitled --

Low Productivity in American

Coal Mining: Causes and Cures

Recommendation:

Congress consider authorizing the Departments of Labor and Energy to jointly fund coal industry programs to train coal management and labor in effective communication and grievance handling.

Response:

The Department of Labor concurs that programs to improve effective communication and grievance handling in the coal industry are necessary for improvement of the industry's labor management relations. These suggestions were included in the recommendations of the President's Commission on Coal issued in March 1980. The Department further agrees that additional government funds should be made available for programs in this area.

In recognition of the importance of this area to improved labor management relations, the Labor-Management Services Administration (LMSA) has already undertaken steps in the following areas: 1) LMSA is providing funding for a grievance training program that will be utilized by grievance committeemen in the coal industry on a pilot basis. The program will provide training in effective communication and handling of grievances and will hopefully form the basis of a continuing UMWA/BCOA training effort in this area, 2) LMSA is providing funding for a one year experimental program in the mediation of grievances. The experimental program will encourage acceptance of the grievance procedure and cut down on the costs of grievance handling for both labor and management, 3). further, LMSA is providing administrative support and both LMSA and MSHA are funding the White House Coal Advisory Council. The Council was established to advise the President and the Secretary of Labor in the areas of labor management relations, mine safety, and productivity in the coal industry.

Recommendation:

MSHA should, wherever possible, establish an agency-wide policy on whether a new Bureau of Mines safety technology will qualify a mine to be exempted from a productivity-reducing regulation.

Response:

MSHA has authority under Section 101(c) of the Federal Mine Safety and Health Act of 1977 to grant modifications on safety standards (regulations) on a mine-by-mine basis upon a showing by the operator that either an alternative method of achieving the result is available which guarantees no less than the same measure of safety to the miners in the mine or that the application of the standard creates a diminution of safety. Procedures governing these petitions for modification are set forth in 30 CFR Part 44. A petition for modification would not be denied if the same degree of protection were provided to the miners by the new technology. This procedure is used frequently by mine operators and many petitions have been granted. Accordingly, if the Bureau of Mines develops new technology that meets these requirements it can be approved through these procedures. A prime example of a new technology implemented in this manner is the procedures developed by the Bureau of Mines and MSHA to plug and mine through abandoned oil wells. MSHA does not have the authority however to exempt operators from safety and health standards on a industry-wide or agency-wide basis.

MSHA is in the process of establishing a system for initiating review of standards for which petitions for modification are usually granted. As revisions of the standards are made, the Department hopes to create a climate in which technological advancements are recognized and further developments are encouraged, and at the same time, reduce the time and paperwork required by continued use of the petition process.

Recommendation:

Congress should consider increasing the required amount of on-the-job safety training for supervisors and miners and increasing MSHA assistance to operators for this purpose.

Response:

The Department concurs that on-the-job safety training is extremely important. However, the department believes that there may be several options available for achieving such goals. The above recommendation is one option which could be considered.

Comments:

The Department believes that GAO has presented an objective and detailed report which clearly illustrates the problems facing the coal industry. It is evident that the subject was extensively researched and many of the factors affecting productivity addressed. The Department wishes to note, however, that other factors such as demand, price, transportation problems and availability of alternative less expensive energy sources have also had an impact on production. Thus, the Department believes it is the cumulative effect of all these factors which has affected the industry adversely.

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