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A Mortality Risk Analysis for OSHA's COVID-19 Emergency Regulations

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Abstract: In 2021, the Occupational Safety and Health Administration (OSHA) issued two emergency temporary standard regulations related to COVID-19 hazards in US workplaces. One regulation covered healthcare sector workers, while the second regulation would have covered workers at firms with 100 or more employees. This paper conducts an original mortality risk analysis for these regulations. Mortality risk analysis evaluates the increase or decrease in expected mortality associated with a new policy, such as a rule or regulation, taking into account economic factors like lost income due to regulatory costs. If we accept OSHA's cost and health benefit estimates at face value, we find that the first regulation related to COVID-19 hazards in the healthcare sector reduces risk initially but increases risk over a longer time horizon. We find that the second regulation would reduce risk according to OSHA's main estimates but may not reduce risk after including some ancillary costs and adjusting the agency's prevented hospitalizations estimate based on more reasonable assumptions. Moreover, OSHA's economic analysis for the two regulations in question does not purport to comprehensively evaluate costs; ergo, our mortality risk estimates probably underestimate countervailing mortality risks stemming from these regulations. We review some of OSHA's underlying assumptions that could change the outcomes of our mortality analysis. These estimates demonstrate that OSHA would benefit from more comprehensive consideration of costs in its economic analysis.

Keywords: mortality risk analysis; COVID-19; OSHA

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1. Introduction

For economically significant regulations (those with annual costs, benefits, or some combination of both exceeding USD 100 million) executive branch agencies in the United States must produce regulatory impact analyses (RIAs). RIAs should include information about the problem an agency is trying to solve through regulation, 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' analyses are often incomplete (Ellig and Fike 2016), and often overlook long-term impacts and opportunity costs, most notably in the benefit–cost analysis portion of RIAs.

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 (Broughel and Viscusi 2021; Broughel and Chambers 2022). A properly conducted mortality risk analysis calculates a regulation's cost-effectiveness (in this case, 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, known as the "cost-per-life-saved cutoff", then 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). 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 casts light on long-term effects and opportunity costs that often go overlooked.

Mortality risk analysis should not be confused with some other forms of economic or health impact analysis. It is sometimes referred to as "health-health analysis" highlighting its similarity to analytical tools like benefit–cost analysis.[1] Health-health analysis is structurally similar to benefit–cost analysis, except it includes only positive and negative health impacts on each side of the ledger (Lutter and Morrall 1994). As such, it is not meant to be a cumulative analysis of all economic impacts stemming from a regulation. It is also distinct from cost-effectiveness analysis of risk-reducing policies, for which there is an enormous literature, including in the context of COVID-19 policies (e.g., Gandjour 2021, 2022). As noted, mortality risk analysis uses cost-effectiveness estimates as inputs, but it is not the same as cost-effectiveness analysis. Nor is it the same as an epidemiological model, like an SEIR model, although some such models do incorporate economic criteria (e.g., Daumann et al. 2021). Mortality risk analysis is also distinct from risk analysis conducted by businesses to assess balance sheet risk (e.g., Gleißner 2019). However, mortality risk analysis shares characteristics in common with some other risk modeling techniques in that it evaluates policymaker decisions under conditions of uncertainty (Gleißner et al. 2021).

This paper conducts an original mortality risk analysis of two emergency regulations issued by the Occupational Safety and Health Administration (OSHA) in 2021. Both rules addressed health threats from COVID-19 in the workplace. One regulation covered workers in the healthcare sector, requiring employers to develop COVID-19 management plans, while the second regulation, related to mandatory vaccination, would have covered workers at firms with 100 or more employees (that regulation never went into effect).

In conducting our mortality risk analysis, we rely on information found in OSHA's RIAs. In other words, we initially take OSHA's estimates of health benefits and costs of its regulations at face value, so as to provide an estimate of the mortality effects of the regulations, based on the agency's own work. Following this approach, we find that the first regulation related to COVID-19 hazards in the healthcare sector reduces risk initially but increases it over a longer time horizon. We find that the second regulation would have reduced risk. However, OSHA's RIAs are not comprehensive by the agency's own admission, which adds uncertainty to the conclusions of these mortality analyses for two reasons. First, OSHA's analyses are feasibility analyses that ask whether it is feasible for employers to implement these regulations. Thus, they exclude costs not falling on employers since these presumably do not impact feasibility. Second, even those costs and benefits that OSHA calculated depend on assumptions that may prove incorrect.

Therefore, we review some of OSHA's assumptions and explain how they might alter our mortality risk analyses' conclusions. One constraint we imposed on ourselves is that we based our analysis on information OSHA had at the time it issued these regulations. COVID-19 is an evolving public health threat, and emergent strains of the virus since 2021, such as the Omicron strain, may impact public health differently than those strains that were most prominent at the time these rules were finalized. Because one goal of this study is to provide the agency with constructive feedback on its economic analysis, our analysis relies on sources the agency had available to act with. The agency can only be expected to act with the information it has at its disposal at the time policies are issued. However, this also adds to uncertainty since more information about these regulations' potential impacts may have been collected since these regulations were issued.

We organize this paper as follows. We begin by providing a background on mortality risk analysis and explain our mortality risk analysis approach. We then analyze the two 2021 OSHA emergency COVID-19 regulations, following the approach previously outlined. As far as we know, this is the first paper to conduct a mortality risk analysis of these regulations. In both cases, we test our own as well as OSHA's assumptions in a sensitivity analysis to account for the inherent uncertainty in several of the parameters in our model. Finally, we conclude by discussing our findings' policy implications, and also discuss

ethical implications that follow from our analysis, as well as how OSHA might improve its analysis going forward by adopting a more comprehensive approach. We believe that the findings and methods used here can inform future policy, both in the COVID-19 context, as well as generally.

2. Theory and Methods

2.1. Background on Mortality Risk Analysis

One way in which regulations produce unintended consequences is by forcing businesses and consumers to spend money to comply with those regulations. Every dollar spent on regulatory compliance is a dollar that would have been spent on competing purposes and the concomitant benefits of those alternative expenditures are lost.[2] One source of foregone benefit is spending on risk reduction: families forgo spending on doctor's visits, safer vehicles, or living in more secure or less polluted neighborhoods when they spend more money at the supermarket because regulations raise the price of food (Chambers and Collins 2019). 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 gives rise to a phenomenon known as the "mortality cost of expenditures" (Broughel and Viscusi 2021; Broughel and Chambers 2022). Given this tradeoff between spending and death risks, 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 typically do not account for the mortality cost of regulatory expenditures, despite being instructed to consider risk tradeoffs under Office of Management and Budget (OMB) guidelines (OMB 2003).

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 USD 75 million and a regulation reduces consumption today valued at USD 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 at least some 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 (Broughel 2021). Additionally, just as regulatory costs tend to grow over time because of the opportunity cost of capital, the cutoff value grows over time (Broughel and Viscusi 2021). This may stem from the fact that society becomes better at reducing some risks over time and therefore it takes a greater loss of resources to induce a death. For these reasons, short-term and long-term risk impacts from expenditures can differ. It may be that a regulation reduces mortality risk in the short term while increasing it over the long term.

2.2. 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 USD 38.6 million (2019 USD) (Broughel and Chambers 2022), whereas a study using the indirect approach estimates the cutoff at USD 108.5 million (2019 USD) (Broughel and Viscusi 2021).

These findings are fairly representative of the literature in that the indirect method tends to produce higher estimates of the cutoff than the direct method.

Both approaches have limitations. The main problem with the direct approach is that the relationship between income and mortality is complicated. Across society, 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 (Smith 1999). 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 later demonstrate, it is also the case that many, if not most, of the fatalities stemming from economic dislocations can be expected in the future. For this reason, 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. Individuals also impose externalities through their savings behavior, which impacts people in the future (Broughel and Kotrous 2021). 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, some spending on food, exercise, or a safer vehicle partly reflects a preference for reducing risk, but these are generally not considered part of health spending. These issues are reasons why the indirect method may overestimate the cutoff. That said, not all health spending is very effective either, which is a reason why the indirect method could underestimate the cutoff.

