Cotton Dust Regulation:

AN OSHA SUCCESS STORY?

W. Kip Viscusi

Abstract

In 1978, OSHA took a major step in attempting to promote the health of workers in the textile industry, tightening its standard on cotton dust levels in textile plants. Because the OSHA cotton dust standard was widely believed to be ineffective, it became the target of a major political debate and a fundamental U.S. Supreme Court decision. The evidence indicates that the standard has had the expected beneficial effect on worker health, and at a cost much lower than originally anticipated. Nevertheless, the costs still remain very high, far higher than estimates of the value of the results they achieve or of the value that workers place on them. Moreover, much more efficient ways of achieving comparable results are available. Nevertheless, large firms in the industry now appear to have a vested interest in maintaining the standard in its original form and are unlikely to constitute a force for change.

A pivotal regulation in the history of the Occupational Safety and Health Administration (OSHA) is its standard to limit the cotton dust exposures of textile workers. This regulation was the subject of a major internal battle within the Carter administration, served as the focal point of a fundamental Supreme Court decision in the risk regulation area, and was the target of a controversial reassessment under the Reagan administration.

The source of the controversy can be traced to several factors. The cotton dust standard is an important regulation from the standpoint of the economic costs it imposes on the textile industry. But the presence of a significant cost impact does not distinguish this regulation. Of much greater significance is the link to worker health, where the health impact in question is a lung disease called byssinosis. Many experts have challenged whether or not there is a causal link between cotton dust and byssinosis. Some have observed that if there is such a link, protective equipment such as

Journal of Policy Analysis and Management, Vol. 4, No. 3, 325–343 (1985)

Published by John Wiley & Sons, Inc. CCC 0276-8739/85/020325-19$04.00

dust masks would be a more cost-effective response than equipment to control the level of cotton dust in the textile plant.

Another factor that has distinguished the controversy over the cotton dust standard is the extent of the analysis to which that standard has been exposed since its adoption. Although it is now routine practice to assess the merits of newly proposed OSHA regulations, they are not usually accorded careful scrutiny once they have been issued. In contrast, the OSHA cotton dust standard was the object of an extensive reassessment during 1982 and 1983, which was much more detailed than the initial analysis. Although firms were not required to be in compliance until 1984, most of the expenditures needed to achieve compliance had been made. The retrospective assessment of the costs and health impacts of these efforts provide a detailed perspective on the impact of OSHA regulations.

GENESIS OF THE STANDARD

OSHA's cotton dust standard was issued in June 1978.[1] The source of the concern behind OSHA's initiative derived from the link between cotton dust and the disease byssinosis, which Ralph Nader labeled "brown lung" disease in an effort to draw a parallel with the "black lung" risks faced by coal miners.

Byssinosis is not a disease with uniform health effects, but instead consists of several stages, with differing degrees of severity.[2] Grade 1/2 byssinosis involves chest tightness or breathing difficulties on the first day of the workweek, normally Monday mornings. Grade 1 byssinosis involves occasional chest tightness or breathing difficulties on every Monday. If the worker experiences such problems on other days as well, he is placed in Grade 2. Finally, workers suffering from Grade 2 symptoms and who show evidence of permanent incapacity are placed in Grade 3. In addition to byssinosis grades of this type for current and recent workers, there are also cases of partial and total disability that have been identified among retired cotton textile workers.

The disease generally involves a progression through a series of grades, and, with the exception of cases in Grade 3 and cases involving actual disabilities, all of these health impacts may be reversible.[3] When transferred to non-cotton-dust areas, workers who fall into the low byssinosis grades are likely to lose the symptoms of the dissease. Rotation of this type is now widespread in the textile industry.

Only Grade 3 byssinosis and cases entailing disabilities clearly involve chronic health effects, notably diminished lung capacity. According to the evidence, this reduction of lung function is not a prelude to some other ailment, such as lung cancer. The worker does not face a major risk of early death, and he is not disabled to the same extent as are victims of severe accidents, such as those who have lost the use of their limbs. Diminished lung capacity and occasional coughing is not a trivial ailment, but it is not as severe as many other targets of OSHA regulation.

The link of chronic byssinosis effects to cotton dust is also controversial because the relevant medical evidence on the nature of the causal link is not conclusive.[4] Is cotton dust the cause of byssinosis, or is it some agent correlated with the presence of cotton dust? The link is difficult to distinguish because of the high rates of cigarette smoking among textile mill workers and the small number of chronic byssinosis cases. Indeed, the major studies that have been conducted on the relationships between cotton dust and byssinosis do not even attempt to distinguish the Grade 3 cases or disabilities, since many of these more severe effects are not apparent until after the worker has retired.[5] Because the available medical evidence is imprecise, various suggestions have been made to refine the evidence, including the possibility of conducting experiments at plants not yet in compliance with the standard.[6]

It is expected that the largest impact of the cotton dust standard will be in preventing the less serious grades of byssinosis. According to estimates, over two-thirds of all cases that will be prevented by the standard fall in Grades 1/2 and 1. Of the remaining cases prevented, only a small number can be said to entail the prevention of serious ailments. Overall it is expected that under 7% of all cases of byssinosis at any one time involve total disability, and these occur with a substantial time lag of up to three decades.

