Mortality Risk Analysis for the Occupational Safety and Health Administration's Occupational Exposure to COVID-19 Emergency Temporary Standard

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November 2021

EXECUTIVE SUMMARY

Overview

For economically significant regulations (those with annual costs, benefits, or both exceeding $100 million) executive branch agencies produce regulatory impact analyses (RIAs).[1] RIAs should include information about the problem an agency is trying to solve, various alternative ways of addressing that problem to achieve a desired outcome, and an assessment of the costs and benefits of each policy option to identify the alternative with the most net societal benefits.

Though RIAs can in theory be helpful for decision-making, in practice, RIAs are rarely comprehensive. For example, agencies often overlook long-term impacts and opportunity costs, most notably in the cost-benefit analysis portion of RIAs. "Opportunity cost" refers to the benefit society gives up when resources are used in an alternative way, such as occurs when governments regulate. This forgone benefit includes risk prevention efforts that regulations displace when they direct resources toward other purposes.

A form of economic analysis known as "mortality risk analysis" identifies the degree to which regulatory costs generate opportunity costs that offset their lifesaving benefits. A mortality risk analysis calculates a regulation's cost-effectiveness (i.e., the cost per life saved) and tracks this cost-effectiveness over time. If the cost per life saved of a regulation exceeds a particular threshold, then

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the regulation can be expected to raise societal mortality (i.e., the regulation can be expected to induce more deaths than it prevents as it displaces risk prevention spending). Though mortality risk analysis is useful for determining when regulations increase mortality, it can also assist regulators who want to make their RIAs more comprehensive because it can cast light on long-term effects and opportunity costs that often go overlooked.

Summary of Findings

On June 21, 2021, the Occupational Safety and Health Administration (OSHA) published an interim final rule that requires certain healthcare employers to develop and implement a plan to identify and control COVID-19 hazards in the workplace.[2] The regulation requires employers in settings that provide healthcare services or healthcare support services (with some exceptions) to implement requirements for patient screening and management, personal protective equipment, building ventilation, face masks, physical distancing, record keeping and reporting requirements, and other provisions and precautions. According to OSHA, the rule is expected to cost approximately $4 billion, prevent 776 people from dying, and prevent roughly 295,000 people from becoming infected.

Relying on data available in OSHA's RIA, we conduct an original mortality risk analysis of the rule. We estimate that the rule will reduce mortality risk in the short term but increase it in the long term. Although the rule is predicted initially to save 735 lives—the net number of expected lives saved in the first period after accounting for the mortality cost of regulatory expenditures—we expect the rule to increase mortality risk after 69 years. After a century has elapsed, the rule is expected to induce 2,134 more deaths than it prevents, and the figures grow less favorable for the rule in the years thereafter.

The results of this mortality risk analysis allow one to make inferences about the overall efficiency of the rule. If one assumes that OSHA's core analysis is correct, the rule likely passes a short-term cost-benefit test. However, if one uses OSHA's own estimates of monetized benefits, the rule still fails a long-term cost-benefit test (40 years and thereafter).

The results of our mortality risk analysis differ from the conclusions in OSHA's RIA primarily because our analysis accounts for the opportunity cost of displaced (and induced) capital investments in the market, whereas OSHA's analysis takes a short-term perspective that neglects long-term opportunity costs. Although some may find it surprising that a regulation issued on a temporary basis can have effects over such a prolonged period, the new investment, new technology, or business formation that a regulation displaces would have produced benefits on a schedule that may not have any relation to the schedule of benefits created by the regulation.

Given the emphasis that President Biden has placed on considering impacts of public policies on future generations,[3] agencies should include a mortality risk analysis as a routine part of RIA

because doing so would help ensure that regulations do not increase mortality in both the short and long terms.

THEORY AND METHODS

Background on Mortality Risk Analysis

Whereas well-designed regulations can protect the public, poorly designed regulations can produce unintended consequences that inadvertently increase health and safety risks. One way that poorly designed regulations produce unintended consequences is by forcing businesses and consumers to spend money. Because expenditures of most kinds result in real resources being exhausted,[4] alternative expenditures are displaced, and the potential benefits of those expenditures are lost. For example, families forgo spending on doctor's visits, safer vehicles, or living in more secure or less polluted neighborhoods when they spend money complying with regulations. Across society, some risks inevitably rise when regulations force private parties to expend resources to achieve regulatory goals instead of their own goals.

Countervailing increases in risk arise from nearly any expenditure because some risk-reducing expenditures are displaced when resources are commandeered and used in a different manner. This phenomenon is known as the "mortality cost of expenditures."[5] Given this tradeoff, a key question for policymakers is whether regulations reduce risk sufficiently to offset increases in countervailing mortality risk from regulatory expenditures. Even regulations intended to save lives can increase mortality if they are sufficiently costly. However, when federal agencies issue economically significant regulations, the RIAs they prepare under various executive orders and Office of Management and Budget (OMB) guidelines typically do not account for the mortality cost of regulatory expenditures.

The monetary threshold at which expenditures become so costly that they increase mortality risk instead of decreasing it is known as the "cost-per-life-saved cutoff," or simply "the cutoff." For example, if the cutoff value is $75 million and a regulation reduces consumption today valued at $15 billion, then the regulation results in 200 expected deaths. If the regulation is also expected to save 100 lives, then the regulation is predicted to increase mortality on net because the expected deaths exceed the expected lives saved. This kind of comparison is an example of mortality risk analysis.

The preceding example is overly simple compared to most real-world scenarios because the hypothetical regulation only affects consumption, whereas most regulations with positive costs also affect investment activity. When investment expenditures are displaced, regulatory costs grow over time owing to "the opportunity cost of capital," or the forgone returns that would have grown the value of the investment over time.[6] Additionally, just as regulatory costs tend to grow over time because of the opportunity cost of capital, the cutoff value grows as incomes rise. For these

reasons, short-term and long-term risk profiles resulting from expenditures can differ. It may be that a regulation reduces mortality risk in the short term while increasing it over the long term.