Fortunately, most of the challenges with estimating the cutoff may not matter that much in practice. These issues relate to estimating the cutoff level with precision. However, the cutoff growth rate is arguably more important, given that what ultimately 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 rate of return foregone under conditions 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 a regulation's total net costs exceed zero, since any positive net cost—if it has a high enough growth rate—will eventually overtake the cutoff. The cutoff level is still important for distributional reasons, such as determining whose life is lost owing to countervailing risks begotten by regulatory costs. For determining if regulations increase or reduce mortality risk overall, the deciding factor is often going

to be whether health, safety, or other regulations make a net positive contribution to the economy's productive capital stock. (Note that removing unproductive capital would also make a net positive contribution).

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 USD 39.1 million (2020 USD) per expected death estimate arrived at using the direct method by Broughel and Chambers (2022), and as an upper bound our analysis uses a USD 109.8 million (2020 USD) per expected death estimate arrived at using the indirect method by Broughel and Viscusi (2021). The midpoint of these values, USD 74.5 million (2020 USD), is the central cutoff estimate in our analysis. Additionally, Broughel and Viscusi (2021) 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 their study, 1.25 percent per year, as its estimate of the growth rate of the cutoff.

2.3. 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. Most previous mortality risk analyses either 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 confused 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 benefit–cost 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.[3] 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 there can be monetary costs or savings associated with saving lives, which affects the timing of cash flows, which matters owing to the time value of money.

2.4. The Shadow Price of Capital

As noted above, 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 benefit-cost analysis (OMB 1992, 2003). Although federal agencies rarely use this method in regulatory analysis, it is well established in the economics literature that this method is correct. For example, a popular textbook on cost–benefit analysis states: "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". (Boardman et al. 2018, p. 260).

The SPC can be expressed using Equation (1):

$$ShadowPriceofCapital = \sum_{t=0}^{\infty}(1-f)ROI \times (1+fROI)^{t} \quad (1)$$

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.[4]

In our analysis, the fraction of the return invested in each period, f, is estimated based on the literature regarding the marginal propensity to consume (MPC) for the United States. For example, Dinerstein et al. (2021) of the University of Pennsylvania analyzed a proposed USD 1400 COVID-19 relief payment to 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. Carroll et al. (2017) developed a model that suggests that the aggregate MPC estimate falls in a range of 0.2 to 0.4 for transitory income shocks. However, many studies in this literature look at relief payments made during recessions, which we believe may not be representative of normal spending patterns. 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. Thus our preferred estimates are drawn from studies based on the permanent income hypothesis, which tend to find much lower MPCs, often in the range of 0.0 percent to 0.5 percent (Krusell and Smith 1998; Hsieh 2003; Jappelli and Pistaferri 2010; Kaplan and Violante 2010, 2014).

We use an MPC of 0.2 here, implying an f value of 0.8, which seems conservative because it is greater than the lower MPCs predicted using the permanent income hypothesis but less than what seem like unusually high estimates 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 et al. (2017), and an f value of 0.8 is similar to the assumed reinvestment rate by Harberger and Jenkins (2015) in a study relevant to benefit-cost analysis. We discuss the sensitivity of our mortality risk analysis to this assumption later in a 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 (Jordà et al. 2019). 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.[5] Corporations' capital investments often earn significantly higher rates of return than do equities. 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 (Damodaran 2007; Zeckhauser and Viscusi 2008). Real estate and equities are, therefore, reasonable destinations for marginal investments.[6]

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.

3. OSHA's Healthcare Worker ETS

3.1. Background on OSHA's Healthcare Worker ETS

On 21 June 2021, 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 (OSHA 2021a). 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 ten or more employees, such plans must be in writing. Because this interim final rule is economically significant, OSHA prepared an RIA for it.

3.2. Initial Expected Deaths

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. 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'" (OSHA 2021a, p. 32484). Hence, OSHA believes it is required to consider only whether the benefits of its rule can be attained, not whether they are economically justified. This approach could be a problem in cases where substantial costs fall on other parties aside from employers, or where benefits are not significant. These are important factors that will not be in the analysis.

A mortality risk analysis can potentially assist in this endeavor because OSHA's mandate to elevate worker health over other concerns presumably means its regulations' effects on mortality are paramount. 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, even if OSHA is prohibited from balancing costs and benefits more broadly.

According to OSHA, its rule will generate approximately USD 4.0 billion (2019 USD) in costs while preventing 776 people from dying and 295,284 people from becoming infected during the six months the rule is in effect.[7] OSHA monetizes the value of preventing deaths and infections by using estimates of the value of a statistical life (VSL) and the value of statistical illness and injury. Following this approach, the agency calculates the value of the rule's benefits to be approximately USD 27 billion (2019 USD).

Our mortality risk analysis assumes OSHA 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 social costs because extending lives also usually 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, we draw on estimates of the expected remaining lifetime contributions of individuals who die prematurely from COVID-19 to account for the financial cost savings from preventing COVID-19 deaths (Broughel and Kotrous 2021). We adjust these estimates for age, since OSHA's rules target workers as opposed to the general populace. Our lifetime contributions estimates allow us to estimate the cost-effectiveness of the OSHA emergency healthcare standard (that is, the financial costs per life saved), which can then be compared with the cutoff estimate (which relates to financial expenditures).[8]

Broughel and Kotrous (2021) estimate that although the average cost per death in the United States is around USD 1 million (deflated to 2019 USD), the average cost per COVID-19 death is approximately USD 334,202 (deflated to 2019 USD) 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, and OSHA's rule specifically targets healthcare workers. Thus, we use an updated value of life based on the age distribution of fatalities among 18–64 year olds, which is a similar age range targeted by the COVID-19 Vaccination and Testing ETS. We believe this is appropriate because the regulations both target a similar working-age population. This adjustment yields an updated estimate of the average cost per COVID-19 death of approximately USD 863,400 (2020 USD), which is a present value discounted at a 5.6 percent rate.[9]

For prevented infections, we calculate the cost savings associated with reductions in medical services and lost work using estimates from Broughel and Kotrous (2021) and hospitalization cost estimates from Amin and Cox (2021). Broughel and Kotrous (2021) estimate that the cost of a symptomatic infection for someone who is not hospitalized is USD 1900, based on missing two weeks of work. Meanwhile, Amin and Cox estimate that an average COVID-19 hospitalization costs USD 20,000. Drawing from the work of

Scobie et al. (2021), we estimate that OSHA prevents 7483 hospitalizations by multiplying OSHA's estimated prevented COVID-19 cases by 5.1 percent (the case hospitalization rate for the relevant age group). Taken together, this suggests the cost savings of prevented medical expenses and deaths result in combined cost savings of roughly USD 1.5 billion (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 USD 2.5 billion (2020 USD), which is the initial cost estimate used in the cost-effectiveness calculation for our mortality risk analysis.

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 (USD [2020])	Total Value (USD [2020] Million)
Net Reduction in Mortality	743		
Prevented COVID-19 deaths (18–64)	776	863,422	670
Expected deaths from lost income (net regulatory cost/cost per life cutoff)	33	1,258,108	42
COVID-19 infections prevented (minus COVID-19 deaths prevented)	294,508	1900	560
Hospitalizations prevented (including COVID-19 deaths prevented)	15,059	20,000	301
Total regulatory cost savings	-	-	1531
Total regulatory costs	-	-	4018
Total net regulatory costs	-	-	2487
Total net regulatory costs + costs from indirect expected deaths	-	-	2529
Initial cost per life saved (total net regulatory cost/gross mortality reduction)	-	-	3.2

Note: Sums may not be exact because of rounding. "Expected deaths" refer to deaths that arise from reductions in spending aimed at reducing mortality risk. Sources: Broughel and Kotrous (2021): OSHA (2021a); Amin and Cox (2021).

