Trading Off Consumption and COVID-19 Deaths
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Abstract
This short note develops a framework for thinking about the following question: What is the maximum amount of consumption that a utilitarian welfare function would be willing to trade off to avoid the deaths associated with COVID-19? The answer depends crucially on the mortality rate associated with the coronavirus. If the mortality rate averages 0.8%, taken from the Imperial College London study, our answer is 37%, or more than 1/3 of one year's consumption. Much of the recent evidence coming in since that study has pointed to a lower mortality rate, however. If the mortality rate averages 0.3% across age groups, our answer is 18%.

1. Introduction
Economies throughout the world are faced with a terrible question: how should we trade off large declines in consumption and GDP versus deaths from COVID-19? As is well appreciated in economics, individuals make life-and-death decisions every day when deciding what job to take or whether to drive across town. We apply the basic framework used to evaluate these kinds of individual decisions to a utilitarian social welfare function to help us think about trading off consumption of survivors versus deaths from COVID-19.\footnote{1We are grateful to Romans Pancs for helpful comments.}

To see our basic result, suppose that, absent any actions, COVID-19 would lead to a death rate of $\delta$ among the population, and that people have an average remaining life expectancy of $LE$ years. Let $v$ denote the value of a year of life measured in years of

\footnote{2Classic references include Schelling (1968) and Usher (1973). Arthur (1981), Shepard and Zeckhauser (1984), and Murphy and Topel (2003) estimate the willingness to pay to reduce mortality risk and calculate the value of life. Nordhaus (2003) and Becker, Philipson and Soares (2005) conclude that increases in longevity have been roughly as important to welfare as increases in non-health consumption, both for the United States and for the world as a whole. Hall and Jones (2007) use a related framework to study the rise in health spending as a share of GDP. Jones and Klenow (2016) construct consumption-equivalent welfare measures across countries and over time for combining consumption, life expectancy, leisure, and inequality. Adler, Ferranna, Hammitt and Treich (2019) advocate a social welfare approach to these types of questions.}
per capita consumption. The basic result of our calculation is that, to avoid this risk, society would be willing to give up a fraction of one year’s consumption given by

$$\alpha \approx \delta \cdot v \cdot LE.$$ (1)

The right hand side of (1) is the value of the lost life-years relative to annual consumption. The intuition for this result is straightforward. The “value of a year of life” $v$ is the price of life in units of annual consumption: each year of life lost is equivalent to $v$ years of consumption. The fraction of consumption society is willing to forego is simply this price multiplied by the expected quantity (per capita) of life years lost due to COVID-19.

To illustrate quantitatively, suppose that $\delta = 0.81\%$ — consistent with the early estimates from the Imperial College London study; a year of life is worth $250,000$ (based on EPA value of life numbers) and per capita consumption (from the BEA) is $50,000$ so that $v = 5$; and $LE$ for victims is $14.5$ years (again based on the University College London study). According to the formula, this would make society willing to give up $59\%$ of consumption for a full year to avoid the elevated mortality associated with COVID-19.

We think this figure is likely to be too high for two reasons. First, since the Imperial College London study, estimates of the mortality rate from COVID-19 have been falling. A lower defensible estimate right now might be $0.3\%$ for $\delta$. Second, the approximation in (1) involves linearizing the utility function. Taking into account curvature will naturally make society less willing to cut consumption. With these adjustments, we calculate a willingness to curtail consumption by $18\%$ for one year to avoid COVID-19 deaths.

2. Model

Suppose lifetime utility for a person of age $a$ is

$$V_a = \sum_{t=0}^{\infty} \beta^t \bar{S}_{a,t} u(c_t) = u(c_0) + \beta S_{a+1} V_{a+1}$$ (2)

where $S_{a+1}$ is the probability a person age $a$ survives to $a + 1$ and $\bar{S}_{a,t} = S_{a+1} \cdot S_{a+2} \cdot \ldots \cdot S_{a+t}$ is the probability a person age $a$ survives for the next $t$ years.
Suppose there is a population that initially contains $N_a$ people of age $a$ and total population $N = \sum_a N_a$. COVID-19 means that the survival rate for each group falls from $S_{a+1}$ to $S_{a+1} - \delta_{a+1}$ for one period. The question is: what fraction $\alpha$ of consumption in the initial period is everyone willing to give up to avoid this risk?

Let $\lambda \equiv 1 - \alpha$ and to simplify, let’s assume that consumption is the same for all groups and all ages apart from this single deviation. Motivated by equation (2) above,

$$V_a(\lambda, \delta) = u(\lambda c) + \beta (S_{a+1} - \delta_{a+1}) V_{a+1}(1, 0)$$

where $V_a(\lambda, \delta)$ is the lifetime utility of a person age $a$ whose consumption is reduced by factor $\lambda$ and whose mortality rate increases for a period by $\delta_{a+1}$.