The Cost-per-Life-Saved Cutoff

Researchers estimate the cutoff using two methods: (a) a direct approach that relies on the statistical association between income and mortality after controlling for confounding variables or (b) an indirect method based on consumer preferences and economic theory. A recent estimate of the cutoff for the United States made using the direct approach is $38.6 million,[7] whereas a study using the indirect approach estimates the cutoff at $108.5 million.[8] These findings are fairly representative of the literature in that the indirect method tends to produce higher estimates of the cutoff than does the direct method. For additional estimates, see table A1 in the appendix.

Both approaches have limitations. The main problem with the direct approach is that the relationship between income and mortality is complicated. For example, across society as a whole risky behaviors tend to rise as income declines, but this relationship is not always true for particular individuals. Reducing the income of some smokers might cause them to buy fewer cigarettes because they have less money. This result could happen even though smoking is more prevalent among lower-income individuals than higher-income individuals. Additionally, poor health (such as that caused by smoking) often causes people to work less, which reduces income.[9] Thus, reverse causality and omitted variables can be important issues and can cause empirical studies following the direct approach to misestimate the causal impact of income on mortality. Typically these issues are thought to cause the direct approach to underestimate the cutoff. However, as our analysis will show, it is also the case that many, if not most, of the fatalities stemming from economic dislocations occur in the future. Because the relevant counterfactual is a situation that never transpires, making such a situation hard to measure, empirical studies examining the relationship between income and mortality in close temporal proximity can fail to account for many deaths, which in theory could lead the direct approach to overestimate the cutoff.

The indirect method, by contrast, may also misestimate the cutoff. One reason for this possibility is that, with the indirect method, economists calibrate a model of rational worker or consumer behavior with data from individuals' observed behavior in the marketplace. Thus, the indirect approach infers the cutoff from people's revealed preferences. The problem with basing policy on particular individuals' revealed preferences is that even if those individuals behave in a manner consistent with what is in their own interests, they are unlikely to behave in a manner consistent with society's interests, except in special circumstances. Society has a longer time horizon than any particular individual, and the psychological phenomenon of time preference also means that individuals put less weight on health effects in the future. Analysts often view their task as assessing effects from a society-wide perspective, so basing policy on the preferences of particular individuals poses problems.

Another reason that the indirect method may misestimate the cutoff is that it uses a model that incorporates a variable known as the "marginal propensity to spend on risk reduction." Because what people spend on risk reduction is hard to measure, economists often rely on health spending as a proxy for spending on risk reduction in their models, because health spending is easier to measure. However, people probably spend more on risk reduction than they spend on health. For example, spending on healthy food, exercise, or a safer vehicle partly reflects a preference for reducing risk. These are reasons why the indirect method may overestimate the cutoff. That said, not all health spending is very effective, which is a reason why the indirect method could underestimate the cutoff.

Fortunately, most of the challenges that arise with estimating the cutoff may not matter that much. These issues relate to estimating the cutoff *level* with precision. However, the cutoff *growth rate* is arguably more important, given that what determines whether a regulation passes or fails a mortality risk test over time is whether the growth rate of the cutoff is larger or smaller than the forgone rate of return in the counterfactual scenario where the regulation is never implemented (i.e., the regulation's opportunity cost). When the cutoff growth rate is below the rate of return on that which the regulation displaces, the regulation can be expected to increase mortality eventually. In such cases, a critical threshold for regulations is whether regulations' total net costs exceed zero. The cutoff level is still important for distributional reasons, such as determining whose life is lost owing to countervailing risks begotten by regulatory costs. It is less important for determining if regulations increase or reduce risk overall.

It seems likely that the direct method may underestimate the cutoff value, whereas the indirect method may overestimate it. Therefore, as a lower bound our analysis uses a $38.6 million per expected death estimate arrived at using the direct method by one of us (Broughel) and Dustin Chambers, and as an upper bound our analysis uses a $108.5 million per expected death estimate arrived at using the indirect method by one of us (Broughel) and W. Kip Viscusi.[10] The midpoint of these values, $73.6 million, is the central cutoff estimate in our analysis. Additionally, one of us (Broughel) and Viscusi find that the cutoff likely grows at a rate of roughly 0.5 percent to 2.0 percent per year based on an income elasticity of mortality risk spending of between 0.5 to 1.0 and labor productivity growth on the order of 1.0 percent to 2.0 percent per year. Our analysis uses the midpoint of the growth rate range from the study, 1.25 percent per year, as its estimate of the growth rate of the cutoff.

Discounting Issues

Our analysis is distinct from some past mortality risk analyses in that it attempts to fully account for the compounding returns to capital that are forgone owing to regulatory costs. Some previous mortality risk analyses ignore the opportunity cost of capital altogether or conflate the opportunity cost of capital with the rate at which health benefits are discounted. The opportunity cost of capital and the rate at which health benefits are discounted are different and should not be con-

fused with one another. For example, if a regulation is expected to save 100 lives in 10 years, an analyst may conclude that those benefits are less valuable to society than if the same number of lives were saved in the current year. The rate at which capital accumulates in value, meanwhile, is a separate and distinct issue.

More concretely, two interest rates are relevant in cost-benefit analysis: one is related to society's rate of time preference and the other is related to the opportunity cost of capital. Our mortality risk analysis uses a social rate of time preference of zero and an opportunity cost of capital interest rate based on the "shadow price of capital" (SPC) method. Using a social rate of time preference of zero is defensible for a number of reasons. First, many scholars question whether it is ethical to discount future benefits such as health or lives saved.[11] Second, economic efficiency requires that a dollar's worth of benefits be treated the same regardless of who receives it.[12] Third, cost-benefit analysis should be grounded in a consequentialist approach that analyzes costs and benefits as they occur. Filtering benefit and cost values through an arbitrary social time preference scale arguably deviates from consequentialism.[13] Fourth, in intergenerational settings, those not yet born cannot be impatient, and most regulations have at least some intergenerational characteristics.[14]

For these reasons, if a regulation saves 100 lives, our analysis treats those lives as equally valuable irrespective of when they occur. That being said, the timing of lives saved or lost still matters because it affects the timing of cash flows, which matters for growth owing to the time value of money. One might criticize the choice not to discount health or lives saved on the basis that such a choice does not conform with current consumer preferences. This criticism is overstated for several reasons. First, preferences change over time and are often influenced by policy interventions.[15] Second, there is no particular reason why *current* preferences should dictate how one values resources for all time. It seems more sensible to value benefits and costs according to the value placed on those benefits and costs by those who receive them when they receive them. Finally, as our analysis will show, even regulations forcing one-time expenditures can have long-term consequences because of the opportunity cost of capital. Different generations have different time preferences, and there is no agreed-upon way to compare these conflicting preferences. Thus, the most sensible solution seems to be to give every generation in the analysis equal weight.

