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Setting Efficient Standards for Occupational Hazards

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The procedures used to set standards for occupational health and safety have seldom adhered to any meaningful economic principles. The Occupational Safety and Health Administration (OSHA) began its standard-setting activity with an indiscriminate adoption of the industry's voluntary safety code as its first set of mandatory standards. Standard-setting thereafter continued to be based on risk and technical feasibility, and it was not until 1975 that OSHA began to systematically calculate the costs and economic effects of its regulations. Notwithstanding these changes, OSHA did not estimate both benefits and costs on a consistent and meaningful basis until 1981. Moreover, the Reagan Administration is the first to impose a formal benefit-cost test on regulations, except where prohibited by the agency's legislation.

The exception for agencies such as OSHA, which have absolute legislative mandates to promote risk reduction, is of substantial consequence. In the U.S. Supreme Court's cotton dust decision, OSHA was explicitly prohibited from basing its policies on a benefit-cost test.[1] Nevertheless, the variation in OSHA's cotton dust standard according to different stages of processing is roughly consistent with a cost-effectiveness test in which the cost per case of byssinosis is equalized across different stages of processing. The Supreme Court did not rule out these variations, but the resulting standard was required to be set at the lowest feasible level, where feasibility was interpreted as "capable of being done." In contrast, imposing a benefit-cost test would also equalize the cost per byssinosis case over the stages of processing, but it would only tighten the standard until the cost per case no longer exceeded the value society placed on preventing a case of byssinosis. Whether the cotton dust decision will interfere with efficient standard-setting of this type is unclear since OSHA continues to calculate benefits and costs, and the basis for the changes in the regulation made during the review of regulatory proposals by the Office of Management and Budget is not disclosed.

Rather than focus on the appropriate basis for regulations in view of these legal constraints, I will consider how regulations should be structured to be efficient, that is, to maximize overall benefits less costs to society. To the extent that this policy criterion is controversial, it is largely because of a misunderstanding of how one values the benefits of risk regulation. Benefits of improved health and safety are not restricted to decreased medical costs and improved productivity, though these factors are not irrelevant. The appropriate benefit measure is how much society is willing to pay for the risk reduction.

In practice, the most reliable guide to society's valuations is the amount workers are willing to pay for improved workplace safety. These amounts are quite large, as workers value their lives at roughly $2 million and a typical lost workday accident at $30,000. These estimates do not imply that a worker would accept certain death for $2 million, but that he would incur a small risk for compensation at the rate of $2 million for his life, e.g., $200 extra income per year to accept an annual death risk of 1/10,000. These estimates are meant to be illustrative of the general range of the estimates of willingness to pay. Subsequent discussion does not hinge on these particular values but rather on the overall principles for policy design.

Fundamentals of Standard Setting

If setting standards were tantamount to dictating levels of health and safety, one could assess the costs and benefits of different risk levels and then select policies accordingly. In practice, the enforcement of standards is seldom completely effective. Particularly for OSHA standards, which are enforced so weakly that noncompliance is rampant, the context for the standard-setting process exerts a profound influence on the implications of different policies.

Enterprises will choose to comply with regulatory standards if the expected costs of noncompliance exceed the expected costs of compliance. In instances in which noncompliance is preferable, a firm will risk the penalty levied on noncompliers and then make the mandated changes in

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workplace conditions only after being inspected and threatened with an ever-increasing schedule of fines for noncompliance.

Stringent standards, such as those linked to the lowest technically feasible risk level, yield the greatest safety gains in an idealized world of full compliance but may have quite different effects in practice. For firms that choose to comply, lower standard levels enhance safety; a counterbalancing influence is that lower-risk standard levels raise the relative costs of compliance, leading more firms to ignore the program and to leave their workplace conditions unchanged. The net effect depends on the relative strength of these influences.

In the extreme case of standards that are subjected to widespread ridicule, the risk of adverse publicity from noncompliance is reduced, and the incentive to invest in workplace health and safety is diminished even further. Even if one advocated that OSHA attempt to promote but a single objective, worker health and safety, it would not typically be desirable to establish standards at the most stringent, technically feasible levels.

Because of the effects of the standards policy on the likelihood of compliance, an analysis of the compliance decision should be incorporated in any assessment of the impacts of different policies. Factors other than the level of the standard also have the expected patterns of influence on compliance. Firms are more likely to comply as the cost of meeting the standard declines and as the expected penalties for noncompliance increase. Enforcement policies such as OSHA's, which have a very weak enforcement mechanism (i.e., low penalty levels, infrequent inspections, and few violations per inspection), consequently will do very little to enhance worker safety.