Let $W(\lambda, \delta)$ denote utilitarian social welfare, where $\delta$ denotes the vector of death rates from COVID-19:

$$W(\lambda, \delta) = \sum_a N_a V_a(\lambda, \delta)$$

$$= Nu(\lambda c) + \beta \sum_a (S_{a+1} - \delta_{a+1}) N_a V_{a+1}(1, 0).$$

The equivalent variation satisfies $W(\lambda, 0) = W(1, \delta)$:

$$Nu(\lambda c) + \beta \sum_a S_{a+1} N_a V_{a+1}(1, 0) = Nu(c) + \beta \sum_a (S_{a+1} - \delta_{a+1}) N_a V_{a+1}(1, 0)$$

$$\Rightarrow u(c) - u(\lambda c) = \beta \sum_a \delta_{a+1} \omega_a V_{a+1}(1, 0) \quad (3)$$

where $\omega_a \equiv N_a/N$ is the initial population share of group $a$.

Now, take a Taylor expansion around $\lambda = 1$ to see that

$$u(\lambda c) \approx u(c) + u'(c) c (\lambda - 1).$$

Plugging this in above gives

$$\alpha \equiv 1 - \lambda = \beta \sum_a \delta_{a+1} \omega_a \bar{V}_{a+1} \quad (4)$$

where $\bar{V}_{a+1} \equiv V_{a+1}(1, 0)/[u'(c)c]$ is the value of life at age $a + 1$, expressed in consump-
tion units (hence the division by $u'(c)$) as a ratio to the flow of consumption, $c$. Note that $\alpha \equiv 1 - \lambda$ (so that $\alpha$ is the fraction of consumption you give up, a number like 18%).

This expression has a nice, basic intuition: the fraction of consumption that society is willing to give up to avoid COVID is the sum of the expected number of COVID deaths $\delta_n \omega_a$ at each age, weighted by the value of life at those ages as a share of consumption.

One more simplification is useful. When $\beta = 1$ so there is no time discounting apart from mortality, equation (2) implies

$$V_a(1, 0) = u(c) \sum_{i=0}^{\infty} \bar{S}_{a,i} = u(c) \cdot LE_a$$

where the last expression comes from the well-known result in demography that the sum of survival probabilities is the (cross-sectional) measure of life expectancy. That is, lifetime expected utility is the product of flow utility and life expectancy. Under this assumption,

$$\bar{V}_{a+1} = \frac{u(c)}{u'(c)c} \cdot LE_{a+1}$$

Letting $v = u(c)/[u'(c)c]$ denote the value of a year of life relative to consumption (e.g. a number like 3) and substituting into equation (4), we have, when $\beta = 1$,

$$\alpha = \sum_a \omega_a v \delta_{a+1} LE_{a+1} \quad (5)$$

There are two simple examples of this formula that are helpful for intuition. First, suppose there is only a single representative agent in the economy. In this case, the equivalent variation describes how the consumer herself trades off her own mortality and her own consumption and gives the simple formula

$$\alpha = \delta \cdot v \cdot LE \quad (6)$$

Alternatively, suppose there are two groups: the old, who face the COVID risk, and the young, who do not face the risk. Moreover, suppose the old are the fraction $1/N$ of the population. In this case, a utilitarian planner would be willing to reduce everyone's
consumption to avoid the COVID risk by

$$\alpha = \frac{\delta \cdot v \cdot LE_0}{N}$$  \hspace{2cm} (7)

In all three cases, the basic intuition is the same. The “exchange rate” between consumption and a year of life is $$v \equiv u'(c)/[u'(c)c]$$. This is the “price” of life in the equation, and it is multiplied by the quantity of life years lost in order to get the equivalent variation $$\alpha$$.

3. Calibration

3.1. A Representative Agent Calibration

To get started, we first consider a calibration in which there is only a single representative agent in the economy, rather than two or more groups. In terms of the model just described, we set $$N = 1$$ so that everyone is effectively in the “old” group that faces the COVID-19 mortality risk and everyone can choose to give up some fraction of one-year’s consumption to avoid that risk.

According to the Imperial College London study by Ferguson et al. (2020), the death rate for all ages from COVID-19 would be 0.81% without mitigation efforts. This is the product of their age-specific mortality rates and the assumption that 75% of all age groups contract the virus in the absence of mitigation. Early estimates of the death rate may be too high, however: as random testing of the type advocated by Stock (2020) and many others comes in, it seems that the percent of the population infected is much higher than the selective and limited testing has revealed. A lower range estimate is that the death rate may possibly be as low as 0.3% (Fernández-Villaverde and Jones, 2020).