There have been other reasons for assuming that the byssinosis threat might be exaggerated. Available studies of the relationships between cotton dust exposures and worker health have taken as their reference point the work practices of the textile industry in 1970 rather than their practices at the time of the standard's introduction.[7] Moreover, they have failed to explore the possibilities of reducing the risk by means other than reducing the cotton dust in the plant's atmosphere. For instance, if there were medical surveillance of workers coupled with a sufficiently vigorous policy of rotation, all chronic byssinosis cases could be prevented. A much more ambitious rotation policy could prevent all Grade 2 cases as well. To reduce the frequency of rotation, workers exposed to cotton dust could be required to wear protective equipment such as disposable cotton masks during the periods of work when the cotton dust levels were high.

OSHA has preferred not to rely on alternatives such as the use of masks and the rotation of workers because of unions' aversion to solutions that entail the use of such equipment; the unions' position has been that it is preferable to make the work environment safe whenever possible. Behind that position has been the widely recognized fact that workers themselves commonly object to wearing protective devices if any alternative control method exists.

The 1978 cotton dust standard did more than simply prescribe limits for the amount of cotton dust in the plant environment. It adopted a mix of approaches to regulating this hazard.[8] The standard provides for engineering controls, medical surveillance, and respirators in situations of extreme exposure, such as during maintenance activities. The most novel aspect of the standard is that it is not uniform for all exposed worker groups. The standard establishes a permissible exposure limit for respirable cotton dust particles of 200 micrograms per cubic meter of air (200 $\mu g/m^3$) for yarn manufacturing, 750 $\mu g/m^3$ for slashing and weaving operations, and 500 $\mu g/m^3$ for all other processes. OSHA required that the medical surveillance provisions should be in place by mid-1979, but firms had until March 1984 to comply with the exposure limits.

This variation in standards is dictated partly by the cost differences that are entailed in controlling cotton dust at different stages of processing and partly by the differences in the severity of the types of cotton dust exposure encountered at each stage. Table 1 presents data reflecting some of these differences at the time the cotton standard was adopted. The figures in Table 1 purport to show what the incremental cost would be for preventing one additional case of byssinosis at different exposure levels. (As we shall presently see, actual costs incurred have proved to be quite different from those that were predicted.) As the table shows, the projected marginal cost per case rises much more rapidly for mill slashing and weaving than it does for yarn preparation.

OSHA's decision to impose a tighter standard for yarn preparation is consistent with the key principle that where a given risk such as byssinosis arises from two different sources, expenditures made to reduce the risk from each of the two sources ought to be equal at the margin in order to maximize the overall effectiveness of those expenditures. The standards selected represent an application of that principle. However, in order to equalize the marginal costs per byssinosis case, the 200-$\mu g/m^3$ standard for yarn preparation should be coupled with a standard for mill slashing and weaving of under 400 $\mu g/m^3$ rather than the more relaxed 750-$\mu g/m^3$ level that was selected. Although the precise basis for OSHA's differentiation is unclear, that feature of the standard may have been the result of either of two factors: It may have been an attempt to equalize the risk of cotton dust exposure,[9] or it may have been an effort to set standards at the level of stringency that could be achieved without vastly increasing the costs of compliance.

The data in Table 1 suggest that on a prospective basis the overall efficacy of the standard in promoting worker health did not appear to be very high. In the case of yarn preparation, where

Table 1. Incremental cost per year of preventing an additional case of byssinosis at three exposure levels, as of 1978 (in thousands of dollars).

	Exposure level (in μg cotton dust particles/m^3 air)		
Stage of processing	500	200	100
Yarn preparation	56	593	6268
Mill slashing and weaving	22	1338	1867

Source: Viscusi, W. Kip, *Risk by Choice: Regulating Health and Safety in the Workplace* (Cambridge, MA: Harvard University Press, 1983), p. 125.

the marginal costs are greatest, the costs per year of preventing an additional case of byssinosis comes to almost $600,000. Since the great majority of these ailments involve only inconsequential health effects (Grades 1/2 and 1), these cost levels appear to be extraordinarily high. If we include only cases of Grade 2 byssinosis or higher, the costs per year rise to almost $2 million per case prevented. This figure is comparable to some of the higher estimates that researchers have made of the value that workers implicitly place on exposing themselves to fatal accidents, where these estimates are based on the wage premiums they receive for such risks.[10] The high projected cost levels for the health benefits achieved and the availability of alternative policies that might be more cost effective led to an extended debate over the efficacy of the standard.

Economists in the Carter White House opposed the standard after it had been proposed by OSHA.[11] Led by the chairman of the Council of Economic Advisers, Charles Schultze, they were successful in obtaining President Carter's support in a decision not to issue the standard. After a subsequent appeal by Secretary of Labor Marshall, the president reversed his earlier decision and decided to issue the regulation.

The attempt to block the cotton dust standard then shifted to the courts. The American Textile Manufacturers' Institute challenged the OSHA standard on the grounds that the benefits were not commensurate with the costs. In a landmark decision that had a major effect on all risk regulation agencies, the Supreme Court upheld the standard and explicitly ruled out the use of a benefit–cost test. The court concluded that OSHA had to promote risk reduction as long as there was a technical possibility of compliance, a criterion that the court interpreted as meaning "capable of being done."[12]

In actual practice, the Supreme Court's criterion has little practical meaning. Almost any risk can be reduced further through additional expenditures. As the data in Table 1 indicate, tighter standards could have been imposed, albeit at higher costs. Studies prepared subsequent to 1978 confirmed, for instance, that the standard for yarn preparation could be tightened considerably at a cost that was double that incurred in achieving the OSHA standard.[13] Any question of feasibility, therefore, cannot escape recognizing cost considerations.