The role of the costs of compliance to the firm is of particular interest since it suggests that there is likely to be a diversity of responses to any uniform standard, as compliance will be observed where the cost needed to meet the standard is low, and noncompliance will prevail when these costs are high. Recognition of this heterogeneity in the design of policies may lead to greater compliance and worker safety. In particular, the standard should be set at tighter levels when the compliance costs are very low. Policymakers might, for example, set different standards for different industries, for different stages of production, or for facilities of different vintage. Heterogeneity in the level of benefits from a standard, as in the case of populations that are particularly sensitive to some occupational exposure, similarly should lead to differentiation in the level of the standard.

Once the effect of different standards policies on the outcomes at different firms is understood, the next step in evaluating policies is to assess the benefits and costs of different standards levels, where the health benefits can be converted into dollar equivalents using a measure of the willingness to pay for risk reduction. There are two interrelated guidelines for optimal policies. The optimal standard should provide the greatest net gains to society, i.e., it should maximize benefits less costs. To achieve such an optimal policy in the usual situation in which the incremental (or marginal) benefits from tightening the standard are declining and in which the marginal costs of compliance with tighter standards are increasing, one should tighten the standard until the additional benefits no longer exceed the additional costs.

These basic principles for policy design ideally should also reflect any heterogeneity of the costs and benefits associated with the standard. If compliance costs are less for new facilities than for existing facilities that must be modified, the regulatory agency should set differential standards based on these cost differences, so that marginal benefits and costs will be equated for each type of facility. The inclusion of a "grandfather" clause in which existing tractors were exempted from the OSHA rollover protection standard is the most prominent example of an OSHA standard that reflects this general principle. While some analysts have bemoaned the "new source bias" in which new facilities face tighter standards, discrimination along these lines should be encouraged as a means to make standards policies more effective.

Full recognition of the heterogeneity in the costs of compliance would make the standards program tantamount to a penalty system, which is generally favored by economists. Suppose that OSHA levied a fine on firms based on their health and safety performance or workplace conditions, where the level of the fine reflected the marginal benefits of additional improvements. Firms could decide whether or not to comply based on the costs involved. The advantage of this approach is that the marginal benefits and marginal costs of compliance could be equated on a decentralized basis, ensuring efficient levels of health and safety.

Under a standards program, many firms will ignore the standard altogether until after found out of compliance. Once identified as a noncomplier, they face substantial penalties that are levied until they are brought into compliance. Unless the standard that must be met has been set at a level reflecting the firm's compliance costs, there will be potentially large inefficiencies as the compliance costs imposed may far exceed any health benefits. So long as standards do not reflect the heterogeneity in benefits and compliance costs, they will inevitably create inefficiencies and unnecessary distortions.

The OSHA Carcinogen Policy: A Case Study in Principles for Standards Design – In one particularly important case, it is possible to make a direct comparison of the guidelines discussed above and OSHA's principles for policy design. Whereas most rule makings involve regulation of specific substances, the OSHA carcinogen policy, which was proposed in 1978 and issued in 1980, established a general set of principles for the identification, classification, and regulation of potential occupational carcinogens.[2] The open-ended nature of these guidelines is reflected in the wide range of cost estimates: $83 billion if OSHA sets loose standards for a small number (38) of substances, $296 billion for the medium scenario of moderate standards for a larger number (1,970) of substances, $526 billion for moderate standards for a large number (2,415) of substances, and prohibitive cost levels for any stringent standards, regardless of which of the three numbers (38, 1,970, or 2,415) of substances is regulated. (These estimates were converted into current prices using cost data presented in the Council on Wage and Price Stability, RARG Report.[3]) The potentially enormous costs associated with the carcinogen policy and the importance of a well-designed cancer policy to the well-being of workers gives this set of guidelines a preeminent role in any risk regulation policy.

Unfortunately, the OSHA carcinogen policy bears little, if any, relation to meaningful guidelines for policy design. OSHA's highly simplistic cancer policy abstracts from almost all of the variations in the costs and benefits of regulating different substances, thus ignoring the essential ingredients of a sound policy. Rather than promulgate rules for standards design along the lines of the principles discussed in the preceding section, OSHA established two classes of risks — category I and category II carcinogens — and uniform standard-setting guidelines for every substance within each category.