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 USD 3.2 million, less than our best estimate of the cutoff of USD 74.5 million (2020 USD). OSHA's rule also yields approximately 34 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.

3.3. Morality Risk over Time

We expect OSHA's rule to impose initial total net costs of roughly USD 2.5 billion. Given an assumed MPC value of 0.2 and an MPS (f) value of 0.8, society would have invested USD 2.0 billion and consumed USD 497 million in the initial period. Thereafter, society would have consumed a consumption stream that grows at a rate of $f \times ROI$ or $(0.8)(0.07) = 5.6$ 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 USD 0.9 billion. Meanwhile, the capital asset that is displaced would have grown to a value of USD 3.5 billion in year 10 (owing to reinvestment). If one uses a cutoff of USD 74.5 million (assumed to grow at 1.25 percent annually), the initial regulatory costs

generate 33 statistical deaths in year 0, which grows to 52 expected deaths by year 10. This calculation is based on the rule's cost as it evolves (which, at any point in time, we count as equal to the sum of two things: (a) the market value of the capital asset displaced by the rule at that point in time and (b) the value of the cumulative consumption stream the capital asset has generated up to that point).[10] The rule fails a cost–benefit test roughly 43 years after implementation (if one uses OSHA's monetized estimate of benefits). The expected deaths induced by the regulation fully offset the expected lives saved 74 years after implementation. Thus, it takes about three-quarters of a century for this rule to increase mortality risk. See Table 2.

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	2.5	2.0	0.4	0	74	33	743	3	0.012
5	3.3	2.7	0.7	35	79	42	734	5	0.002
10	4.4	3.5	0.9	46	84	52	724	6	0.002
25	10.0	8.0	2.0	106	102	99	677	15	0.001
50	39.8	31.9	8.0	422	139	287	489	81	0.002
100	627.7	502.2	125.5	6653	258	2433	−1657	−379	0.005

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, owing to more investment, 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.

The projections in Table 2 imply that this rule could, over 100 years, generate 1657 more statistical deaths than it saves, at a cost of USD 665 billion up to that point. Whereas the regulatory costs appear to be large, they represent approximately 0.005 percent of cumulative GDP over the same period. Our mortality risk analysis's and OSHA's RIA's results are similar in the short term but differ in the long term primarily because our analysis (a) better accounts for the opportunity cost of capital by using the shadow price of capital method, (b) distinguishes between regulatory costs that would otherwise be invested and those that would be consumed, (c) considers a longer horizon, and (d) uses a social rate of time preference of zero.

One lesson from our mortality risk analysis is that even regulations only in place temporarily can have ongoing costs when they displace investments. Thus, a regulation's opportunity cost 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. A related implication of this analysis is that the metrics like the VSL OSHA uses for monetizing nonmarket benefits can recommend policies that increase risk, because they do not account for how differing benefits (pecuniary vs. nonpecuniary) are evolving across time at different rates of growth.

Given the uncertainty of making predictions 100 years in the future, the takeaway from Table 2 is not that exactly 1657 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 have profound effects over time. Due to these forces, this regulation is likely to increase risk at some point in the future. Although we do not filter the results of our analysis through a social rate of time preference—because our goal is to anticipate the actual impacts of the regulations going forward, not to make assertions about which impacts matter and which do not—it should be obvious that the less weight one places on the future, the less one

might be concerned about risk externalities our actions impose on successor generations. These distributional implications of the regulation could be of concern to policy makers and are worth noting.

3.4. Discussion of Uncertainty

Our mortality risk analysis has several areas of uncertainty. One important source of uncertainty is that our cost estimates may be an underestimated because we draw them from OSHA's feasibility analysis as opposed to from a cost–benefit analysis. Due to this limitation, one might question the decision to evaluate OSHA's regulations from a mortality risk perspective. However, we believe mortality analysis can be informative in instances such as this one where an agency's statutory obligations lead it to avoid conducting a comprehensive cost–benefit analysis. If OSHA underestimated its rules'costs, as seems likely, our mortality risk analysis can be viewed as conservative in the sense that the rule probably increases mortality 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.[11] 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 commonplace 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 (f) is 0.95, in line with the permanent income hypothesis, then this rule would produce a net increase in mortality risk 14 years sooner—that is, 60 years after the rule is implemented as opposed to 74 years after. On the other hand, if one assumes the marginal propensity to save (f) is 0.60, then the date when the rule produces a net increase in mortality risk would be pushed back to 108 years after the rule is implemented. Similarly, using a cost per life saved cutoff of USD 109.8 million, as opposed to USD 74.5 million in the core specification, pushes back the date at which the rule leads to a net increase in mortality risk to 83 years after implementation. Using the lower cutoff estimate of USD 39.1 million brings the date the rule produces a net increase in mortality risk forward to year 58 after implementation. Reducing the cutoff's annual growth rate to 0.5 percent moves the year the rule leads to a net increase in mortality risk to year 63 after implementation—11 years sooner—whereas increasing the cutoff growth rate to 2.0 percent per year pushes the turning point year back to year 89 after implementation—15 years later.

Finally, there is uncertainty with regard to whether infections that are asymptomatic impose costs, as well as surrounding the fraction of infected individuals who are hospitalized. If preventing asymptomatic infections is not cost saving, then the estimates here are too favorable to OSHA's healthcare worker ETS. The fraction of infected individuals that are hospitalized could be over or underestimated given uncertainty surrounding the number of individuals infected at any given time, since many infections go unidentified.

4. OSHA's Vaccination and Testing ETS

4.1. Description of the Vaccination and Testing ETS Rule

On 5 November 2021, OSHA published its COVID-19 Vaccination and Testing ETS regulation (OSHA 2021b), which required certain employers with over 100 employees to implement a vaccine mandate for their employees. Shortly after publication, several state attorneys general filed lawsuits against OSHA. A federal court stayed the regulation, pending the lawsuits' results, and a few days later OSHA formally suspended the regulation's implementation. The suspension was later overturned, however, and the case

eventually went to the Supreme Court where the regulation was found to be outside of OSHA's legal authority to issue. Thus, the regulation never went into effect. Despite this series of developments, we believe the regulation's economic analysis can still be useful to shed light on analytical practices at OSHA that could potentially be improved with the use of mortality risk analysis.

If the regulation had gone into effect, it would have mandated that employers with at least 100 employees require their workers to become fully vaccinated or undergo weekly testing for COVID-19 and wear masks. Specifically, employers would have needed to either mandate employees be vaccinated (known as the mandatory option) or implement a policy whereby employees can choose between getting vaccinated or remaining unvaccinated so long as they submit to weekly COVID-19 tests and wear facial coverings (the voluntary option). Some workers would have been exempt for medical or religious reasons, but these individuals must still undergo testing and wear masks. OSHA's ETS also excluded certain workplaces while they were covered by the previous ETS related to healthcare employees (OSHA 2021a), or an executive order and subsequent guidance related to COVID-19 workplace safety for federal contractors and subcontractors (Biden 2021; Safer Federal Workforce Task Force COVID-19 Workplace Safety 2021). OSHA's COVID-19 ETS also excepted certain workplaces where workers are without physical contact with other humans, working from home, or where the workplace is outdoors.

The rule stated that employees who do not fully vaccinate 60 days after the rule's publication must use an FDA "cleared, approved, or authorized" SARS-CoV-2 viral test that can detect a current infection (OSHA 2021b, p. 61450). This requirement includes both PCR and antigen tests that detect active infections. Employees could administer their own test as long as it was done following the authorized instructions. However, unless an employer or authorized telehealth proctor supervised the employee, a SARS-CoV-2 test could not be both self-administered and self-read. OSHA's rule also required firms to establish a COVID-19 vaccine policy, determine their workforce's vaccination status, provide paid time off for vaccination and recovery, enforce their unvaccinated employees' weekly testing and masking requirements, and record their employee's vaccination and testing status. OSHA states that its ETS did not require that employers pay for their employee's vaccination or testing but acknowledges that other statutes may require employers to cover the cost of testing workers who obtain a vaccine exemption (OSHA 2021c).