The Supreme Court's decision that OSHA's legislative mandate prohibits the use of a benefit–cost test has had widespread ramifications. Before the issuance of that decision, Carter's White House staff routinely had applied a cost-effectiveness test to the proposed measures of the regulatory agencies and had urged them to take greater cognizance of the relationship of benefits to costs. Under President Reagan's Executive Order 11291, the Office of Management and Budget has attempted to impose a benefit–cost test on new regulations, but in recognition of the Supreme Court decision it has specifically exempted cases that "violated the agency's legislation." Accordingly, agencies may sometimes disregard the balancing of benefits and costs, as in the case of the EPA ambient air standards for which the Clean Air Act specifically prohibits any consideration of costs.

As part of the Reagan administration's review of potentially unproductive regulations, OSHA undertook a full reassessment of the merits of the cotton dust standard. This review included an analysis of the cost effectiveness of loosening or tightening the standard as well as the efficacy of mandating the use of protective equipment, such as the use of cotton dust masks.[14] Although the use of such masks for a few hours a day in high-exposure situations coupled with a rotation policy would often produce the same benefits as a cotton dust standard, OSHA did not pursue this option; the agency's general aversion to solutions that leave the source of the hazard unchanged continued to dictate its recommendations.

It is clear that the costs of the mask-and-rotation approach would be below the costs of changing the workplace technology. There might, however, be problems of enforcement and discomfiture for the workers.[15] But there is some evidence that even if such factors are taken into account, the mask-and-rotation alternative would still be a more cost-effective approach except in extreme exposure situations.

Because OSHA has required that such masks be worn as a temporary measure in situations where compliance had not yet been achieved, some experience with the approach already exists. In 1978, for example, 35% of all workers exposed to cotton dust were required to wear dust masks; yet no serious problems of worker noncompliance with the regulation have been reported.[16] To be sure, some problems would still arise if the widespread use of masks were mandated. Some types of masks, notably those required in high-exposure areas, may not fit the worker's face, particularly for workers with full beards. Workers may surreptitiously discard their masks if they find them uncomfortable. But the costs associated with overcoming such problems appear of an order of magnitude that does not impair the relative cost effectiveness of this politically unattractive alternative.

Among the various important lessons to be drawn from the country's experience with the cotton dust standard is the fact that industry's responses to such standards will not be simple. During the Carter administration, the American Textile Manufacturers Institute (ATMI), composed mainly of the larger firms in the industry, had expressed bitter opposition to the application of the cotton standard, and it took its case to the U.S. Supreme Court. During the Reagan administration's reassessment of the standard, ATMI continued to request a relaxation of the standard, but it focused its lobbying effort with OSHA almost exclusively on the details of the monitoring and surveillance provisions. The Office of Management and Budget pressed for the more cost-effective protective equipment-and-rotation approach and, after the interagency debate had reached Vice-President Bush, OMB explicitly requested the industry's support for that alternative. But ATMI failed to act in support of OMB. That failure was probably a consequence of the substantial investments already made to comply with the standard; the industry had already made almost two-thirds of the expenditures needed to achieve compliance.[17] Moreover, the large firms that dominate ATMI, already largely in compliance, could use the standard to squeeze some of the smaller competitors which had not yet reached the same level of compliance. As a result, after OSHA had given the cotton dust standard a more thorough retrospective assessment than any other OSHA regulation has yet received, the agency did not alter the essential features of the standard.

COSTS AND CONSEQUENCES

The source of much of the political controversy over the cotton dust standard was the high levels of costs that would be imposed. To meet the cotton dust exposure limits, firms often had to make substantial changes in their production technology. In some instances, these modifications would be made without basically altering the existing technology. Ventilation and air filtration equipment most often fit this characterization. When these measures were not sufficient to ensure compliance, however, firms had to make more fundamental changes in their technology, and many firms used this opportunity to overhaul their plant and equipment.

One particular case of such changes was in the operations in which the cotton bales are opened, the cotton is cleaned and blended, and the fiber is converted into a continuous piece (carding). Firms replaced lower-speed cards with higher-speed cards, equipping the new cards with up-to-date dust control features. Firms also introduced automatic opening systems, chute feed systems for cards, and automatic systems for waste collection.[18] According to a 1983 estimate, the industry would spend about $171 million on ventilation equipment and $428 million on new production equipment between 1978 and the time when full compliance is achieved.[19]

Although many of these investments are perhaps being triggered by the standard, most of them have been undertaken in order to increase productivity. For instance, about $353 million of the $428 million of new production equipment was intended for that purpose, rather than to meet the standard. Consequently, capital costs specifically attributable to the standard will amount to only $246 million by the time compliance is achieved. Most of the remaining costs associated with reducing cotton dust exposure have been energy costs and labor costs, which are directly related to the operation of the ventilation equipment and the production equipment. If one converts these capital costs and operating costs to an equivalent annual expenditure, the total comes to $53 million.[20]

What effects on the health of workers can be discerned? The usual starting point for analyzing any such impact is to examine reported rates of occupational injuries and illnesses. In the textile industry as in other industries, the illness data do not exist in a long and continuous time series. Moreover, byssinosis cases, representing illnesses rather than accidents are notoriously underreported. The less severe grades of byssinosis do not have sufficiently adverse effects to lead to lost workdays or to other consequences that might be reflected in the statistics. Chronic byssinosis cases only emerge after a considerable period of exposure, so that the effects of the new standard in reducing the incidence of such cases would not yet be apparent.