The Shadow Price of Capital

As noted earlier, our mortality risk analysis accounts for the opportunity cost of capital using the SPC method. OMB's *Circular A-4* and *Circular A-94* publications state that the SPC method is the analytically preferred method of accounting for the opportunity cost of capital in a cost-benefit analysis.[16] Although federal agencies rarely use this method, it is well established in the economics literature that this method is correct.[17]

The SPC can be expressed using equation 1:

$$\text{Shadow Price of Capital} = \sum_{t=0}^{\infty} (1 - f)ROI \times (1 + fROI)^t \qquad (1)$$

Equation 1 states that the SPC accounts for the total value of the consumption stream that a capital asset generates over time, which depends on the fraction of capital's return that is reinvested each period, f, and the social rate of return on investment net of depreciation, ROI.[18]

In our analysis, the fraction of the return invested in each period, f, is based on the literature regarding the marginal propensity to consume (MPC) for the United States. For example, Marcos Dinerstein of the University of Pennsylvania and coauthors analyze a proposed $1,400 COVID-19 relief payment and find that roughly 27 percent of relief payments would go to consumption and 73 percent to savings, with MPC income quintiles that range from 0.55 to 0.12.[19] Christopher Carroll and coauthors develop a model that suggests that the aggregate MPC estimate falls in a range of 0.2 to 0.4 for transitory income shocks.[20] These expenditure patterns may reflect that individuals smooth consumption during recessions and, therefore, may overstate how much income is typically consumed out of the marginal dollar. Studies based on the permanent income hypothesis, for example, tend to find much lower MPCs, often in the range of 0.0 percent to 0.5 percent.[21]

We use an MPC of 0.2 here, implying an f value of 0.8, which seems reasonable because it is greater than the lower MPCs predicted using the permanent income hypothesis but less than some of the higher estimates in the literature that come from analysis of spending during recessions. An MPC of 0.2 is also the aggregate MPC predicted in the core model used by Carroll and coauthors, and an f value of 0.8 is similar to the assumed reinvestment rate in a study by Arnold Harberger and Glenn Jenkins.[22] We discuss the sensitivity of our mortality risk analysis to this assumption in the discussion of uncertainty.

For ROI, we use a value of 7 percent, given that the long-term rate of return on real estate and equities is roughly 7 percent per year.[23] Whereas 7 percent is an average rate of return on these assets, the average rate of return on equities and real estate may be a good approximation of the *marginal* rate of return to capital generally. Corporations' capital investments often earn significantly higher rates of return than do equities.[24] It is not uncommon for investors to use hurdle rates (that is, a minimum acceptable rate of return) of 15 percent to 20 percent when considering investment opportunities available to them.[25] Real estate and equities are therefore reasonable destinations for marginal investments.[26]

Combining an ROI of 7 percent with an f value of 0.8 yields a consumption stream that, according to equation 1, grows at 5.6 percent per period, which is the opportunity cost of capital rate of return used in our mortality risk analysis.

MORTALITY RISK ANALYSIS

Initial Expected Deaths

OSHA's rule requires certain healthcare employers to develop and implement a plan to identify and control COVID-19 hazards in the workplace to protect healthcare workers and healthcare support service workers.[27] The rule applies to all settings where any employee provides healthcare services or healthcare support services (with some notable exceptions, for instance, for retail pharmacies and some ambulatory care centers). Employers have to develop plans and implement precautions related to factors such as patient screening and management, personal protective equipment, building ventilation, face masks, physical distancing, record keeping and reporting requirements, and other provisions. For covered employers with 10 or more employees, such plans must be in writing. Because this interim final rule is economically significant, OSHA prepared an RIA for it.[28]

OSHA considers its economic analysis an economic feasibility analysis, meaning that the analysis focuses exclusively on costs to employers to ascertain whether it is feasible for them to implement the rule.[29] OSHA performs this limited type of analysis because, according to the agency, "The OSH Act 'place[s] the "benefit" of worker health above all other considerations save those making attainment of this "benefit" unachievable.'"[30] Hence, OSHA believes it is required to consider only whether the benefits of its rule can be attained, not whether they are economically justified. That said, a mortality risk analysis can assist in this endeavor because OSHA's mandate to elevate worker health over other concerns presumably means its regulations' effects on mortality are of paramount importance. If a regulation were found to increase mortality risk, then modifying the regulation in response to that finding is presumably consistent with OSHA's statutory obligations.