4.2. More Background on Economic Feasibility Analysis

OSHA again performed a technological and economic feasibility analysis on its rule, assuming that it will be in effect for six months. OSHA found no technological feasibility barriers, which OSHA loosely interprets as something "capable of being done," or, alternatively, that the "average employer covered by this ETS can comply" (OSHA 2021b, p. 61447). For this reason, OSHA's economic feasibility analysis only includes employers' regulatory costs. Unlike the cost–benefit analysis required by presidential executive orders or the cost-effectiveness analysis performed in this mortality risk analysis, OSHA's economic feasibility analysis again ignores many broader costs and benefits (including cost savings) that accrue to society.

In this case, the feasibility approach is arguably more detrimental to the comprehensiveness of the analysis, relative to the healthcare ETS, since, for the latter rule, it is conceivable that most costs do indeed fall on the employer. With the vaccine and testing ETS, on the other hand, the agency does not account for many costs falling on employees (e.g., the cost of tests and face coverings for those who opt to remain unvaccinated), costs to taxpayers (e.g., the costs of the vaccines), or friction costs to employees (e.g., costs of switching jobs for those who leave their place of employment because they refuse to comply with OSHA's ETS). OSHA acknowledges that such "costs would be attributable to the ETS in a regulatory impact analysis" (OSHA 2021b, p. 61459). However, because these costs do not fall directly on the employer, and because they can be avoided by the employee

(e.g., through vaccination), OSHA takes the position that these costs have little effect on the feasibility of implementing the ETS.

According to OSHA, the rule would have generated approximately USD 3.0 billion in costs for employers (OSHA 2021b), which increases to USD 5.2 billion if one includes the cost of testing exempt workers (see Table 3) (OSHA 2021c, 2021d). Meanwhile, OSHA's main health estimate found that the ETS would have prevented 830,533 COVID-19 cases, 277,736 hospitalizations (excluding fatalities), and 6830 fatalities for non-healthcare and non-federal contractor workers between 18 and 64 years old (OSHA 2021e). However, OSHA also includes an alternative scenario that includes workers ages 18–74. Under OSHA's age 18–74 scenario, 13,847 fatalities and 563,102 hospitalizations would have been prevented. OSHA prefers its analysis for workers between 18 and 64 years old as its analysis for those 18–74 may overstate the benefits estimate, since "people in the workforce in this age group tend to be closer to 65 years old while the fatalities related to COVID-19 are higher for people over 70 where there are fewer people in the workforce" (OSHA 2021e, p. 3). Therefore, OSHA considers the former estimate to be its main health estimate.

Table 3. OSHA's COVID-19 Vaccination and Testing ETS Costs.

Category	Value (Millions of USD 2020)
Familiarization and Vaccine & Testing Policy	145
Support for employee vaccine	1911
Communication with Employees	4
Determining Employee Vaccination Status	313
Recordkeeping Cost	608
Recording all test results	604
Reporting Fatalities	4
Total Cost, excluding testing	2981
Recordkeeping Cost for Vaccine Exemption Requests	133
Unvaccinated Testing Cost—Exempt Workers	2023
Masking Cost	79
Total Cost, including testing	5216

Source: OSHA Analytical Spreadsheets in Support of the COVID-19 Vaccination and Testing ETS.

4.3. Mortality Risk Analysis

We begin our second mortality risk analysis by again initially assuming OSHA has accounted for all the rule's costs while recognizing that in this case, it almost certainly has not done so, given that OSHA's feasibility analysis explicitly accounts only for costs to employers. Later in this report, we discuss other sources of cost to address some of this uncertainty surrounding this rule's impacts. Nevertheless, we believe using OSHA's main estimates is a good starting point. Like the previous regulation, if we assume the compliance costs are comprehensive, they will tend to overstate the rule's costs because extending lives also saves resources (thereby offsetting some compliance costs). Therefore, the financial savings from extending lives need to be subtracted from the compliance expenditures to produce an unbiased estimate of the regulation's cost-effectiveness for comparison with the cutoff estimate.

Given that OSHA predicted the ETS would prevent 6830 COVID-19 deaths, at USD 863,400 per life the ETS generates USD 5.9 billion in cost savings from extending lives. These savings are enough to make the regulation cost saving on balance at OSHA's higher end of cost estimates. In other words, the regulation can probably be expected to contribute to society's stock of productive capital on balance. However, there are also additional cost savings. From OSHA's hospitalization estimates, we calculate the cost savings associated with reductions in required medical services and lost work using the approach described above. This approach yields additional cost savings of roughly USD 13.2 billion because of prevented illnesses and hospitalizations (see Table 4). Subtracting these cost savings from total regulatory costs calculated by OSHA yields a total net cost figure (that is, costs net of

cost savings) of −USD 7.9 billion. This total net cost figure is the initial estimate used in the cost-effectiveness calculation for our mortality risk analysis. Since it is negative, that means the regulation is overall cost saving.

Table 4. Initial Period Costs, Cost Savings and Total Net Costs of OSHA's COVID-19 Vaccination and Testing; Emergency Temporary Standard.

Category	Estimate	Value per Person (2020 USD)	Total Value Millions (USD 2020)
Net Reduction in Mortality	6937		
Prevented COVID-19 deaths (18–64)	6830	863,422	5897
Expected deaths from lost income (net regulatory cost/cost per life cutoff)	−107	1,258,108	−134
COVID-19 infections prevented (excluding COVID-19 deaths prevented)	823,703	1900	1565
Hospitalizations prevented (including COVID-19 deaths prevented)	284,566	20,000	5691
Total regulatory cost savings	-	-	13,154
Total regulatory costs	-	-	5216
Total net regulatory costs	-	-	−7938
Total net regulatory costs + costs from indirect expected deaths	-	-	−8072
Initial cost per life saved (total net regulatory cost/gross mortality reduction)	-	-	−1.2

Sources: Broughel and Kotrous (2021); OSHA (2021b); Amin and Cox (2021); authors' calculations.

If OSHA's calculations are correct and comprehensive, this rule would have reduced mortality risk in the initial period (and pass a cost–benefit test in the initial period). The cost per life saved is approximately −USD 1.2 million, far less than our best estimate of the cutoff of USD 74.5 million. OSHA's rule also yields approximately 107 initial expected lives saved from increases in income. In other words, this rule's cost savings generate coincident health benefits because it fosters additional spending on private risk reduction. Moreover, like with the previous rule that imposed net costs, this is not the end of the story because society might have invested some of the income saved by this rule. Thus, the expected lives saved count can be assumed to grow over time as some of capital's returns are reinvested each period.

Again, assuming a marginal propensity to save of 0.8 (f), society would invest USD 6.4 billion and consume USD 1.6 billion in the initial period. Thereafter, society will consume a consumption stream that grows at a rate of $f \times$ *marginal rate of return* or (0.8)(0.07) = 5.6 percent per year. By year 10, we expect the cumulative consumption stream that society has gained because of increased investment activity to be worth roughly USD 2.8 billion. Meanwhile, the capital asset that is generated will have grown to a value of USD 11.2 billion in year 10 (owing to reinvestment). If one uses a cutoff of USD 74.5 million (growing at 1.25 percent annually), the initial regulatory cost savings save 107 statistical deaths in year 0, which grow to 166 expected lives saved by year 10. This calculation is based on the rule's cost savings as it evolves. After 50 years, the net mortality risk reduction increases from 6937 lives saved in year zero to 7747 lives saved.