As a result, the limited data on illnesses can only be suggestive.[21] From 1978 to 1982, the incidence of reported work-related illnesses in the textile mill products industry dropped from 1.9 cases per 1000 workers to 1.5 cases per 1000 workers. Over that same period, the rate of illnesses per 1000 workers involving at least one lost day of work dropped from 0.6 to 0.5. In each instance, the trend is in the expected direction if the standard has had a favorable effect. However, the coverage of series of this kind is notoriously incomplete and it is likely that only a fraction of the byssinosis cases are captured in the statistics.

In my efforts to measure the effects of the standard upon the health of workers, I uncovered one unanticipated phenomenon that could well be characteristic of other cases involving the introduction of machinery on a large scale. Byssinosis cases represent an illness, not an injury. But the more typical analysis of OSHA's role concentrates on injuries as well as illnesses. Accordingly, following the usual design of OSHA-related studies, I analyzed the injury and illness rates of the textile mill products industry for what clues they might offer. Figure 1, which portrays the rates of injuries and illnesses among workers in the industry that entailed at least one lost day of work, presents some quite unexpected results.

Somewhat contrary to expectations, the measure exhibits an alarming upward jump in 1978, the year the standard was introduced. Not until 1982 does it return to the level prevailing in 1976 and 1977. The fact that the measure remained high for four consecutive years suggests that the increase was not a random aberration but the result of a substantial change in the risks to which workers were exposed in the textile industry.

One possibility to be considered, of course, was that the increase in risk was a phenomenon associated with cyclical fluctuations in the industry. Using data for the period 1960–1982, I explored that possibility with some care. The details of my statistical analysis appear in the Appendix. In essence, I used the experience of 1960–1977, the years before the introduction of the standard, to predict the risk level that should have been expected from 1978 to 1982, given the level of activity of the industry, the proportion of female employees in the industry, and the proportion of production workers in the industry in each of those years.

The statistical manipulations generate the "predicted" values shown in Figure 1. As the data in the Appendix show, each of the variables mentioned did have their expected relation to rates of injury and illness involving a lost workday; but taken together they predicted a significantly lower rate for the period after 1977

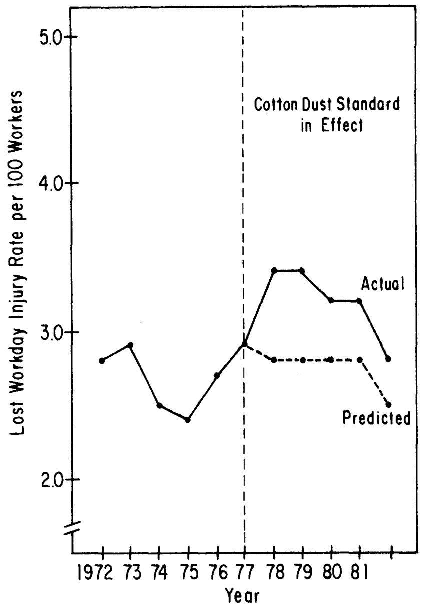

Figure 1. Trends in injury and illness rates for textile mill products industry.

than in fact occurred. That low expected value, it should be noted, was due in part to the fact that the U.S. textile industry, unlike the country as a whole, did not experience an upswing in 1978 and 1979.[22] Over the 1978–1982 period, the reported accidents and illnesses exceeded the predicted figure by 19,000, or 13%.

There are several conjectures one might advance to explain the increase in injury rates. First, the higher level of lost workday accidents may have been a consequence of the new technologies that were introduced in connection with meeting the standard. These technologies often involve faster production speeds and higher productivity both in yarn preparation and in weaving. The pattern shown in Figure 1 is consistent with the hypothesis that the new equipment may have led to a temporary increase in accidents associated with a learning period.

However, as noted earlier, less than one-fifth of the new production equipment purchased from 1978 to 1982 was directly related to compliance with the standard,[23] the rest being a response to the fact that modernization of the industry's equipment had been long overdue. The safety implications of adjustment to new technologies merit further exploration, but it seems unlikely that the cotton dust regulation was principally responsible for this increase in accidents.

A second possible explanation for the accident increase is that the imposition of the cotton dust standard made firms more vigilant in their reporting of injuries and illnesses; the initial years of OSHA regulation, for example, had apparently led to a sharp increase in the reporting of injuries. Nevertheless, that hypothesis does not seem very plausible. OSHA's imposition of the cotton standard was not accompanied by any evidence of increased vigilance on its part. In the years following the introduction of the standard, the number of inspections per worker declined somewhat, and the total penalties per worker imposed by OSHA inspectors remained unchanged.[24] Besides, if the announcement of the new standard had stimulated more complete reporting, the statistical effect would not have greatly affected the data on the incidence of reported accidents involving lost workdays since the identification of these injuries is less a matter of discretion than the overall accident rate. If any tie existed between the adoption of the standard and an increase in reporting coverage, it may have been through the fact that the larger and more modern firms expanded their operations while many older plants ceased operations in reaction to the introduction of the standard. As a rule, larger firms are known to be more vigilant in reporting injuries.