A substance is placed in category I if it is a potential occupational carcinogen in (1) humans or (2) in a single mammalian species in a long-term bioassay, where the evidence is either in concordance with other scientific evidence of potential carcinogenicity or if the Secretary of Labor chooses to waive the concordance requirement. If the evidence of carcinogenicity is only "suggestive" or if it is based on mammalian bioassays that are not in "concordance" with other evidence, the substance is placed in category II. Substances placed in category I must be reduced using engineering and work practice controls to the lowest feasible level or the level at which it has been shown that there is no risk. Moreover, if a suitable substitute exists, no occupational exposure level is permitted. Standards for category II carcinogens are not as tight or as well-defined; these standards will be set to "appropriate" levels on a case-by-case basis. Although no substances have yet been categorized under this policy, in 1980 OSHA identified 107 substances for possible classification.[4]

What is most striking about the carcinogen policy is that it is not designed to promote the interests of the workers or society at large. The driving force behind the regulatory policy is the strength of evidence pertaining to possible carcinogenicity. The level of risk is not a matter of concern to OSHA. Following these guidelines, one would possibly ban substances for which there was strong evidence of a minor hazard and not regulate substances for which there was weak evidence of a substantial risk. These relative priorities are certainly misplaced. OSHA should utilize whatever information is available and focus on regulating substances based on the greatest potential net benefits to society. Even if one chose to ignore the costs of regulation, as does OSHA, some consideration of the magnitude of the risk must enter in order to determine the health benefits to the workers who are being protected.

OSHA's decision to reduce category I carcinogens to no-risk or lowest feasible levels completely ignores the types of benefit-cost tradeoffs that are critical to a balanced policy. Rather than have critical cutoffs for carcinogens that must be effectively banned, it is more desirable to assess the benefits and costs associated with different exposure levels and then set the standard offering the greatest net benefits.

The only area in which cost considerations enter explicitly is with regard to banning substances when suitable substitutes exist. In this instance, economic feasibility also may enter OSHA's deliberations. The difficulty is that the level of costs per se should not dictate whether a substance is banned. It may be inexpensive to replace substances that pose trivial hazards, and it may be very expensive to replace very hazardous substances. In each case, consideration of the level of costs and evidence of possible carcinogenicity are not a sufficient basis for making policy. Carcinogen regulations should be based on their overall merits, not crude rules of thumb.

Once the economic framework for assessing carcinogen policies is structured appropriately, policymakers will begin to develop the kind of information needed to make meaningful decisions. At present, the assessment of benefits consists of little more than ascertaining the degree to which a substance can be classified as a carcinogen. With a benefit-cost approach, three types of information are required: (1) the nature of the dose-response relationship; (2) the size of the population affected by the risk and any heterogeneity in the nature of the response; and (3) an assessment of the value of the health effects — their severity, reversibility, and, if possible, their comparable monetary value.

Information regarding the nature of the dose-response relationship is usually restricted to the establishment of some exposure level at which the risk is not zero. Even limited information can be utilized in a more effective manner than at present by making some reasonable assumptions about the dose-response relationship. In the case of risk thresholds, a common assumption in the medical literature is that the risk is zero below the threshold and increases linearly thereafter. OSHA's obsession with eliminating all risks that pass some threshold can only be justified if the risk rises discontinuously, perhaps from zero to one, once the threshold has been reached.

Moreover, even a properly formulated threshold model may simply be a reflection of our general ignorance of the properties of different substances. When we have a small number of studies of carcinogenicity of a substance, there is a tendency to identify as the threshold the lowest level at which significant cancer risks have been observed. The underlying process generating the risk may be better characterized by continuous relationships, which often have superior statistical properties. (Two examples are the logit and log-probit models.)

The next two informational inputs, the population affected and the distribution of the health effects, present fewer practical difficulties. Perhaps most important and least considered is the assessment of the severity of the health effects. If the health effects are relatively minor or potentially reversible, the benfits from risk reduction will be much less than if workers are being killed or permanently disabled. While the evidence on the value of life and worker injuries is often instructive, there is a continuing need for refinement of the appropriate values for the diverse health effects that are the focus of risk regulation policies.