4.4. Discussion of Uncertainty

We believe that the mortality risk analysis above likely overstates risk reduction benefits because of several of OSHA's methodological choices and assumptions. In a forthcoming paper, we provide a more in-depth discussion of OSHA's core assumptions in the vaccine and testing ETS, including providing revised estimates in some cases. However, for this analysis, we simply review some of the key assumptions and, in several of the more notable cases, offer some back of the envelope alternative estimates to OSHA's estimates to show how the topline results of the mortality analysis might change in response.

4.4.1. Reasons OSHA's Benefits May Be Underestimated or Costs Overestimated

OSHA states that its cost estimates are an upper bound because OSHA has not fully disentangled the cost to some employers covered by other policies. For example, OSHA has its separate ETS related to the healthcare sector (OSHA 2021a), and on the same day as the vaccine and testing ETS was issued, CMS issued a regulation related to Medicare

and Medicaid providers that requires a vaccination policy regardless of firm size (CMS 2021a). There is also a separate administration policy related to federal contractors (Biden 2021; Safer Federal Workforce Task Force COVID-19 Workplace Safety 2021). The CMS regulation was allowed to go into effect by the Supreme Court, while the federal contractor mandate was stayed nationwide. These competing regulations and court cases somewhat obscure the degree to which there is overlap between these policies.

Putting the legal issues aside, OSHA makes several choices in its analysis that make its cost and benefits estimates not directly comparable. For example, the agency includes costs to employers for employees aged 65–74, but drops these workers from its main benefits calculation. OSHA claims its health benefit estimate is a lower bound for this reason. This choice is problematic because it means the costs and benefits are evaluated across different populations.

Additionally, OSHA's main health benefit estimate ignores "secondary health impacts of avoided COVID–19 cases among family and friends" (OSHA 2021e, p. 3). Presumably, there is a positive externality that vaccinated workers extend to other community members, and these are not counted in OSHA's analysis. Nor, for that matter, are health benefits counted that might accrue from testing individuals and finding out they have COVID-19 (thereby resulting in quarantine and prevention of spread to others). If OSHA's assessment is that it is overestimating costs and underestimating benefits, then this would imply that the vaccine ETS is more cost saving than the analysis above describes. However, there are also reasons why OSHA's health benefits could be overestimated and cost estimates underestimated, which complicates the picture further.

4.4.2. Missing Costs and Overestimated Benefits

Recall that OSHA's analysis for the vaccine and testing ETS is an economic feasibility analysis. As such, OSHA does not include many of the regulation's social costs. One source of additional costs is the cost of the vaccines themselves. OSHA does estimate vaccine costs associated with traveling, wait times, and adverse vaccination outcomes, which all matter from the employer's perspective, but it does not include the cost of producing, distributing, and administering the vaccine, since these costs fall on other individuals. For instance, when CMS estimated the cost of vaccination, it did include the cost of the vaccine and administration (CMS 2021a).

Here, we provide an estimate of the cost of vaccination, following an approach similar to CMS. A U.S. Centers for Medicare & Medicaid Services announcement from March 2021 states "that the national average payment rate for physicians, hospitals, pharmacies, and many other immunizers [is] USD 40 to administer each dose of a COVID-19 vaccine" (CMS 2021b). Thus we consider the cost of administering the vaccine to be USD 40. For the cost of the vaccines themselves, in terms of their production and sale by pharmaceutical companies, we assume the following prices Pfizer/BioNTech (USD 19.50 per dose), Moderna (USD 15 per dose), and J&J (USD 10 per dose) (Kaplan and Wehrwein 2021).

We next separate vaccinated workers into four groups: (1) workers who received one dose according to OSHA (8.75 percent) and require an additional dose, (2) workers who will take J&J according to OSHA (5 percent),[12] (3) workers who take two doses of Moderna, (4) workers who take two doses of Pfizer/BioNTech. We assume that 5 percent of unvaccinated workers will take J&J (OSHA 2021d). We assume that 8.75 percent of unvaccinated workers (those who OSHA estimates already took one dose) only require an additional dose of Moderna/Pfizer. We assume that the remaining 86.2 percent of unvaccinated workers will take two shots of Moderna or Pfizer, and we split these vaccinations 50–50. Under these assumptions, vaccination costs increase OSHA's estimated costs by USD 2.0 billion—see Table 5.

Table 5. OSHA's COVID-19 Vaccination and Testing ETS, Vaccine Costs.

Category	J&J	Moderna/Pfizer (Require 1 Dose)	Moderna	Pfizer	Total
Vaccine Cost per dose, USD	10	17.25	15	19.5	-
Number Of Doses Required for Vaccination	1	1	2	2	-
Pct Vaccinated, By Vaccine Type	5.0%	8.75%	43.13%	43.13%	100%
Vaccine Administration Costs per dose, USD	40	40	40	40	40
Employees Vaccinated Under ETS	0.9	1.7	8.2	8.2	18.9
Doses Required by Group	0.9	1.7	16.3	16.3	35.2
Total Vaccination Cost, (Millions of USD)	47.3	94.7	897.3	970.7	2010.0

Sources: Centers for Medicare & Medicaid Services; Kaplan and Wehrwein (2021), author's calculations.

Another source of overlooked costs is the cost of testing. OSHA does calculate the cost to firms from testing workers exempt for medical or religious reasons, but it does not calculate the testing costs of non-exempt workers who opt to test in firms allowing for the voluntary option. From a societal perspective, a cost-effectiveness analysis should include the cost of testing all these workers. Therefore, we use OSHA's estimate of the testing cost per worker (USD 40.46 for testing per week,) to estimate the costs associated with testing the 3.1 million workers not exempt for religious or medical reasons who test under voluntary employer policies. We also use OSHA's estimates regarding masking costs (USD 1 for masking per week) for exempt workers to estimate the masking costs associated with non-exempt workers (OSHA 2021c). We find that including these additional costs to the vaccination costs above raises total costs by roughly USD 9.3 billion—see Table 6.

Table 6. OSHA's COVID-19 Vaccination and Testing ETS, including all Testing and Vaccine Costs.

Category	Value (Millions of USD 2020)
Familiarization and Vaccine & Testing Policy	145.2
Support for employee vaccine	1910.9
Communication with Employees	4.2
Determining Employee Vaccination Status	313.2
Recordkeeping Cost	607.9
Recording all test results	603.5
Reporting Fatalities	4.4
Recordkeeping Cost for Vaccine Exemption Requests	132.6
Unvaccinated Testing Cost	4011
Exempt	2023
Nonexempt *	1988
Masking Cost	128
Exempt	79
Nonexempt *	49.1
Cost of Vaccinating Workers (from Table 5) *	2010
Total Cost	9263

Notes: Line items with asterisk are author's calculations. Source: OSHA Analytical Spreadsheets in Support of the COVID-19 Vaccination and Testing ETS; author's calculations.

OSHA also makes some unusual assumptions in its health benefits analysis, which could lead to the overestimation of health benefits. OSHA estimates 277,736 prevented hospitalizations by dividing the 6830 estimated fatalities prevented (among the 18–64 unvaccinated population) by the number of hospitalizations that result in fatalities (for the 18–49 vaccinated and unvaccinated population), which is 2.4 percent, and then subtracting prevented fatalities. This method overstates the number of expected hospitalizations prevented because of COVID-19′s differential impact on those of different ages. OSHA's estimate implies that the proportion of COVID infections resulting in hospitalization is 33.4 percent. If one re-estimates hospitalizations including the proportion of COVID-19 associated hospitalizations of 50 to 64 years old that ended in fatalities (7.9 percent) (CDCP 2021a), hospitalizations fall to 133,201 and the infection-hospitalization ratio falls to 16.2 percent.