Because the illness-and-injury data suffer from such obvious limitations as a guide to the effectiveness of the standards in controlling byssinosis, I turned to other measures that might be reflecting this relationship. The data on worker quit behavior offered an alternative possibility. According to my statistical studies using several sets of data, about one-third of the difference in quit rate levels among different industries is accounted for by variations in the risks that workers experience in those industries.[25] If the cotton dust standard were effective, therefore, one would expect to see some decline in the quit rates experienced by the textile industry. To be sure, the relationship might not be very strong. Severe byssinosis cases, as we observed earlier, are a long time in gestation. On the other hand, milder forms of byssinosis occur more rapidly and are more rapidly reversible, so that one would expect workers to be aware of the improvement in their health that resulted from a decrease in the cotton dust exposure.

The solid line in Figure 2 represents the quit rate trend in the textile industry from 1972 to 1981; after that year, the Bureau of Labor Statistics suspended collection of the turnover data. After the advent of the cotton dust standard, the quit rate rose for one year, then resumed a downward trend that had dominated through most of the 1970s. The "predicted" rates in Figure 2, portrayed by a dotted line, were derived by a procedure similar to that used earlier, when predicting the injury and illness rates of the textile products industry; the details of that estimating process appear in the Appendix.

In order to derive these estimates, I hypothesized that worker quit rates would be positively related to the injury rate and to the fraction of female employees in the industry. Higher wages should reduce the quit rate, and there should be an increase in quit rates during cyclical upturns, such upturns being reflected in hours worked and overtime hours worked per week. For the years 1960–1977, the data conformed closely to expectations, with the fraction of female employees, wages, and overtime hours making the largest contributions; the resulting equations provided the basis for the "predicted" data from 1978 to 1981.

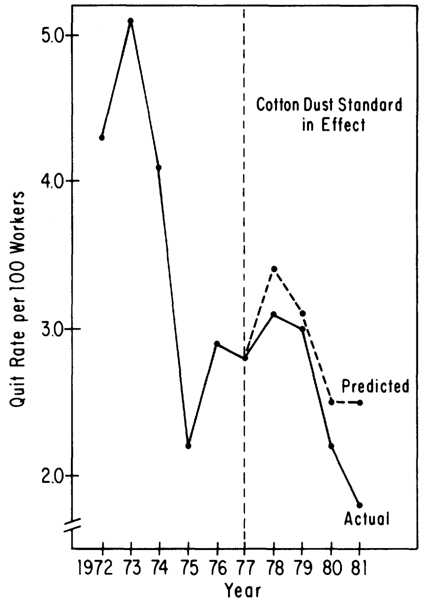

Figure 2. Trends in quit rates for textile mill products industry.

The data illustrated in Figure 2 indicate that even though quit rates rose in 1978, they were below the predicted level. This disparity was even more apparent in 1981, when quit rates dropped substantially. The trend is consistent with the view that there has been a growing impact of the standard on health over time, which is what one could expect as the year 1984, the deadline date for compliance, grew closer. The gap between actual and predicted rate was quite large, representing an average reduction of 43,000 worker quits per year in the period from 1978 to 1981.

Of course, many workers' decisions to quit may be motivated not by actual changes in their health but by their perception of the effect the job will ultimately have on their health. Similarly, because byssinosis is not disabling or severely limiting in its early stages, some workers suffering from the disease will refuse to quit. The evidence for quit rates consequently does not provide a measure of the health impact *per se.* The quit rate results in conjunction with the limited data on illnesses are consistent with the view that the cotton dust standard had a beneficial health effect, but they do not enable us to calculate the magnitude of the effect.

ESTIMATING COST EFFECTIVENESS

Although each of the approaches that have been presented so far offers some basis for estimating the cost effectiveness of the cotton dust standard, there is another approach that lends itself more readily to such a calculation. In this approach, we begin by estimating the health effects of the cotton dust standard from two kinds of data: the number of workers operating or expected to operate in textile product factories after 1978, and field medical studies on the relative incidence of byssinosis under different conditions of exposure to cotton dust. Coupling these two sets of data, we can produce estimates of the number of cases of byssinosis, according to year of onset and grade of severity, that could be expected to be prevented by the standard. As noted above, these health relationships do not take into account the role played by medical surveillance and worker rotation, both of which increased in the 1970s; as a result, the estimates may overstate the impact of the changes in the workplace technology. But to some extent medical surveillance and other measures were undertaken in response to the standard; accordingly, the data may be interpreted as providing an estimate of the overall impact of all of the features of the regulation.

Table 2 summarizes our estimates of the reduction in byssinosis cases between 1978 and 1982 brought about by introduction of the standard, as well as the additional reductions to be anticipated after 1984, the year when full compliance was to be achieved. Although OSHA did not require that firms comply with the cotton dust exposure requirements until 1984, firms had made sufficient changes by 1982 to justify the assumption that over two-thirds of the anticipated reduction in byssinosis cases was already occurring in that year. In short, the estimates suggest that the firms' health-related investments were already having a substantial impact.