Setting the Level of the Standard

An instructive technique for analyzing the efficacy of a standard is to assess the cost per adverse health impact prevented and, if this amount is clearly disproportionate to the value of the health benefits or if the costs are higher than those of other programs producing these health gains, the policy should not be adopted. Table 1 presents the costs per health impact associated with different proposed standards. In cases such as acrylonitrile, in which OSHA

Table 1 – Costs of Health Improvements Under OSHA Standards*

Description of Proposed Standard	Health Impact	Average Cost per Case
Lead: 100 μg/m³ of lead in air	High lead levels in blood	$276,000
Cotton dust: 0.2 mg/m³ of respirable dust in air	Byssinosis cases	$415,000
Noise: 85 dB	Hearing loss	$169,000
Acrylonitrile: 2.0 ppm† of acrylonitrile in air	Cancer Death	$1.8 million, $4.6 million
Arsenic: 0.004 mg/m³ of arsenic in air	Death	$5.6 million (midpoint of range)
Coke oven: 0.3 mg/m³ particulate in air	Death	$13.9 million

* Source: Calculations by the author using data from the Council on Wage and Price Stability (see discussion in the text)
† parts per million

proposed several options, the standard actually adopted is listed. I calculated the costs per case using data provided as part of the White House regulatory review process. (The costs per case represent present values calculated in terms of 1980 prices, using a 10% interest rate whenever possible. The data used are drawn from several reports of the Council on Wage and Price Stability.[5-10] Alternative costs estimates are presented for cotton dust by Morrall[11] and for the four carcinogens by Broder and Morrall.[12]) Although similar calculations are often made by the regulatory oversight group when sufficient information is available, often the data needed to assess the benefits of the standard have not been presented by OSHA. Even more troublesome is that such calculations have not been a routine part of OSHA policy design.

The figures in the final column of Table 1 highlight the diverse ways in which the government can allocate resources to affect individual health. With these policies, we can reduce lead in workers' blood below the levels linked with serious health effects for $270,000 per affected worker, eliminate byssinosis at $415,000 per case, reduce hearing loss at $169,000 per affected worker, eliminate cancer for $1.8 million per case, and extend lives for $4.6 million to $13.9 million per life.

Before we can allocate resources efficiently, we must make some judgments across health impacts of their relative importance. Is it more desirable to prevent three cases of hearing impairment than to prevent one case of byssinosis? To date, OSHA has yet to make such comparisons, focusing instead on lowest feasible risk levels.

The cost figures also highlight some clearcut inefficiencies. More lives could be saved for fewer dollars by, for example, loosening the coke oven standard and tightening the acrylonitrile standard. (Both of these policies are relatively inefficient methods for extending lives, however.) Once we begin the process of trying to actually set the standard level optimally, we need two additional pieces of information: the value of the health impact and the influence of different levels of the standard on the benefits and costs, which we will consider in the cases below.

A Continuous Choice: Arsenic – (The following discussion is based on my calculations and material in the Council on Wage and Price Stability.[9] Using different risk assumptions, Broder and Morall[12] estimate much higher costs for this standard. All cost estimates for this standard are partial estimates.) The choice of the optimal level for the standard can be illustrated using the cost per life associated with arsenic standards of differing stringency. The average cost per life saved for different standards is given in column 2 of Table 2, and the marginal costs per life appear in column 3. The final column is of principal interest since it is the incremental cost per unit benefit that should determine how stringent any regulatory policy should be.

The marginal cost per life escalates dramatically as the standard is successively tightened, rising to a value of $68.1 million at the 0.004-mg level proposed by OSHA. This cost dwarfs any reasonable estimate of the value of life. The lives being extended in this instance are those of workers in the zinc, lead, and copper smelting industries, none of which are particularly safe. One would expect that these workers had relatively low values of life based on their decision to work in these industries so that the value of life estimate of $2 million for the average worker substantially overstates these workers' willingness to pay for risk reduction. Even if a value of life just over $1 million per worker were used, only the least stringent alternative would be warranted.

The escalation of marginal costs per life and the much more modest increase in the average cost per life shown in Table 2 highlight the importance of focusing on incremental changes. When the costs of a tighter standard are averaged, the efficacy of the policy may look much greater than would appear if the changes in the costs and benefits were isolated.