Also problematic, however, is that OSHA's estimate of the fraction of hospitalizations that end in death includes vaccinated workers, and therefore underestimates the ratio for unvaccinated workers, who are the focus of the vaccine and testing ETS. Using a separate study from M. Scobie et al. (2021), and correcting for the age issues described above, a more reasonable estimate of the case-hospitalization rate is 5.1 percent based on the age distribution of the unvaccinated COVID-19 cases OSHA prevents, which leads the estimate of prevented hospitalizations to fall to 42,558—see Table 7.

Table 7. COVID-19 Cases, Fatalities, and Hospitalizations Adverted by Age.

	Category	18–29	30–49	50–64	Total
OSHA Estimates	US Population, Age Distribution	26.7%	42.0%	31.3%	100%
	Workers likely to vaccinate	5,052,368	7,944,902	5,917,258	18,914,528
	COVID-19 Case Rate Per 100k, Unvaccinated	302.1	330.4	280.6	307.3
	Total Cases By Group, Unvaccinated	396,830	682,530	431,666	1,511,026
	Total Cases By Group After Adjustments, Unvaccinated	218,830	373,426	238,276	830,533
	COVID-19 Fatality Rate Per 100k, Unvaccinated	0.25	1.51	6.17	2.6
	Total Fatalities By Group, Unvaccinated	334	3128	9499	12,970
	Total Fatalities By Group After Adjustments, Unvaccinated	181	1666	4983	6830
	Hospitalizations that End in Death (vaccinated + unvaccinated)	2.4%	2.4%	2.4%	2.4%
	Inferred Hospitalizations, ((Fatalities/In hospital Deaths)—Fatalities)	7374	67,740	202,622	277,736
	Case Hospitalization Rate	3.4%	18.1%	85.0%	33.4%
Author Estimates	Hospitalizations that End in Death (vaccinated + unvaccinated), Age Corrected *	2.4%	2.4%	7.9%	4.1%
	Inferred Hospitalizations, (Fatalities/In hospital Deaths)—Fatalities	7374	67,740	58,087	133,201
	Case Hospitalization Rate, Corrected for Age	3.4%	18.1%	24.4%	16.0%
	Incidence Rate Ratio, Case/Hospitalizations Unvaccinated	3.2%	3.2%	9.9%	5.1%
	Estimated Hospitalizations (Hospitalizations × Incident Rate Ratio)	7052	12,033	23,473	42,558

Sources: OSHA (2021b, 2021d); CDCP (2021a); Scobie et al. (2021); author's calculations. Notes: * OSHA uses the proportion of COVID-19 associated hospitalizations of 18 to 49 year old's that ended in fatalities from 1 March 2020, through 31 August 2021: 2.4 percent, accessed 4 October 2021. We use the proportion of COVID-19 associated hospitalizations of 50 to 64 years old's that ended in fatalities of 7.9 percent for those 50 to 64. We access our data using a web archive for 2 October 2021.

Whereas relying on OSHA's economic feasibility analysis yields total regulatory cost savings of USD 13.1 billion, our revised cost and benefits estimates reduce cost savings to USD 8.3 billion. Similarly, total regulatory costs increase from USD 5.2 billion to USD 9.3 billion, and total net regulatory costs (costs net of cost savings) increase from −USD 7.9 billion to USD 950 million, meaning the regulation imposes net costs. With positive and growing net costs, the regulation can be expected to eventually increase risk because it reduces the stock of society's productive capital, though it will likely take a considerable amount of time for that to occur, given the high number of initial estimated prevented deaths.

That being said, we do acknowledge that there could be positive externalities associated with vaccination that lead to a more optimistic picture than that presented here. Moreover, OSHA's regulation should be considered within a larger national policy goal of getting the U.S. population vaccinated at a level commensurate to achieve herd immunity. If that goal could be achieved, significant cost savings in terms of health and mortality could be realized. Producing an estimate of these broader social costs and benefits is outside the scope of this study.

4.4.3. Workers' Likelihood of Vaccination May Be Overstated

OSHA's analysis makes two additional assumptions that we do not attempt to quantify here but which have the potential to alter this regulation's risk calculus. Both relate to the degree to which workers are likely to get vaccinated under the rule. First, OSHA uses CDC COVID-19 vaccine confidence data (CDCP 2021b) to separate unvaccinated workers into two categories: unvaccinated but not hesitant and vaccine hesitant. OSHA bases its estimate of the number of workers that opt to test rather than vaccinate off of the percent of CDC respondents who answer they probably or definitely will not get vaccinated

(13.8 percent). OSHA labels these workers as vaccine-hesitant. Otherwise, OSHA assumes that unvaccinated workers are not vaccine-hesitant.

Several surveys, however, including CDC's COVID-19 vaccine confidence data, suggest that OSHA's assumptions may be too optimistic (CDCP 2021b; Uslu et al. 2021; Hamel et al. 2021a, 2021b). For example, if one instead defined vaccine hesitant as anyone who is less than certain they will get vaccinated in the CDC data, the proportion of vaccine hesitant could rise to as much as 90 percent of the unvaccinated population, when defined as those who have taken less than one dose.

Second, OSHA also uses survey data to estimate that 25 percent of employers had vaccine mandates in place before the ETS would be enacted (meaning workers must vaccinate or face termination) (Mishra and Hartstein 2021; Willis Towers Watson 2021; Arizona State University 2021), and assumes that absent the ETS, the percentage of firms with such mandates would remain 25 percent (OSHA 2021b). Using the same surveys, OSHA states that 60 percent of employers will have employer mandates (vaccinate or face termination) after the ETS (OSHA 2021b). The 40 percent of remaining covered firms will opt for voluntary employer policies (vaccine or test). However, OSHA overlooked that many of the surveyed firms responded that they do not impose consequences for their vaccine mandates in line with OSHA's definition of an employer mandate. For example, in one survey, 21 percent of firms reported that their current or planned vaccine mandate requires at least some of their employees to vaccinate. Among these firms, only 33 percent reported that they would terminate their non-compliant employees, while 49 percent stated they allow for testing instead of vaccination, suggesting a voluntary rather than a mandatory policy (Mishra and Hartstein 2021).

To the extent more firms opt for the voluntary policy of vaccination or optional weekly testing, OSHA's ETS regulation will have higher costs and lower benefits. Furthermore, to the extent that more employees opt for weekly testing over vaccination, as a result of being vaccine hesitant, OSHA's benefits will drop and costs rise as more tests are conducted and workers are forced to wear masks in their places of employment.

5. Conclusions

This paper examined the mortality implications of OSHA's two 2021 emergency testing standard regulations, using data contained in OSHA's economic feasibility analysis. For the emergency COVID-19 healthcare worker rule, we find the regulation is likely to reduce risk and pass a cost–benefit test in the short term but may increase risk and fail a cost–benefit test over longer time horizons. For the agency's 2021 vaccine and testing regulation, we find sufficient risk mitigation to expect a high number of lives would have been saved rendering this regulation cost-saving on balance. However, after including some basic ancillary costs and re-estimating OSHA's prevented hospitalizations, we find that the regulation could have imposed net costs under reasonable assumptions, and therefore generate risk in the long term. In both cases, OSHA's economic feasibility analysis is problematic because it does not include many costs to society that a mortality risk analysis or a benefit–cost analysis would consider. Consequently, economic feasibility analysis yields an incomplete picture of the effects of regulation on worker safety and should not be the test that authorizes a regulation to be issued.

Additionally, some of OSHA's methodological approaches and assumptions may overestimate the benefits and underestimate the costs of these rules. This is especially true of the vaccine and testing ETS, which overlooks the costs of producing and administering vaccines, the cost of testing medically and religious exempt workers, and may overstate the willingness of vaccine hesitant workers to get vaccinated or for employers to impose a strict vaccination mandate. Our mortality risk analysis attempts to quantify some of these issues, thereby reducing some of the uncertainty.