According to estimates of this sort, the number of byssinosis cases eliminated annually when full compliance is in effect will be over 9000, although over half of these are in the less severe Grades 1/2 and 1. The total number of disabling cases eventually eliminated per year is about 1700, of which about 500 are total disabilities. The severe cases prevented by the standard will not be among active workers but among workers who have retired, and the reduction will not be apparent for many years because of the long lags involved.

In order to assess the efficacy of the standard, it is necessary to obtain some measure of the costs. The costs of the program from 1978 to 1982 could be estimated from sources already de-

Table 2. Estimated reduction in byssinosis cases associated with introduction of cotton dust standard.

Type of case	Number of cases reduced per year, 1978–1982	Total cases reduced per year with full compliance[a]
Byssinosis Grades 1/2 and 1	3517	5047
Byssinosis over grade 1	1634	2349
Partial disabilities	843	1210
Total disabilities	339	487

Source: Exhibit 5-8 of Centaur Associates (1983) and calculations by the author.
[a] The results pertain to the steady-state outcome.

scribed; and the incremental costs after the deadline year, 1984, could also be estimated. Similarly, the benefits in each year can be estimated using results along the lines of those in Table 2. In each case, one should discount the deferred impacts appropriately to take into account the different timing of the effects. Most of the costs are immediate, whereas the benefits are deferred, particularly for the more severe health effects. The discounting rate used for this purpose was 10%.

Table 3 summarizes the result of these calculations for different grades of byssinosis. Obviously, these cost estimates exclude the costs of any increased accidents that may have resulted from the change in workplace technologies; but, given the tenuous nature of the link between those accidents and the cotton dust standard, that exclusion seems justified. The average costs per case prevented will be higher with full compliance than for the 1978–1982 period. This pattern reflects the expectation that the cost per case is likely to be higher for firms that were not yet in compliance by 1982 than for those in compliance by that date; a similar pattern is found in other regulatory contexts, and it is to be expected on theoretical grounds.[26]

It is instructive to compare the estimates in Table 3 with those that had been prepared in 1978, shown in Table 1. The cost per reduced case year shown in Table 3 is roughly $9,000, which is only a fraction of the various 1978 projections.

The 1978 projections appear to have been high for a number of reasons, including various methodological differences in the estimates of benefits. By far the most important difference was that OSHA and firms in the industry had initially overestimated their compliance costs. Based on discussions with industry officials, OSHA originally projected that the capital costs would be $971 million in 1982 prices; but by 1983, these estimates were lowered to $246 million.[27] It is widely believed that benefit estimates are usually less precise than are the cost estimates. Experience in the cotton dust case suggests that cost estimates merit close scrutiny as well.

Table 3. Estimated cost per year of preventing one case of byssinosis by introduction of cotton dust standard (in thousands of dollars).

Type of case	Years 1978–1982	With full compliance
All cases	9	9
Total byssinosis cases over Grade 1 and disabilities	50	54
Total partial and total disabilities	350	378
Total disabilities	1220	1318

Source: Exhibit 5-9 of Centaur Associates (1983) and calculations by the author.

The estimates in Table 3 provide measures of the costs of preventing byssinosis cases, distinguishing between cases of increasing severity. Some of the patterns in the table are noteworthy. Grades 1/2 and 1 of the byssinosis disease, it will be remembered, manifest themselves by some difficulty in breathing on the first day of the workweek, a difficulty that is reversible by changing the environment. Such cases are preventable at a cost of $10,000 per case per year, which is below the estimate of $25,000 of the value placed by workers on avoiding a serious accident, as revealed in their wage–risk tradeoffs.[28] At face value, the costs seem somewhat disproportionate to the benefits. It should be noted, too, that the costs of avoiding a case of partial or total disability also seem high—$378,000 per year for cases of partial and disability and over $1,000,000 per year for total disability alone. These magnitudes are comparable to some estimates that have been obtained for the implicit value of avoiding a premature death.[29]

The cotton dust standard appears most clearly justified for its effects in preventing moderately serious cases, those that fall in Grade 2 and above; these cases, it will be remembered, involve some loss of lung function throughut the work week. Even in such cases, however, it takes a cost of $54,000 per year to avoid the symptoms involved.

The fundamental regulatory policy issue, however, is not so much whether workers' health should be better protected but whether the cotton dust standard approach is the most cost-effective means of achieving that result. In absolute terms the standard is a relatively costly means to promote worker health. Moreover, as was observed earlier, the relative costs of the standard are high compared with an option that utilizes protective equipment such as masks in conjunction with the rotation of workers. The chief cost of the alternative is likely to be the discomfort to workers of wearing the masks. But these would need to be worn only a few hours a day in most cases, so the level of extra wage compensation needed to make the protective equipment option preferable to workers may not be great.

Perhaps the greatest impediment to the introduction of equipment solutions such as these may not be unions' opposition to such measures but rather OSHA's failure to fashion a mechanism for ensuring that there is adequate financial compensation for the affected workers. In a competitive market, the wages for jobs involving the use of protective devices such as masks will presumably rise to take into account the associated discomfort. Formalizing such compensation, however, creates an apparent link between the compensation and the change in workplace conditions, thereby improving the chances that workers will accept the change.