Heterogeneous Standards: Cotton Dust and Noise – (Technical information for this is based on material from several Council on Wage and Price Stability reports.[6,7,11,13,14]) In instances in which there are wide variations in compliance costs, it is often desirable to establish several standards reflecting the differences in the relative costs per unit benefit achieved. One type of variation is within an industry. Different phases of the production process may entail different costs of meeting the standard as well as different benefits. In the case of cotton dust, the risk of byssinosis increases in the later stages of processing, for any given

Table 2 – Cost per Life for Different Arsenic Standards

Standard Level, mg/m³	Average Cost per Life	Marginal Cost per Life
0.10	$1.25 million	$1.25 million
0.05	$2.92 million	$11.5 million
0.004	$5.63 million	$68.1 million

* Source: Calculations made from data of the Council on Wage and Price Stability.[9]

concentration of dust, because of the greater toxicity of the dust in the weaving stage than in the yarn preparation stage. The costs of compliance also vary by stage of processing.

The net effect of these variations is captured in the data in Table 3 pertaining to the marginal costs of preventing byssinosis in different stages of processing. The greatest health benefits per dollar are achieved by regulating mill slashing and weaving. For higher values placed on byssinosis, it is then optimal to regulate yarn preparation as well, after which it becomes more cost-effective to tighten the mill slashing and weaving standard. Only for very high values placed on byssinosis will it be optimal to set a very tight standard for yarn preparation.

Suppose, for example, that most cases of byssinosis prevented were comprised of reversible grades of the disease involving occasional chest tightness. If this health outcome were valued at $22,000, a standard of 0.5 mg/m^3 would be desirable for mill slashing and weaving but not for yarn preparation. If most byssinosis cases were of the severe (grade 3) type involving permanent incapacity, but not necessarily any excess mortality, a value per case of $300,000 might be more appropriate. In that case, a mill slashing and weaving standard of 0.44 mg/m^3 would be warranted, as compared with a tighter yarn preparation standard of 0.36 mg/m^3.

Even more dramatic variations in cost-effectiveness are exhibited in the case of noise regulation. Table 4 summarizes the cost per worker protected from hearing loss in 17 different industries. (Since these data pertain to average rather than marginal costs, they will be used to highlight the variations in cost-effectiveness rather than to analyze where a standard in a particular industry should be set.) The cost variation is quite dramatic. Under the 95-dB standard, the cost per case of hearing loss prevented ranges from $19,000 for electrical equipment and supplies to $233,000 for the machinery industry. The variation is even greater for an 85-dB standard, ranging from $39,000 per case to a high of $395,000 per case in the textile mill products industry. The cost per case estimates in the most costly instances are sufficiently high to warrant a major reassessment of whether it is worthwhile to spend hundreds of thousands of dollars to prevent a case of 25-dB hearing threshold loss after 20 years of exposure.

The optimal standards system that would emerge after some value per case of hearing loss was established would involve the use of differential standards. Some industries, such as electrical equipment and supplies, should be tightly regulated; others, such as the chemicals and allied products industry, might be regulated at modest levels; in many instances in which the costs of noise reduction are extremely high, as for machinery and textile mills, no engineering controls may be warranted.

Table 3 – Impact of Variations in the Cotton Dust Standard*

	Marginal Cost per Case (in thousands of dollars)		
	Cotton Dust Standard, mg/m^3		
Stage of Processing	0.5	0.2	0.1
Yarn preparation	56	593	6268
Mill slashing and weaving	22	1338	1867

* Source: Calculations made from data of the Council on Wage and price Stability.[6]

Table 4 – Industry Cost Variations for the OSHA Noise Standard*

	Cost per Worker Protected (Thousands of Dollars)	
	90 dB	85 dB
Food and kindred products	75	179
Tobacco manufactures	104	200
Textile mill products	227	395
Lumber and wood products	228	303
Furniture and fixtures	150	151
Paper and allied products	62	78
Printing and publishing	108	215
Chemicals and allied products	80	132
Petroleum and coal products	215	257
Rubber and plastics products	38	68
Stone, clay, and glass products	53	96
Primary metal industries	218	372
Fabricated metal products	192	188
Machinery, except electrical	233	245
Electrical equipment and supplies	19	39
Transportation equipment	87	111
Electric, gas, and sanitary services	137	189
Weighted average	119	169

* Source: Calculations made from data of the Council on Wage and Price Stability.[1]

Performance *v* Design Standards

The efficacy of a particular standard depends not only on its stringency but also on the nature of the standard. (A very detailed report on the advantages of performance standards was edited by MacAvoy.[15]) OSHA safety standards typically specify precise characteristics that the workplace must meet, while the health standards are defined in terms of objective workplace conditions rather than the level of the risk itself.