Importantly, the analysis presented here is based on information the agency had at its disposal at the time these rules were issued. In that sense, we are simply pulling together information from the agency's own analysis and other related sources in order to

highlight specific impacts, in this case impacts related to risk. If necessary, it would also be appropriate to consider ethical or political considerations in the context of these rules, since risk considerations are just one input involved in a decision. For example, the institutional credibility of the government could be harmed amongst the public if it failed to act during a pandemic, even if some of its actions increase risk.

One goal of this study is to help the agency produce better-informed risk analysis. As such, we have sought to avoid criticizing the agency for failing to utilize information it could not possibly have possessed at the time its rules were finalized. We recognize, however, that this adds additional uncertainty to the analysis above. For example, the Omicron variant of the coronavirus is known to be less lethal than many earlier variants, and it may also infect those who are vaccinated against COVID-19 at higher rates. These examples highlight how the COVID-19 pandemic is an evolving situation, where important information needed to set policy can change rapidly.

There are several conclusions we can draw from our analysis. First, as already noted, economic feasibility analysis has many shortcomings, and some of these could be addressed by supplementing that form of analysis with other information. Presumably, even if OSHA is prohibited from benefit–cost balancing, it is not prohibited from considering whether its regulations increase or reduce risk on balance. Our mortality risk analysis demonstrates that there is value in producing a more comprehensive tally of costs than is done under a feasibility analysis because, without a more accurate cost appraisal, a comprehensive mortality risk assessment cannot be conducted. Second, there is considerable uncertainty surrounding the impacts of OSHA's 2021 emergency regulations, and a policymaker is unlikely to get a sense of this uncertainty simply by reading OSHA's feasibility analysis. The agency could benefit from a more transparent representation of the range of potential impacts that are possible based on the available information it is acting upon.

Interestingly, the Supreme Court prohibited the implementation of the vaccine and testing regulation, while the healthcare worker regulation was allowed to go into effect. This occurred despite the fact that OSHA's analysis seemed to support, if anything, that the vaccine ETS would have reduced risk more than the healthcare ETS. While economics and risk analysis appear to have played little or no role in the decisions by courts as to whether to allow these regulations to proceed, future mortality risk analyses can improve our understanding of how regulations impact public health and could be considered by courts when making decisions about the legality of particular regulations. We therefore hope that the analysis presented here can inform the analytical methods adopted by policy makers, both in the context of future pandemic regulations as well as for regulatory policy more generally.

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Notes

1 The term "health-health analysis" is confusing since most such analyses focus exclusively on mortality risks, not health risks generally. That is why we choose not to adopt that terminology here.

2 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 aggregate resource value is created or destroyed in the process.

[3] Using a social rate of time preference of zero is defensible for several reasons. First, many scholars question whether it is ethical to discount future benefits such as health or lives saved. Second, economic efficiency requires that a dollar's worth of benefits be treated the same regardless of who receives it. While discounting cash flows is sensible owing to the time value of money, the time value of money does not apply to nonpecuniary health and safety benefits. Thus, if the analyst applies a social rate of time preference other than zero, he or she is not measuring economic efficiency. Third, cost–benefit analysis should be grounded in a consequentialist approach that analyzes costs and benefits as they actually occur. Filtering benefit and cost values through an arbitrary social time preference scale deviates from consequentialism. Fourth, in intergenerational settings, those not yet born cannot be impatient, and most regulations have at least some intergenerational characteristics because their impacts are not instantaneous. Fifth, a social time preference discount rate converts benefits into an ordinal measure of welfare, and the concept of cost-effectiveness is incoherent when benefit values represent rankings. Therefore, any social rate of time preference other than zero is arguably incompatible with mortality risk analysis.

[4] 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 drops out of Equation (1).

[5] 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, which is based on national income and product accounts data (OMB 2003). 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 (CEA 2017).

[6] As discussed in a 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.

[7] It is unclear from OSHA's regulation whether the COVID-19 cases prevented represent symptomatic infections or a combination of symptomatic and asymptomatic infections. In this analysis, we assume that every prevented COVID-19 case is a symptomatic infection. In that sense, "infections" can be thought of as similar to "cases" often reported for COVID-19, which are COVID-19 infections that have usually been identified with a positive test result. With OSHA's COVID-19 Vaccination and Testing ETS, it is also unclear if OSHA believes that every infection prevented is symptomatic. To the extent that OSHA is including asymptomatic COVID-19 infections in its estimates of prevented infections, the cost savings from prevented infections discussed below are likely overstated since asymptomatic infections may not result in any costs whereas symptomatic infections are likely to result in missed work. Overstated cost savings would result in an underestimate of total net costs and too favorable a view of the risk impacts of OSHA's regulations.

[8] The expenditure estimates in Broughel and Kotrous (2021) are based on estimates of worker contributions to market and nonmarket production. We acknowledge that market inefficiencies can cause earnings to deviate from productive output in some cases. The latter is the theoretically correct measure of worker value, but the former is what is available. When combined with the shadow price of capital, this is our best estimate of the cost savings accruing from lives saved.

[9] Because the exact timing of cash flows from extended life are unknown, we assume undiscounted cash flows are spread evenly across one's remaining expected lifespan, and then convert this stream of cash flows to a present value using the opportunity cost of capital rate (5.6 percent in our analysis's core specification).

[10] The cost of the regulation is calculated in this way to demonstrate how mortality risk is evolving up to a particular point in time. This matters for distributional reasons, i.e., for determining who is made better off and who worse off, in terms of risk, by this regulation. For aggregate purposes, 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.

[11] 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, it is possible regulations forcing recurring expenditures are 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.

[12] OSHA does not make a prediction about the composition of vaccinations, however, the agency notes that recent history suggests 5 percent took J&J.

References

Amin, Krutika, and Cynthia Cox. 2021. Unvaccinated COVID-19 Hospitalizations Cost Billions of Dollars. Peterson-KFF Website, Health System Tracker. Available online: healthsystemtracker.org/brief/unvaccinated-covid-patients-cost-the-u-s-health-system-billions-of-dollars/ (accessed on 18 December 2021).

Arizona State University. 2021. *COVID-19 Diagnostic Commons*. Arizona: College of Health Solutions (ASU, Spring 2021).