According to OSHA, the rule will generate approximately $4 billion in costs while preventing 776 people from dying and roughly 295,000 people from becoming infected during the six-month period the rule is in effect.[31] OSHA monetizes the value of the infections and the deaths prevented by using the value of a statistical life (VSL) and the value of statistical illness and injury estimates.[32] The agency calculates the value of the rule's benefits to be approximately $27 billion in 2019 dollars.[33]

Our mortality risk analysis assumes OSHA has accounted for all the rule's costs while recognizing that it may not have, given that OSHA's feasibility analysis explicitly accounts only for costs to employers. Notwithstanding that issue, the compliance costs (if one assumes that they are comprehensive) will tend to overstate the rule's costs because extending lives also saves money (thereby offsetting some of the compliance costs). Therefore, the financial savings from extending lives need to be subtracted from the compliance costs to produce an accurate cost-effectiveness estimate of the regulation. The VSL cannot be used for this purpose because, in addition to financial savings, it includes the value to individuals of nonpecuniary benefits, such as leisure and time spent with friends and family. Thus, our analysis uses estimates from one of us (Broughel) and Michael Kotrous regarding the expected

Table 1. Initial Period Costs, Cost Savings, and Total Net Costs of OSHA's Occupational Exposure to COVID-19 Emergency Temporary Standard

CATEGORY	CASES	VALUE PER CASE (US$ [2019])	TOTAL VALUE (US$ [2019] MILLION)
Net reduction in mortality	735	—	310.4
Prevented COVID-19 deaths	776	453,000	351.5
Initial expected deaths from lost income	41	1,003,300	41.1
COVID-19 infections prevented	295,284	—	—
Symptomatic infections prevented	224,416	1,900	426.4
Hospitalizations	5,702	11,000	62.7
ICU admissions	1,403	57,800	81.1
Mechanical ventilation	773	70,500	54.5
ARDS cases	195	247,000	48.2
Total cost savings	—	—	1,024.4
Total costs (includes costs from indirect expected deaths)	—	—	4,010.8
Total net costs	—	—	2,986.4
Initial cost per life saved (total net cost/ gross mortality reduction)	—	—	3.8

Note: ARDS = acute respiratory distress syndrome; ICU = intensive care unit; OSHA = Occupational Safety and Health Administration. Sums may not be exact because of rounding. All dollar values are deflated to 2019 dollars. "Expected deaths" refer to deaths that arise from reductions in spending aimed at reducing mortality risk. Beyond adjusting for inflation, we adjust value of life estimates from the Broughel and Kotrous study because original values were calculated using a 5 percent (financial) discount rate, which differs from the opportunity cost of capital rate in our mortality risk analysis's core specification. Because the exact timing of cash flows from extended life are unknown, we convert the present value of cash flows to an annualized value according to the expected remaining lifetime of individuals, and then we convert annualized values back into a present value using the opportunity cost of capital rate (5.6 percent in our mortality risk analysis's core specification). Because prevented medical services would presumably happen over a shorter time horizon, we make no adjustments from the core Broughel and Kotrous estimates beyond adjusting for inflation.
Sources: Authors' calculations based on James Broughel and Michael Kotrous, "The Benefits of Coronavirus Suppression: A Cost-Benefit Analysis of the Response to the First Wave of COVID-19 in the United States," *PLOS ONE* 16, no. 6 (2020): e0252729. Occupational Safety and Health Administration, Occupational Exposure to COVID-19; Emergency Temporary Standard, 86 Fed. Reg. 32376 (June 21, 2021).

remaining lifetime contributions of individuals who die prematurely from COVID-19 to account for the financial cost savings from preventing COVID-19 deaths.[34] These estimates allow for estimation of the cost-effectiveness of the OSHA rule (that is, the financial costs per life saved), which can then be compared with the cutoff estimate (which relates to financial expenditures).

One of us (Broughel) and Kotrous estimate that although the average cost per death in the United States is around $1 million (deflated to 2019 dollars), the average cost per COVID-19 death is approximately $334,202 (deflated to 2019 dollars) in lost output because those who die from COVID-19 tend to be older. However, the age distribution of deaths from COVID-19 has become slightly younger since the time that study was published. Accounting for these differences in the age of COVID-19 victims and adjusting for the fact that the discount rate applied to earnings in the Broughel and Kotrous study is slightly different from the rate of return to capital estimated in our analysis yields average cost savings of $453,002 per life saved from OSHA's rule.[35]

For prevented infections, we calculate the cost savings associated with reductions in required medical services and lost work using again estimates from one of us (Broughel) and Kotrous.[36] This approach yields combined cost savings of roughly $1,024 million because of extended lives and prevented illnesses (see table 1). Subtracting these cost savings from the total costs calculated by OSHA yields a total net cost figure (that is, costs net of cost savings) of $3 billion, which is the initial cost estimate used used in the cost-effectiveness calculation for our mortality risk analysis.

If OSHA's calculations are correct, this rule will reduce mortality risk in the initial period (and pass a cost-benefit test in the initial period). The cost per life saved is approximately $3.8 million, less than our best estimate of the cutoff of $73.6 million. OSHA's rule also yields approximately 41 initial expected deaths from reductions in income. If this rule were to affect only consumption, then this would be the end of our mortality risk analysis. However, the word "initial" is important because society would likely have invested some of the money that went toward expenditures forced by this rule. Thus, the expected death count can be considered a present value that evolves as displaced capital's returns would be reinvested. Although we estimate that the rule reduces mortality risk in the first period, this result may not hold up over longer time horizons.

Morality Risk over Time

We expect OSHA's rule to have initial total net costs of roughly $3 billion: given an assumed MPC value of 0.2 and an f value of 0.8, society would have invested $2.4 billion and consumed $597 million in the initial period. Thereafter, society would have consumed a consumption stream that grows at a rate of $f \times ROI$ or (0.8)(.07) = 5.6 percent per year. By year 10, we expect the cumulative consumption stream that society has forgone because of displaced investment activity to be worth roughly $1 billion. Meanwhile, the capital asset that is displaced would have grown to a value of $4.2 billion in year 10 (owing to reinvestment). If one uses a cutoff of $73.6 million (assumed to grow at 1.25 percent annually), the initial regulatory costs generate 41 statistical deaths in year 0, which grow to 63 expected deaths by year 10. This calculation is based on the rule's cost as it evolves (which, at any point in time, is equal to the sum of the value of the capital asset displaced by the rule and the cumulative consumption stream the capital asset has generated up to that point).[37] The rule fails a cost-benefit test roughly 40 years after implementation (if one uses OSHA's monetized estimate of benefits). The total cost of the rule overtakes the cutoff value 69 years after implementation. Thus, it takes about seven-tenths of a century for this rule to increase mortality risk. See table 2.