Standards pertaining to workplace characteristics are typically referred to as design standards, engineering standards, or specification standards. Standards stated more directly in terms of the reduction in worker risk are termed performance standards. There is clearly a continuum of such possibilities, depending on the leeway permitted by the regulation.

Prominent examples of specification standards can be found throughout OSHA regulations. Handrails are not simply required to be sturdy; OSHA instead imposes meticulously defined requirements pertaining to their height (30 to 34 in), thickness (at least 2 in for hardwood and 1½ in for metal pipe), spacing of posts (not more than 8 ft), and clearance with respect to the wall or any other object (minimum of 3 in). (See reference 16[pp 20-21]). In the case of lawnmowers used professionally, OSHA not only imposes detailed requirements for lawnmower design, but also insists on an overwhelming set of "Caution" signs near each discharge opening, at the engine starting control point, near the opening for the catcher assembly, and in the instruction manual. (See reference 16[pp 421-422]). The most extreme case to date of engineering standards is that of the U.S. Department of Transportation's standards for city buses, which are almost tantamount to complete bus designs. It is also noteworthy that most of these buses have developed major structural defects.

Performance standards place a greater direct emphasis on the desired policy outcomes. The best known performance standard now in existence is the Environmental Protection Agency's "bubble policy," which relaxes the pollution requirements for each emissions point and imposes instead an overall requirement on emissions leaving a hypothetical bubble over the plant. Firms are then free to choose which pollution sources to control, reducing their compliance costs.

President Ford's Task Force on OSHA explored in detail the implications of such performance standards for machinery and machinery guarding. Current OSHA specification standards are so narrowly defined that they are only pertinent to 15% of all machines, and for these cases enterprise discretion is limited. (See the "preface" of MacAvoy[15].) The model standard developed by the Task Force outlines the broad types of risks that may arise and the various options available to reduce these hazards, permitting the firm to select the least costly alternative.

In the extreme cases of a job risk performance standard, there might be no requirements whatsoever regarding the safety of particular workplace conditions. If worker injuries and illnesses can be monitored accurately and if these outcomes are a reliable index of the risk facing workers, as they should be in large firms, a penalty could be levied based on the adverse effects on workers rather than on workplace characteristics.

Although performance standards may often be superior to specification standards and should always be included among the policy options, it is an oversimplification to claim that they are always preferable. The choice between the two types of standards hinges on four types of issues.

The first concern is the degree of certainty regarding the nature of the regulation, which affects not only the equity of the standard but also the degree to which firms can make investments that they can be confident are in compliance. Under a program of engineering standards, the regulatory requirements are specified quite precisely and, once these are met, there will be no risk of penalty unless the regulation is changed. There may, however, be other uncertainties with engineering standards. The immense volume of OSHA standards made enterprises uncertain of which standards OSHA will choose to enforce. The enforcement process has been fairly uneven, as readily monitorable hazards have received most attention. If enterprises instead are subjected to a performance-oriented exhortation to make the workplace safe, the result may be a capriciously enforced program that creates so much uncertainty regarding the nature of the regulation that firms forego any improvements until after they are inspected and penalized.

The reliability with which one can predict the outcome under a regulation is a quite legitimate policy concern. Insofar as possible, performance standards should be formulated in terms of objective criteria (e.g., lead levels in workers' blood or the number of workers killed) to provide a sound basis on which firms can make decisions. Even if it is not possible to equal the predictability of a specification standard, there may be other benefits of performance standards that offset these differences.

A second oft-cited advantage of specification standards is that they provide information to firms on how to improve safety. Since most OSHA standards consist of voluntary industry standards, which were modified by changing the discretionary "should" to a more demanding "shall," it is difficult to maintain that OSHA did much more than increase the prominence that this information was given. For health exposure standards set at the lowest technically feasible levels, the standard conveys no useful risk information at all. More generally, there is no inherent incompatibility of performance standards with efforts to provide firms with information about alternative methods of compliance.

A third concern is which type of standard is more effective in promoting health and safety. Under design standards, we do this indirectly by penalizing workplace conditions, such as a slippery staircase, that are believed to pose risks. In some cases, the relationship between the environmental condition and the level of risk is unclear. Cotton dust exposure levels are strongly, but imperfectly, correlated with byssinosis, and no causal link between the two has yet been established. If cotton dust actually causes byssinosis or if the reduction of cotton dust also leads to a reduction in the agent that does cause the disease, the regulatory policy will be effective. It is also possible that the regulation will not improve worker health even if cotton dust exposures are reduced. In instances where we regulate workplace characteristics correlated with the risk rather than the risk itself, it is especially important to monitor the effectiveness of the policies. For performance standards in which the standard is more clearly linked to health outcomes than the work environment, these problems are diminished.