Such market-oriented compensation schemes have not been used in the regulation of labor markets. But they have been used in other regulatory situations; airlines that overbook now offer compensation to bumped passengers or to volunteers who will accept the bumping in return for the compensation. Financial compensation could play a similar beneficial role in promoting safety policies for workers in situations such as those posed by the cotton dust hazard.

CONCLUSION

As a general rule, OSHA regulations are not widely believed to have significantly influenced health and safety in the factory. In the cotton dust case, however, the data suggest that the standard is having a considerable impact. Data on the relationship between exposure doses and disease incidence, as well as the fragmentary illness data and the evidence based on worker turnover, suggest that the risks of byssinosis have been reduced dramatically.

The current exposure levels are not the lowest that are "capable of being done," and if one were to follow the Supreme Court's guidance a tightening of the standard would be warranted. Such an action, however, would not generate health benefits commensurate with the value that workers place upon them. Indeed, there are at least two grounds for concluding that the present standard is not an efficacious means for promoting worker health. One is its cost, which is extraordinarily high by comparison with any value that can be reasonably placed upon its achievements. The second is the fact that a much cheaper alternative is available.

In defense of the standard, however, it should be noted that the standard has proven to be much more cost effective than was anticipated originally, in large part because the costs of compliance were greatly exaggerated. The overestimation of the costs of compliance should be a signal of the potential biases in industry-based compliance cost assessments and should highlight the importance of increased attention to the cost estimates in regulatory analyses. Both the benefit and cost estimates of regulations merit careful scrutiny.

The prospect for any change in the standard, however, is not great. Now that the large firms in the industry are in compliance, they no longer advocate changes in the regulation. Presumably, the reason is that the capital costs of achieving compliance represent a barrier to the entry of newcomers into the industry. This is simply one more illustration of the familiar point that surviving firms often have a strong vested interest in the continuation of a regulatory system.

APPENDIX

Injury Rate and Quit Regression Results

The forecasted lost workday injury and illness rates in Figure 1 and the forecasted quit rates in Figure 2 were each based on a regression equation estimated for the preregulation period, which was then used to predict the postregulation experience.

The time period for the injury rate equation to be estimated was 1960–1977.[30] Because of the change in the injury rate data series after the advent of OSHA, I merged the pre-OSHA and post-OSHA series after placing them on a comparable basis.[31] The dependent variable in the analysis was the log-odds of the lost workday rate (i.e., the natural logarithm of the lost workday accident rate divided by 100 minus this rate), which avoids the otherwise constrained nature of an accident rate variable, which cannot be outside the interval [0, 100].

The explanatory variables are intended to capture both cyclical influences and changes in the technology of the industry. The cyclical variable is average hours per week, which should be positively related to the risk level. The fraction of female employees and the fraction of production workers also should be positively related to the risk level in this industry. Each of these variables is strongly related to the types of cotton processing operations regulated by the standard. This pattern is somewhat unusual because unlike most industries where the riskier blue collar jobs are held by males, in textile mills women often have very hazardous jobs. Finally, a lagged dependent variable has been included as a proxy for the current stock of health and safety capital in the industry.

The regression results in Table A1 follow the expected patterns, with cyclical and technological mix variables performing the strongest. This preregulation equation is used to forecast the predicted risk levels after 1977, and these predicted values are given by the dashed line in Figure 1.

The prediction of worker quit rates in Figure 2 was quite similar. To isolate the effect of the standard, I used an equation patterned after my analyses of manufacturing quit rates.[32] The dependent variable was the log-odds of the quit rate. Worker quitting should be positively related to the injury rate and to the fraction of female employees, which serves in part as a proxy for the job mix. Higher wages should diminish quitting, and there should be increased

Table A1. Regression equation for the log-odds of injuries and illness involving at least one lost workday in the textile mill products industry, 1960–1977.

	Coefficients (standard errors)
Independent variables	
Intercept	−13.86
	(4.77)
Average weekly hours of labor force in industry	0.041
	(0.013)
Fraction of female employees in industry	6.81
	(2.41)
Fraction of production workers in industry	5.25
	(3.58)
Lagged dependent variable	
$\ln [IR_{t-1}/(100 - IR_{t-1})]$	−0.113
	(0.242)
Summary statistic	
$\bar{R}^2$	0.78

Table A2. Regression equation for the log-odds of the quit rate in the textile mill products industry, 1960–1977.

Independent variables	Coefficients (standard errors)
Intercept	33.08 (38.17)
Injury rate in industry	0.21 (0.39)
Fraction of female employees in industry	15.53 (9.43)
ln(wage rate in industry)	−0.91 (0.32)
ln(average weekly hours in industry)	−12.83 (9.76)
ln(average weekly overtime hours in industry)	2.54 (1.06)
Summary statistic:	
$\bar{R}$	0.90

turnover during cyclical upturns as reflected in the work hours and overtime hours variables. The significant coefficients in Table A2 follow the expected patterns, with the fraction of female employees, wages, and overtime hours being the most instrumental. This equation, estimated for the pre-OSHA period was used to predict quit rates after imposition of the standard. The predicted quit levels are those shown in Figure 2 by the dashed line.