The projections in table 2 imply that this rule could, over 100 years, generate 2,134 more statistical deaths than it saves, at a cost of $742 billion up to that point. Whereas the regulatory costs appear to be large, they represent approximately 0.006 percent of cumulative GDP over the same period. The results of our mortality risk analysis are similar to those of OSHA's RIA in the short term but differ in the long term primarily because our analysis (a) better accounts for the opportunity cost

Table 2. Mortality Risk over a Century Owing to OSHA's Occupational Exposure to COVID-19 Emergency Temporary Standard

YEAR	REGULATORY COST TO DATE (BILLIONS OF DOLLARS)	TOTAL DISPLACED CAPITAL (BILLIONS OF DOLLARS)	TOTAL CONSUMPTION STREAM (BILLIONS OF DOLLARS)	ANNUAL CONSUMPTION FROM DISPLACED INVESTMENT (MILLIONS OF DOLLARS)	COST-PER-LIFE-SAVED CUTOFF (MILLIONS OF DOLLARS)	TOTAL EXPECTED DEATHS, FROM LOST INCOME	NET MORTALITY REDUCTION	COST PER LIFE SAVED (MILLIONS OF DOLLARS)	REGULATORY COST (% OF CUMULATIVE GDP)
0	3.0	2.4	0.6	0	74	41	735	4	0.014
5	4.0	3.2	0.8	42	78	51	725	5	0.003
10	5.2	4.2	1.0	56	83	63	713	7	0.002
25	12.0	9.6	2.4	127	100	119	657	18	0.001
50	47.4	37.9	9.5	502	137	346	430	110	0.002
100	741.9	593.5	148.4	7,864	255	2,910	−2,134	−348	0.006

Note: We assume that expected deaths are spread evenly across society and cause further indirect financial costs. We assume the marginal propensity to save to be 0.8 and the marginal rate of return to private capital in the US economy to be 7 percent. We assume the growth rate of the cost-per-life-saved cutoff to be 1.25 percent annually, and we assume the projected annual rate of growth of GDP to be 3.0 percent. Cumulative GDP is the sum of GDP flows based on projected GDP increases. Note that in the absence of this rule, GDP would presumably be higher, so the cost of the rule as a fraction of cumulative counterfactual GDP would presumably be lower than what we present here.

Source: Authors' calculations.

of capital by using the shadow price of capital method, (b) distinguishes between regulatory costs that are invested and those that are consumed, (c) considers a longer horizon, and (d) uses a social rate of time preference of zero.

One lesson from the present analysis is that even regulations only in place temporarily can have ongoing costs when they displace investments. Thus, the opportunity cost of a regulation should not be confused with the expenditures mandated by that regulation. Opportunity cost is what is forgone when a regulatory action is undertaken, which may have a completely different time profile from regulatory expenditures. In the case of OSHA's rule, expected ongoing opportunity costs mean the rule is likely to eventually fail a cost-benefit test and increase mortality risk.

Given the uncertainty of making predictions 100 years in the future, the takeaway from table 2 is perhaps not that exactly 2,000 people will die on net over the next century because of this rule, but rather that because of the power of compound interest, small changes today can have profound effects over time. Ignoring this phenomenon leads to unsound economic analysis that can potentially do great harm, especially in the future. In January 2020, President Biden directed OMB and executive departments and agencies to find ways to "promote public health and safety, economic growth . . . and the interests of future generations."[38] Our analysis suggests that RIAs that place more consideration on displaced investments, compound interest, and opportunity cost could do a considerable amount to promote important indicators of social welfare in these areas.

Discussion of Uncertainty

Our analysis of countervailing mortality risk has several areas of uncertainty. One important source of uncertainty is that the cost estimate in OSHA's analysis may be an underestimate because it is drawn from a feasibility analysis and not a cost-benefit analysis. If the costs of OSHA's rule are underestimated, as seems likely, our mortality risk analysis can be viewed as conservative in the sense that the rule may increase risk earlier than we estimate.

An additional source of uncertainty is whether returns to capital are diminishing, constant, or increasing. Our analysis assumes constant returns, although some might argue that diminishing returns to capital are more realistic. Diminishing returns could imply rather modest costs from the current rule, costs that would fall mostly in the category of transition dynamics.[39] However, if there is even a small chance of increasing returns to capital, then our analysis is too optimistic, because increasing returns from displaced investments would have severe implications in terms of increased mortality risk. An assumption of constant returns to scale seems to balance the extreme divergence in policy implications between the diminishing and increasing returns assumptions. Moreover, a constant returns assumption is consistent with the common practice of constant exponential discounting of cash flows.

Our analysis is also sensitive to certain parameters in the model. For example, if one assumes that the marginal propensity to save is 0.95, in line with the permanent income hypothesis, then this rule would increase mortality risk 13 years sooner—that is, 56 years after the rule is implemented as opposed to 69 years after. On the other hand, if one assumes the marginal propensity to save is 0.60, then the date when the rule increases mortality risk would be pushed back to 101 years after the rule is implemented. Similarly, using a cutoff of $108.5 million, as opposed to $73.6 million in the core specification, pushes back the date at which the rule increases mortality risk to 79 years after implementation. Using the lower cutoff estimate of $38.6 million brings the date the rule increases mortality risk forward to year 53 after implementation. Reducing the cutoff's annual growth rate to 0.5 percent moves the year the rule increases mortality risk to year 59 after implementation—10 years sooner—whereas increasing the cutoff growth rate to 2.0 percent per year pushes the turning point year back to year 84 after implementation—15 years later.

CONCLUSION

In addition to the findings specific to OSHA's emergency COVID-19 healthcare worker rule, several overarching takeaways from our analysis are relevant to federal agency rulemaking generally.

First, OSHA's rule, though likely to reduce risk and pass a cost-benefit test in the short term, is predicted to increase risk and fail a cost-benefit test over longer time horizons. These unintended consequences are missed in OSHA's regulatory analysis owing to its short-term focus and emphasis on expenditures rather than opportunity cost. Including mortality risk analysis as a routine part of an agency's RIA could help assure the public that regulations save lives on balance in both the short and long runs, even after accounting for the opportunity cost of expenditures.