The central advantage of performance standards is that the firm has the opportunity to select the least costly means of compliance. The cost savings do not stem solely from the greater technical expertise of businessmen, though this may be a pertinent factor. The greatest gains from this discretion arise from the wide variations in technologies of different vintage and of quite different type. Although one compliance approach may be most efficient in many contexts, uniform risk reduction technologies will seldom be optimal in all situations.

The scope of possibilities introduced by performance-oriented standards encompass much more than simply offering a firm several alternative ways of guarding a punchpress. Other, more imaginative responses can be introduced. Firms might require workers to wear respirators to decrease health hazard exposures rather than make more costly changes in the workplace. In the case of the noise standard, protective devices could achieve a 90-dB exposure level at the cost of $15,000 per worker, as compared with $119,000 per worker for the engineering standards proposed by OSHA. (These estimates are calculated using data from the Council on Wage and Price Stability.[7])

The protective devices of these types may, however, raise other problems. If they are uncomfortable, workers may not wear them and, if they do wear them, they may require higher wages to compensate for the increased discomfort. Earmuffs and other devices to muffle noise may prevent hearing loss but may also increase the risk of accidents if workers cannot hear warning shouts regarding imminent dangers. These caveats suggest that the attractiveness of alternative modes of regulation should be assessed on a case-by-case basis. No single regulatory mode is likely to be always dominant.

A final possibility is that the enterprise may choose to meet a performance standard not by altering the workplace or protecting the worker, but by changing the workers exposed to the risk. Since early stages of byssinosis, for example, have mild symptoms that are reversible, workers could be removed from their jobs before the disease reached advanced stages. Similarly, workers exposed to lead could be rotated to different jobs once the lead in their blood reached levels linked to serious health effects.

Whether or not rotating workers is desirable depends on the nature of the health impacts. If the early stages of byssinosis are sufficiently less harmful than the later stages, rotating workers will reduce the overall adverse health effects. When the rotation is based on some risk exposure, as in the lead case, the nature of the dose-response relationship assumes critical importance. If, for example, the risk of cancer rises linearly with one's exposure to radiation, on average no lives will be saved through rotation; but if there is no risk threshold before such a linear increase in the risk begins, there may be considerable health benefits from a rotation policy. As our understanding of the underlying determinants of worker health is improved, we will be better able to identify situations in which rotating workers is desirable.

Personal Characteristics and Optimal Standards

Individual differences in the risk posed by a particular job are widespread and quite varied, ranging from differing sensitivities to toxic substances to the greater risk of assault faced by short policemen. Many particularly controversial instances involve risks strongly correlated with one's sex or race. Blacks with the gene for sickle cell anemia may incur a greater risk of harm from the low-oxygen conditions faced by a pilot, and female mail sorters face a greater risk of back injury when moving the standard 70-lb mail sacks.

In the absence of government intervention, market allocations of individuals to jobs will promote efficient matchups in many instances. If the worker bears all of the harm associated with the risk and if he is cognizant of his own particular risk, not simply the average risk for all, then he will select his job optimally. Since these informational requirements are more stringent than when there are no major differences in the riskiness of a job, there may be an additional motivation for intervention if the heterogeneity of the risk is not well understood.

The employer and the worker's fellow employees also may have a stake in the worker's riskiness. Worker injuries and illnesses disrupt production, lead to additional training costs, boost workmen's compensation benefits, and affect the firm's reputation, which in turn alters wage rates. Careless behavior may also lead to injuries to other workers. (The self-selection of workers to jobs may not yield efficient outcomes in many of these instances.[17])

For many jobs involving strength, dexterity, and other risk-related physical characteristics, employers are very selective in filling positions. Sometimes this selectivity is related quite explicitly to the risk. Smokers are not permitted to work at the Johns-Mansville asbestos plant since they face a risk of lung cancer almost 100 times greater than nonsmokers. Similarly, no women are permitted to work in the pigment paint division of the American Cyanamid Corporation because lead exposures pose considerably larger risks to pregnant women.

These distinctions based on sex have been widely condemned, in part because the women previously working in the division became sterilized to keep their jobs. In contrast, the ban on smoking received widespread favorable publicity and, unlike the lead case, did not lead to a critical OSHA review. A fundamental difference in these situations is that society may feel more strongly about distinctions based on unalterable personal characteristics than it does about individual choices that have increased one's riskiness in a job.