The author was the principal consultant to Centaur Associates and a co-author of the Centaur report cited. The superb efforts of John Birdsong (costs) and Paul Kolp (benefits) are also acknowledged without implicating them with respect to the policy views and contents of this paper.

W. KIP VISCUSI is Professor and Director, Center for the Study of Business Regulation at Duke University.

NOTES

1. *Federal Register, 122*(43) (June 23, 1978): 27350–27399.
2. These stages were devised by Schilling, B. F., et al., "A Report on a Conference on Byssinosis," *Excerpta Medica International Congress Series, 11*(62) (1963) and amended by Merchant, J., et al., "An Industrial Study of the Biological Effects of Cotton Dust and Cigarette Smoke Exposure," *Journal of Occupational Medicine, 15* (1973).
3. See Schilling, *op. cit.,* and Merchant et al., *op. cit.* There is some debate over the implications of Grade 2 byssinosis, which may pose a small risk of early death among retirees.
4. For a critical review of the medical evidence and a summary of the weakness of the evidence supporting the causal link, see the National Research Council Committee on Byssinosis, *Byssinosis: Clinical and Research Issues* (Washington, DC: National Academy of Sciences, 1982).

5. See Merchant et al., *op. cit.*
6. Such experiments remain controversial and thus far have not been initiated.
7. Even these health impact estimates may be too high. The relationships between cotton dust exposures and worker health (i.e., the dose–response relationships) in the medical literature are based on individuals with long worklives at high levels of cotton dust exposure, thereby being somewhat unrepresentative of workers in the mills at the present time. See Morrall, John F., "Cotton Dust: An Economist's View," *The Scientific Basis of Health and Safety Regulation*, R. Crandall and L. Lave, Eds. (Washington, DC: Brookings Institution, 1981), pp. 93–108.
8. *Federal Register, op. cit.*
9. See Morrall, *op cit.*, for support of this view.
10. See Viscusi, W. Kip, *Risk by Choice: Regulating Health and Safety in the Workplace* (Cambridge, MA: Harvard University Press, 1983), Chap. 6.
11. See particularly Litan, Robert, and Nordhaus, William, *Reforming Federal Regulation* (New Haven, CT: Yale University Press, 1983), and also Viscusi, *op. cit.*
12. *American Textile Manufacturers Institute v. Donovan*, 452 U.S. 490 (1981).
13. The total annualized cost of the tighter standard would be $222 million compared with $91.9 million for the present standard. These estimates were calculated using data from the report by Centaur Associates, *Technical and Economic Analysis of Regulating Exposure to Cotton Dust*, Vol. I, report prepared for the Occupational Safety and Health Administration, 1983.
14. The report that emerged from this effort is that by Centaur Associates, *op. cit.*
15. The protection factor for such masks is quite high since they have 93–99% filter efficiency for removing the dust from the air. See Merchant, J., et al., *op. cit.*, 1973b.
16. For dust mask usage data, see the Centaur report, *op. cit.*, p. 4–41.
17. This estimate was calculated using data from Centaur Associates, *op. cit.*, pp. 6-7 and 6-10.
18. Centaur Associates, *op. cit.*, p. 4–4. The Centaur study was based on a telephone survey of 170 textile firms and a field survey of 14 plants.
19. *Ibid.*, p. 1-8.
20. *Ibid.*, p. 6-7.
21. The data in this paragraph are drawn from U.S. Bureau of Labor Statistics, *Occupational Injuries and Illnesses in the United States by Industry*, 1978 and 1982 (Washington, DC: U.S. GPO, 1980 and 1984).
22. See U.S. Department of Labor, *Employment and Earnings*, various issues.
23. See the Centaur report, *op. cit.*, p. 1-8. The limited data that do exist on the nature of the capital expenditures related to compliance with the regulation are suggestive of a possible link with the rise in accidents. For example, sales of new cotton system cards rose from 800 in 1977 to 1500 by 1982. See the Centaur report, *op. cit.*, p. 4-18.
24. These patterns are based on unpublished OSHA computer printouts generated for the author.

25. See Viscusi, *Risk by Choice*, and Viscusi, W. Kip, *Employment Hazards: An Investigation of Market Performance* (Cambridge, MA: Harvard University Press, 1979).
26. See Viscusi, W. Kip, and Zeckhauser, Richard, "Optimal Standards with Incomplete Enforcement," *Public Policy*, *26* (1979): 437–456.
27. The prospective estimates appear in the *Federal Register*, *122*(43) (1978): 27369, and the 1983 estimates appear in Centaur Associates, *op. cit.*, p. 1-8.
28. See Viscusi, *Risk by Choice.*
29. *Ibid.*
30. This equation was patterned after that used in Viscusi, W. Kip, "The Impact of Occupational Safety and Health Regulation," *Bell Journal on Economics*, *1*(10) (1979): 117–140.
31. More specifically, I predicted the injury rate (IR) for 1972 using the pre-OSHA data and used the ratio of the observed IR_{72} to this predicted value to scale up the pre-OSHA variable. Although the resulting data series is not ideal, the cotton dust standard occurs sufficiently after 1972 and the IR shift in 1978 is so stark that the results are not greatly sensitive to the data series merger.
32. See Viscusi, *Employment Hazards*, pp. 189–197.