Second, regulatory interventions pass a critical threshold when their total net costs exceed zero. When the rate of return on a displaced capital investment exceeds the growth rate of the cutoff, which generally seems likely, regulations that are cost saving will tend to reduce risk, whereas those imposing positive net costs will tend to increase mortality risk eventually.[40] Thus, the best way to ensure that public policies increase social welfare in the sense that they pass a cost-benefit test and reduce risk over the long term may be to ensure that regulations are cost saving on balance. (Energy efficiency regulations that save money on utility bills and reduce air pollution are potentially examples of interventions that can both save lives and reduce costs.)

Third, as the Biden administration updates existing RIA guidelines, it would be wise for it to recommend that agencies give more consideration to displaced investments, compound interest, and the opportunity cost of capital, as shown in our analysis. Improvements in these areas could help federal agencies "promote public health and safety, economic growth . . . and the interests of future generations" by adopting a regulatory framework that is consistent with promoting these important indicators of societal well-being.[41]

APPENDIX

Table A1. Studies Estimating the Cost-Per-Life-Saved Cutoff			
STUDY	**APPROACH**	**CUTOFF (MILLIONS OF 2019 DOLLARS)**	**DESCRIPTION**
Keeney (1990)	Direct	8.7–20.2	First model to formally estimate the cutoff; mortality risk is a function of income with no additional controls used; cutoff varies depending on distribution of regulatory costs; study is open to critiques of ecological bias and confounding bias.
Chapman and Hariharan (1994)	Direct	22.2	Controls for initial health status to account for possibility of reverse causation; Social Security data are used for males around retirement-age.
Chapman and Hariharan (1996)	Direct	12.2–28.0	Controls for initial health, marital status, age, a quadratic income variable, assets (a measure of patience), and time varying (fixed) effects.
Keeney (1997)	Direct	8.8–24.7	Uses individual-level data rather than census tract data to correct for ecological bias but does not control for other confounding variables; study finds little difference in fatalities from concentrated versus dispersed costs; estimates of fatalities vary significantly across income and racial groups.
Elvik (1999)	Direct	6.1–75.9*	Uses Norwegian data; cutoff varies depending on controls used in regression analysis; controls include healthcare spending, age, and sex.
Gerdtham and Johannesson (2002)	Direct	10.6–15.3*	Uses Swedish data; controls for initial health status and various personal characteristics.
Ashe, de Oliveira, and McAneney (2012)	Direct	15.6–39.0*	Builds on the Keeney (1997) model; assumes that American correlations between income and mortality hold for Australia, which may be incorrect.
Broughel and Chambers (published ahead of print)	Direct	38.6	Calculates the mortality income elasticity as the coefficient on log per capita income in a regression in which the natural log of all-cause US mortality is regressed onto a common intercept, period fixed effects, and log per capita income, with additional controls for federal regulation, inequality, unemployment, obesity, female-to-male ratio, elderly, health spending, and the marriage rate.
Viscusi (1994)	Indirect	90.9	First study to employ the indirect approach; builds a structural model of the income and mortality risk relationship; incorporates the VSL and MPSH; avoids problems of endogeneity and reverse causation found in direct approaches.

STUDY	APPROACH	CUTOFF (MILLIONS OF 2019 DOLLARS)	DESCRIPTION
Table A1 (continued)			
Hjalte et al. (2003)	Indirect	19.7*	Calibrates the Viscusi (1994) model with Swedish data; estimates the MPSH based on surveys; finds that the MPSH varies by income level (MPSH is 0.20 for individuals in lowest quintile of household income and 0.14 for individuals in top quartile for household income).
Broughel and Viscusi (2021)	Indirect	108.5	Following the indirect method, the authors use a VSL of $10.3 million (based on a US Department of Transportation internal guide) and an MPSH with an expected value of around 0.1.
Lutter and Morrall (1994)	Modified Indirect	15.9–21.1	Coined the term "health-health analysis"; works with the Viscusi (1994) model but incorporates income elasticities of various health measures from cross-country studies; these adjustments introduce the possibility of confounding and ecological bias.
Lutter, Morall, and Viscusi (1999)	Modified Indirect	27.3	Begins from the Viscusi (1994) model; incorporates income elasticities of various risky behaviors into the model, which could lead to confounding and reverse causation biases and a misestimation of the cutoff.

* Cutoff value is not for the United States.

Note: MPSH = marginal propensity to spend on health; VSL = value of a statistical life.

Sources: James Broughel and W. Kip Viscusi, "The Mortality Cost of Expenditures," *Contemporary Economic Policy* 39, no. 1 (2021): 156–67; James Broughel and Dustin Chambers, "Federal Regulation and Mortality in the 50 States," *Risk Analysis* (published ahead of print), https://doi .org/10.1111/risa.13774; Ralph L. Keeney, "Mortality Risks Induced by Economic Expenditures," *Risk Analysis* 10, no. 1 (1990): 147–59; Kenneth S. Chapman and Govind Hariharan, "Controlling for Causality in the Link from Income to Mortality," *Journal of Risk and Uncertainty* 8, no. 1, (1994): 85–93; Kenneth S. Chapman and Govind Hariharan, "Do Poor People Have a Stronger Relationship between Income and Mortality Than the Rich? Implications of Panel Data for Health-Health Analysis," *Journal of Risk and Uncertainty* 12, no. 1 (1996): 51–63; Ralph L. Keeney, "Estimating Fatalities Induced by the Economic Costs of Regulations," *Journal of Risk and Uncertainty* 14, no. 1 (1997): 5–23; Rune Elvik, "Can Injury Prevention Efforts Go Too Far? Reflections on Some Possible Implications of Vision Zero for Road Accident Fatalities," *Accident Analysis and Prevention* 31, no. 3 (1999): 265–86; Ulf-G. Gerdtham, and Magnus Johannesson, "Do Life-Saving Regulations Save Lives?," *Journal of Risk and Uncertainty* 24, no. 3 (2002): 231–49; Brian Ashe, Felipe Dimer de Oliveira, and John McAneney, "Investments in Fire Management: Does Saving Lives Cost Lives?," *Agenda: A Journal of Policy Analysis and Reform* 19, no. 2 (2012): 89–103; W. Kip Viscusi, "Mortality Effects of Regulatory Costs and Policy Evaluation Criteria," *RAND Journal of Economics* 25, no. 1 (1994): 94–109; Krister Hjalte et al., "Health-Health Analysis—An Alternative Method for Economic Appraisal of Health Policy and Safety Regulation: Some Empirical Swedish Estimates," *Accident Analysis and Prevention* 35, no. 1 (2003): 37–46; Randall Lutter and John F. Morrall III, "Health-Health Analysis: A New Way to Evaluate Health and Safety Regulation," *Journal of Risk and Uncertainty* 8, no. 1 (1994): 43–66; Randall Lutter, John F. Morrall III, and W. Kip Viscusi, "The Cost-per-Life-Saved Cutoff for Safety-Enhancing Regulations," *Economic Inquiry* 37, no. 4 (1999): 599–608.