Biden, Joseph R., Jr. 2021. *Executive Order on Ensuring Adequate COVID Safety Protocols for Federal Contractors*. Washington, DC: The White House.
Boardman, Anthony E., David H. Greenberg, Aidan R. Vining, and David L. Weimer. 2018. *Cost-Benefit Analysis: Concepts and Practice*, 5th ed. Cambridge: Cambridge University Press.
Broughel, James. 2021. *Rehabilitating the Opportunity Cost of Capital in Cost-Benefit Analysis*. Fairfax: Mercatus Center at George Mason University Working Paper.
Broughel, James, and Dustin Chambers. 2022. Federal regulation and mortality in the 50 States. *Risk Analysis* 42: 592–613. [CrossRef] [PubMed]
Broughel, James, and Michael Kotrous. 2021. 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: e0252729. [CrossRef] [PubMed]
Broughel, James, and W. Kip Viscusi. 2021. The Mortality cost of expenditures. *Contemporary Economic Policy* 39: 156–67. [CrossRef]
Carroll, Christopher, Jiri Slacalek, Kiichi Tokuoka, and Matthew N. White. 2017. The distribution of wealth and the marginal propensity to consume. *Quantitative Economics* 8: 977–1020. [CrossRef]
Centers for Disease Control and Prevention. 2021a. *A Weekly Summary of U.S. COVID-19 Hospitalization Data, Characteristics of COVID-19-Associated Hospitalizations*; Washington, DC: Centers for Disease Control and Prevention.
Centers for Disease Control and Prevention. 2021b. *Trends in COVID-19 Vaccine Confidence in the US*; Washington, DC: Centers for Disease Control and Prevention.
Centers for Medicare & Medicaid Services. 2021a. *Medicare and Medicaid Programs; Omnibus COVID-19 Health Care staff Vaccination, 86 Fed Reg.61555–61627*; Washington, DC: Centers for Medicare & Medicaid Services.
Centers for Medicare & Medicaid Services. 2021b. *Biden-Harris Administration Increases Medicare Payment for Life-Saving COVID-19 Vaccine*; Washington, DC: Centers for Medicare & Medicaid Services.
Council of Economic Advisers. 2017. *Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate*; Washington, DC: Council of Economic Advisers.
Chambers, Dustin, and Courtney Collins. 2019. How do federal regulations affect consumer prices? An analysis of the regressive effects of regulation. *Public Choice* 180: 57–90. [CrossRef]
Damodaran, Aswath. 2007. *Return on Capital (ROC), Return on Invested Capital (ROIC) and Return on Equity (ROE): Measurement and Implications*. New York: NYU Stern School of Business.
Daumann, Frank, Florian Follert, Werner Gleißner, Endre Kamarás, and Chantal Naumann. 2021. Political decision making in the COVID-19 pandemic: The case of Germany from the perspective of risk management. *International Journal of Environmental Research and Public Health* 19: 397. [CrossRef]
Dinerstein, Marcos, Zheli He, and Xiaoyue Sun. 2021. *Background: Marginal Propensities to Consume in the 2021 Economy*. Philadelphia: Wharton School of the University of Pennsylvania.
Ellig, Jerry, and Rosemarie Fike. 2016. Regulatory process, regulatory reform, and the quality of regulatory impact analysis. *Journal of Benefit Cost Analysis* 7: 523–59. [CrossRef]
Gandjour, Afschin. 2021. How many intensive care beds are justifiable for hospital pandemic preparedness? A cost-effectiveness analysis for COVID-19 in Germany. *Applied Health Economics and Health Policy* 19: 181–90. [CrossRef]
Gandjour, Afschin. 2022. Cost-effectiveness of future lockdown policies against the COVID-19 pandemic. *Health Services Management Research. Online First edition*. [CrossRef]
Gleißner, Werner. 2019. Cost of capital and probability of default in value-based risk management. *Management Research Review* 42: 1243–58. [CrossRef]
Gleißner, Werner, Florian Follert, Frank Daumann, and Frank Leibbrand. 2021. EU's Ordering of COVID-19 vaccine doses: Political decision-making under uncertainty. *International Journal of Environmental Research and Public Health* 18: 2169. [CrossRef]
Hamel, Liz, Lopes Lunna, Sparks Grace, Kirzinger Ashley, Kearney Audrey, Stokes Mellisha, and Mollyann Brodie. 2021a. *KFF COVID-19 Vaccine Monitor: September 2021*. San Francisco: Kaiser Family Foundation.
Hamel, Liz, Lopes Lunna, Sparks Grace, Kirzinger Ashley, Kearney Audrey, Stokes Mellisha, and Mollyann Brodie. 2021b. *KFF COVID-19 Vaccine Monitor: October 2021*. San Francisco: Kaiser Family Foundation.
Harberger, Arnold C., and Glenn Jenkins. 2015. Musings on the social discount rate. *Journal of Benefit-Cost Analysis* 6: 6–32. [CrossRef]
Hsieh, Chang-Tai. 2003. Do consumers react to anticipated income changes? Evidence from the Alaska Permanent Fund. *American Economic Review* 93: 397–405. [CrossRef]
Jappelli, Tullio, and Luigi Pistaferri. 2010. The consumption response to income changes. *Annual Review of Economics* 2: 479–506. [CrossRef]
Jordà, Òscar, Knoll Katherina, Kuvshinov Dmitry, Schularick Moritz, and Alan M. Taylor. 2019. The Rate of Return on Everything, 1870–2015. *Quarterly Journal of Economics* 134: 1225–98.
Kaplan, Deborah, and Peter Wehrwein. 2021. *The Price Tags on the COVID-19 Vaccines*. New Jersey: MHE Publication, vol. 31.
Kaplan, Greg, and Giovanni L. Violante. 2010. How much consumption insurance beyond self-insurance? *American Economic Journal: Macroeconomics* 2: 53–87. [CrossRef]
Kaplan, Greg, and Giovanni L. Violante. 2014. A model of the consumption response to fiscal stimulus payments. *Econometrica* 82: 1199–239.

Krusell, Per, and Anthony A. Smith Jr. 1998. Income and wealth heterogeneity in the macroeconomy. *Journal of Political Economy* 106: 867–96. [CrossRef]

Lutter, Randall, and John F. Morrall. 1994. Health-health analysis: A new way to evaluate health and safety regulation. *Journal of Risk and Uncertainty* 8: 43–66. [CrossRef]

Mishra, Devjani H., and Barry A. Hartstein. 2021. *Littler Survey: Employers Increasingly Consider Vaccine Mandates as COVID-19 Delta Variant Spreads*. San Francisco: Littler.

Occupational Safety and Health Administration. 2021a. *Occupational Exposure to COVID-19; Emergency Temporary Standard. 86 Fed. Reg. 32376-32628*; Washington, DC: Occupational Safety and Health Administration.

Occupational Safety and Health Administration. 2021b. *COVID-19 Vaccination and Testing; Emergency Temporary Standard. 86 Fed. Reg.61402–61555*; Washington, DC: Occupational Safety and Health Administration.

Occupational Safety and Health Administration. 2021c. *Costs Associated with Reasonable Accommodation: Testing, Face Coverings, and Determinations*; Washington, DC: Occupational Safety and Health Administration.

Occupational Safety and Health Administration. 2021d. *Analytical Spreadsheets in Support of the COVID-19 Vaccination and Testing ETS*; Washington, DC: Occupational Safety and Health Administration.

Occupational Safety and Health Administration. 2021e. *Health Impacts of the COVID-19 Vaccination and Testing Emergency Temporary Standard (ETS)*; Washington, DC: Occupational Safety and Health Administration.

Office of Management and Budget. 1992. *Circular A-94*; Washington, DC: Office of Management and Budget.

Office of Management and Budget. 2003. *Circular A-4*; Washington, DC: Office of Management and Budget.

Safer Federal Workforce Task Force COVID-19 Workplace Safety. 2021. *Guidance for Federal Contractors and Subcontractors*. Washington, DC: Safer Federal Workforce Task Force COVID-19 Workplace Safety.

Scobie, Heather M., Amelia G. Johnson, Amitabh B. Suthar, Rachel Severson, Nisha B. Alden, Sharon Balter, Daniel Bertolino, David Blythe, Shane Brady, Betsy Cadwell, and et al. 2021. *Monitoring Incidence of COVID-19 Cases, Hospitalizations, and Deaths, by Vaccination Status—13 U.S. Jurisdictions, April 4–July 17*. Washington, DC: US Department of Health and Human Services/Centers for Disease Control and Prevention, Morbidity and Mortality Weekly Report, vol. 70, pp. 1284–90.

Smith, James P. 1999. Healthy bodies and thick wallets: The dual relation between health and economic status. *Journal of Economic Perspectives* 13: 145–66. [CrossRef]

Uslu, Ata, David Lazer, Roy Perlis, Matthew Baum, Alexi Quintana, Katherine Ognyanova, James Druckman, Jennifer Lin, Mauricio Santillana, Jon Green, and et al. 2021. The COVID states project #63: The decision to not get vaccinated, from the perspective of the unvaccinated. USA: *OSF Preprints*, 16 September 2021. Available online: https://www.covidstates.org/reports/the-decision-to-not-get-vaccinated-from-the-perspective-of-the-unvaccinated (accessed on 18 December 2021).

Willis Towers Watson. 2021. *COVID-19 Vaccination and Reopening the Workplace Survey*. London: Willis Towers Watson.

Zeckhauser, Richard J., and W. Kip Viscusi. 2008. Discounting dilemmas: Editors' introduction. *Journal of Risk and Uncertainty* 37: 95–106. [CrossRef]