Another mechanism by which markets might reduce the costs imposed on others from this heterogeneity is by altering the worker's wage rate. Workers who impose greater losses on others should be paid a lower wage to reflect these expected costs. This wage flexibility is often limited in practice by wage floors (e.g., the minimum wage), limitations on the variation of wage rates if the source of the heterogeneity in riskiness is highly correlated with personal characteristics (particularly race, sex, and age), and institutional rigidities that prevent variation of the wage structure on an individual basis. (Some of these rigidities may reflect quite reasonable economic behavior; for small productivity differences, it may be quite costly both administratively and in terms of morale to vary the wage rate for a job.) Financial mechanisms also may have inherent limitations since there can be no adequate *ex post* compensation for a worker who is killed as a result of hazardous behavior by his co-workers. (Workers will, of course, receive *ex ante* wage premiums to reflect the expected number of accidents that will be inflicted on them. However, this mechanism seldom, if ever, reflects the risk associated with one's particular job. If one worker in a hundred is careless, the overall risk for the firm is small, but if he is working on an adjoining job, the risk to you may be quite high.)

Once the costs are imposed on parties beyond the labor market transaction, market processes become even more inadequate. The imposition on taxpayers of social insurance costs for injured workers has traditionally been the most pressing concern of this type. Much more disturbing problems have arisen in the past few decades as we have begun to learn more about the possibly catastrophic implications of workplace exposures for fetuses subjected to radiation, lead, and other carcinogens. Although the mother may take the baby's interests into account in selecting a job, there is no assurance that the preferences of the unborn will be fully reflected in these decisions. Moreover, even if these interests are fully recognized, the mother may not have complete information regarding the risk to the fetus, or she may be unable to alter the risk. For example, a woman with high lead levels in her blood before becoming pregnant will continue to have possibly hazardous lead levels even if she leaves the job associated with the exposure.

Situations such as these may pose major difficulties for the employer as well. If he prevents such exposures by excluding all women from the job, he may exclude substantial numbers of workers who would have not had any baby exposed to the risk. Alternatively, failure to discriminate in this fashion may increase his liability and the pressure for him to incur the costs needed to prevent possible adverse outcomes. In instances such as this, government regulations that define the employer's obligations precisely may benefit the employer by sharing some of the responsibility for his decisions.

To the extent that these issues have been addressed, it has been through rather simplistic policies. Most efforts have attempted to eliminate the risk for all, irrespective of the cost. While the past performance of affirmative action programs indicates an apparent willingness to sacrifice economic efficiency to promote other social objectives, these concerns are not unbounded.

Rather than adopt rigid policies that mandate, somewhat implausibly, the objective of equal risk for all, it would be preferable to review the need for such regulations on a case-by-case basis. If the cost of reducing the risk is small compared with the benefits of increased access, such measures should be pursued. (One prominent factor influencing these costs is whether workers are being excluded from new jobs or being moved from their present jobs. The costs to the firm and the worker are typically greater in the latter instance.)

But even in this situation, some heterogeneity in riskiness will remain. We cannot provide jobs of equal safety for all any more easily than we can ensure that all individuals will be productive on a particular job irrespective of their strength, diligence, or intelligence. Indeed, attempts to promote such equalization undermine a major beneficial feature of all market allocations. Workers are not assigned at random to jobs throughout the economy because the economy can function much more effectively if the differences in one's productivity on different jobs are reflected in the job matchups. An individual's sensitivity to various hazards or proclivity toward accidents is simply one aspect of his overall productivity. If this heterogeneity is exploited in matching up workers to jobs, rather than suppressed, the overall safety and efficiency of the economy will be enhanced.

Concluding Caveats

While designing regulations on the basis of their benefits and costs will promote risk reduction policies that better reflect the diverse impacts on society, our knowledge of these effects remains very imprecise. Uncertainties regarding the level of many health hazards, the nature of the dose-response relationships, the prospects for cost-reducing technological progress, and the appropriate valuation of health effects are but a few of the recurring problems. Application of benefit-cost criteria will not eliminate these inadequacies. It will, however, organize what we do know in a systematic manner and make it possible to determine how the optimal policy is affected by changes in these assumptions. So long as there are no systematic biases in the assessment of the expected net benefits of policies, the design of regulatory policies will be enhanced considerably.

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