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NOTES

1. Exec. Order No. 12866, 58 Fed. Reg. 51735 (October 4, 1993).

2. Occupational Safety and Health Administration, Occupational Exposure to COVID-19; Emergency Temporary Standard, 86 Fed. Reg. 32376 (June 21, 2021).

3. Executive Office of the President, Modernizing Regulatory Review, 86 Fed. Reg. 7223 (January 20, 2021).

4. These resources could be physical goods that are consumed, the time and energy of service workers, or capital goods that are used to produce other capital or consumer goods. The key to understanding the opportunity cost of expenditures is to focus on the resources that are exhausted in the economy when expenditures occur, not the money that changes hands. A pure transfer would occur when money is exchanged but no real resources are affected in the process.

5. James Broughel and W. Kip Viscusi, "The Mortality Cost of Expenditures," *Contemporary Economic Policy* 39, no. 1 (2021): 156–67.

6. On the opportunity cost of capital, see generally, James Broughel, "Rehabilitating the Opportunity Cost of Capital in Cost-Benefit Analysis" (Mercatus Working Paper, Mercatus Center at George Mason University, Arlington, VA, September 2021).

7. James Broughel and Dustin Chambers, "Federal Regulation and Mortality in the 50 States," *Risk Analysis* (published ahead of print), https://doi.org/10.1111/risa.13774.

8. Broughel and Viscusi, "The Mortality Cost of Expenditures."

9. J. P. Smith, "Healthy Bodies and Thick Wallets: The Dual Relation between Health and Economic Status," *Journal of Economic Perspectives* 13, no. 2 (1999): 145–66.

10. Broughel and Chambers, "Federal Regulation and Mortality in the 50 States"; Broughel and Viscusi, "The Mortality Cost of Expenditures."

11. Many philosophers agree that discounting lives is undesirable. Derek Parfit, *Reasons and Persons* (Oxford: Clarendon Press, 1984), 480–86; Tyler Cowen and Derek Parfit, "Against the Social Discount Rate," in *Philosophy, Politics, and Society: Justice between Age Groups and Generations*, ed. James S. Fishkin and Peter Laslett, vol. 6 (New Haven, CT: Yale University Press, 1992), 144–61; John Broome, "The Well-Being of Future Generations" in *The Oxford Handbook of Well-Being and Public Policy*, ed. Matthew D. Adler and Mark Fleurbay (New York: Oxford University Press, 2016), 901–28.

12. Richard A. Posner, "Cost-Benefit Analysis: Definition, Justification, and Comment on Conference Papers," *Journal of Legal Studies* 29, no. S2 (2000): 1152–77.

13. Tyler Cowen, "Consequentialism Implies a Zero Rate of Discount," in *Philosophy, Politics, and Society: Justice between Age Groups and Generations*, ed. James S. Fishkin and Peter Laslett, vol. 6 (New Haven, CT: Yale University Press, 1992), 162–68.

14. The simplest reason is that people are continually being born and dying. On this topic, see James Broughel, "The Regulatory Budget in Theory and Practice: Lessons from the U.S. States" (CSAS Working Paper, C. Boyden Gray Center for the Study of the Administrative State, Arlington, VA, forthcoming).

15. Tyler Cowen, "The Scope and Limits of Preference Sovereignty," *Economics and Philosophy* 9, no. 2 (1993): 253–69.

16. Office of Management and Budget, *Circular A-4*, September 17, 2003; Office of Management and Budget, *Circular A-94*, October 29, 1992.

17. "There is now considerable agreement that the correct conceptual method of discounting is to shadow price investment flows and to discount the resulting consumption equivalents using a consumption-based discount rate." Anthony E. Boardman et al., *Cost-Benefit Analysis: Concepts and Practice*, 5th ed. (Cambridge, UK: Cambridge University Press), 260.

18. The SPC also depends on the social rate of time preference, which, as explained previously, we assume to be zero in our analysis. Hence, it is not included in equation 1.

19. Marcos Dinerstein, Zheli He, and Xiaoyue Sun, *Background: Marginal Propensities to Consume in the 2021 Economy* (Philadelphia: Wharton School of the University of Pennsylvania, 2021).

20. Christopher Carroll et al., "The Distribution of Wealth and the Marginal Propensity to Consume," *Quantitative Economics* 8, no. 3 (2017): 977–1020.

21. Per Krusell and Anthony A. Smith Jr., "Income and Wealth Heterogeneity in the Macroeconomy," *Journal of Political Economy* 106, no. 5 (1998): 867–96; Chang-Tai Hsieh, "Do Consumers React to Anticipated Income Changes? Evidence from the Alaska Permanent Fund," *American Economic Review* 93, no. 1 (2003): 397–405; Tullio Jappelli and Luigi Pistaferri, "The Consumption Response to Income Changes," *Annual Review of Economics* 2 (2010): 479–506; Greg Kaplan and Giovanni L. Violante, "How Much Consumption Insurance Beyond Self-Insurance?," *American Economic Journal: Macroeconomics* 2, no. 4 (2010): 53–87; Greg Kaplan and Giovanni L. Violante, "A Model of the Consumption Response to Fiscal Stimulus Payments," *Econometrica* 82, no. 4 (2014): 1199–1239.

22. Carroll et al., "The Distribution of Wealth"; Arnold C. Harberger and Glenn Jenkins, "Musings on the Social Discount Rate 1," *Journal of Benefit-Cost Analysis* 6, no. 1 (2015): 6–32.

23. Òscar Jordà et al., "The Rate of Return on Everything, 1870–2015," *Quarterly Journal of Economics* 134, no. 3 (2019): 1225–98.

24. OMB also uses a 7 percent rate of return to represent the average before-tax rate of return to private capital in the US economy that is based on national income and product accounts data. In 2017, the Council of Economic Advisers updated OMB's estimate and found that from 1947 to 2014, the average rate of return remained 7 percent. Council of Economic Advisers, *Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate*, January 2017.

25. Richard J. Zeckhauser and W. Kip Viscusi, "Discounting Dilemmas: Editors' Introduction," *Journal of Risk and Uncertainty* 37, no. 2 (2008): 95–106; Aswath Damodaran, *Return on Capital (ROC), Return on Invested Capital (ROIC) and Return on Equity (ROE): Measurement and Implications* (New York: NYU Stern School of Business), 53.

26. As discussed in the section on uncertainty later, our analysis assumes constant returns to scale, meaning that the rate of return on investment is constant over time. There is also the question of whether the social rate of return deviates from the private rate of return. The social rate could, in theory, be higher or lower than the private rate. Agglomeration effects or increasing returns could cause the social rate of return to exceed the private rate of return, whereas negative externalities could produce the opposite result.

27. Occupational Safety and Health Administration, Occupational Exposure to COVID-19; Emergency Temporary Standard, 86 Fed. Reg. 32376 (June 21, 2021).

28. An interim final rule is a regulation that is finalized without the agency first publishing a proposed rule. It is typically interim in the sense that the final rule is considered temporary or the agency leaves open the possibility of changing the final rule later.

29. Occupational Safety and Health Administration, Occupational Exposure to COVID–19; Emergency Temporary Standard, 86. Fed Reg. 32376, 32483 (June 21, 2021).

30. Occupational Safety and Health Administration, Occupational Exposure to COVID–19; Emergency Temporary Standard, 86. Fed Reg. 32376, 32484 (June 21, 2021).

31. Occupational Safety and Health Administration, Occupational Exposure to COVID–19; Emergency Temporary Standard, 86. Fed Reg. 32376, 32495 (June 21, 2021).

32. Occupational Safety and Health Administration, Occupational Exposure to COVID–19; Emergency Temporary Standard, 86. Fed Reg. 32376, 32544–32546 (June 21, 2021).

33. Occupational Safety and Health Administration, Occupational Exposure to COVID–19; Emergency Temporary Standard, 86. Fed Reg. 32376, 32507 (June 21, 2021).

34. James Broughel and Michael Kotrous, "The Benefits of Coronavirus Suppression: A Cost-Benefit Analysis of the Response to the First Wave of COVID-19 in the United States," *PLOS ONE* 16, no. 6 (2020): e0252729.

35. Revised COVID-19 death calculations are based on the Centers for Disease Control and Prevention June 2021 provisional death counts for COVID-19 as reported on August 18, 2021. "Weekly Updates by Select Demographic and Geographic Characteristics," Centers for Disease Control and Prevention, accessed August 18, 2021, https://www.cdc.gov/nchs/nvss /vsrr/covid_weekly/index.htm. Because the exact timing of cash flows from extended life are unknown, we convert the present value of cash flows to an annualized value on the basis of the expected remaining lifetime of individuals, and then we convert the annualized values back into a present value using the opportunity cost of capital rate (5.6 percent in our analysis's core specification).

36. Following one of us (Broughel) and Kotrous, our analysis here assumes that 76 percent of COVID-19 infections are symptomatic. Of symptomatic cases, 2.5 percent require hospitalization. About 24.6 percent and 13.5 percent of hospitalizations result in ICU admission and mechanical ventilation, respectively, and 6.6 percent of hospitalizations will develop acute respiratory distress syndrome. Broughel and Kotrous, "The Benefits of Coronavirus Suppression."

37. The cost of the regulation is calculated in this way to demonstrate how mortality risk is evolving up to a particular point in time. Usually, the total cost of a regulation should be assessed by converting the capital asset's value into equivalent units of consumption on the basis of returns accruing in all time periods, including future periods.

38. Executive Office of the President, Modernizing Regulatory Review, 86 Fed. Reg. 7223 (January 20, 2021).

39. A related issue is the question of whether investments are simply delayed, rather than forgone completely, owing to mandatory regulatory expenditures. Our analysis assumes marginal investments are just that—marginal—and are therefore forgone completely. However, regulations with ongoing costs may be more likely to indefinitely postpone marginal investments than regulations that force one-time expenditures (as is the case with the OSHA regulation considered here). The possibility of increasing returns would make even one-year delays in investments have severe consequences, however. For a classification scheme of various kinds of policy impacts, see James Broughel, *Regulation and Economic Growth: Applying Economic Theory to Public Policy* (Arlington, VA: Mercatus Center at George Mason University, 2017).

40. OSHA's RIA assumes a fixed 776 lives saved from this regulation. Other agencies' RIAs sometimes assume ongoing lives saved each year in perpetuity, but the number of lives is not likely to compound at the rate of return that capital can be reinvested at and earn in markets. Catastrophic risks or extinction-level events can provide exceptions to this general case, thereby offsetting the indirect mortality risks described here. These situations deserve special consideration but are beyond the scope of the present analysis.

41. Executive Office of the President, Modernizing Regulatory Review, 86 Fed. Reg. 7223 (January 20, 2021).