Estimates of the value of a year of life used in the literature typically range from $100,000 to $400,000. The U.S. Environmental Protection Agency (2020) recommends $7.4 million for the full value of life (not per year) in 2006 dollars, which is equivalent to $9.5 million today. Given life expectancy at age forty of 40 years, this implies a value

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of a year of life equal to $9.5m/40$=$237,000. With consumption per person in the U.S. of $45,000, this number implies that a year of life is worth just over 5 times annual consumption. We therefore take $v = 5$ as our benchmark value.

Based on life expectancy tables, the life expectancy of victims would average 14.5 years.\(^4\) Taking the product of these parameters in equation (6) with the baseline death rate of 0.81% yields $\alpha = 0.587$. With the lower death rate of 0.3%, we get $\alpha = 0.218$. Thus a representative agent would be willing to sacrifice more than 1/2 of a year’s consumption with the high death rate and nearly 22% of consumption with the low death rate to avoid deaths from COVID-19, according to the calculation with the Taylor approximation. As we will see, assuming the marginal utility of consumption is constant in the Taylor approximation leads these numbers to overstate the exact calculation.

### 3.2. Calibrating the Full Model

Here we use the formula (5) with all age groups. More specifically, we use population shares by age from the U.S. Census source mentioned above, age-specific mortality rates due to COVID-19 from the Imperial College London study, and remaining years of life expectancy by age from Social Security Administration data referenced above. Figure 1 displays the mortality rates, which of course rise sharply with age. Interestingly, they rise at a fairly stable 11% rate with age. Figure 2 plots expected years of life remaining, which naturally fall with age. With these two ingredients, we incorporate that those at greatest risk of dying from COVID-19 are those with the fewest years of life remaining. This means fewer life years are at stake than if the virus struck down all ages with the same probability or was particularly lethal for younger people.

Table 1 provides our estimates using all ages. The first panel is based on the simple formulas that linearize the utility function, equations (4) and (5) above. With $v = 5$ and $\delta = 0.81\%$, we calculate $\alpha = 0.587$, or 59%. When using a lower and arguably more realistic $\delta = 0.3\%$, we obtain 22%. These numbers are the same as we calculated using the representative agent formula due to the linearity of (4). The second panel in the Table shows exact results using CRRA utility with $\gamma = 2$ rather than the linear approximation. When we incorporate diminishing marginal utility, society would be willing

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Figure 1: COVID Mortality by Age Group

Mortality rate rises by ~11.2 percent per year of age

Note: Age-specific mortality rates associated with COVID-19 are from the Imperial College London study of Ferguson et al. (2020).

Figure 2: Life Expectancy by Age Group

Note: Life expectancy by age group is based on survival rates from the Social Security Administration: https://www.ssa.gov/oact/STATS/table4c6_2015.html
Table 1: Willing to Give Up What Percent of Consumption?

<table>
<thead>
<tr>
<th>Average mortality rate</th>
<th>— Value of Life, $v$ —</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta$</td>
<td>4 5 6</td>
</tr>
</tbody>
</table>

**Using Taylor series linearization:**

- 0.81% 47.0 58.7 70.5
- 0.30% 17.5 21.8 26.2

**Using CRRA utility with $\gamma = 2$:**

- 0.81% 32.0 **37.0** 41.3
- 0.30% 14.9 **17.9** 20.7

Note: The first panel reports the results using equation (5) with age-specific death rates using the Taylor approximation for $u(c)$. The second panel is exact but requires us to specify a utility function. We assume $u(c) = \bar{u} + c^{1-\gamma}/(1-\gamma)$. The formula, going back to equation (3), then becomes

$$\lambda_{full} = \left[1 + (\gamma - 1)\alpha\right]^{\frac{1}{1-\gamma}}$$

where $\alpha$ is the expression given in equation (5), and the full result is given by $\alpha_{full} = 1 - \lambda_{full}$.

to sacrifice notably less, namely 37% when $\delta = 0.81\%$ and 18% when $\delta = 0.30\%$. The Table provides estimates for higher and lower values of $v$, as well, as there is of course uncertainty about the value of a year of life (measured in units of years of consumption per person). As one would expect, the higher the value of life the bigger the sacrifice society should be willing to make to save lives.

Figure 3 breaks down the contribution to $\alpha$ from each age group. It is low at younger ages (below 50) because of the low mortality risk of these age groups. The contribution also falls past age 74 because of low remaining life expectancy. The contributions start to build noticeably for those ages 50-59, peaking for those ages 60-74. In total, 1/3 of our $\alpha$ comes from those under age 65, and the other 2/3 from those 65 and over.
Figure 3: Contribution of Different Age Groups to $\alpha$

PERCENT CONTRIBUTION TO ALPHA (SUMS TO 100)

Note: Each bar is $\omega a v \delta a+1 LE_{a+1}$, divided by the total $\alpha$ and multiplied by 100. See equation (5).

3.3. Factors to add

The framework could be extended to capture:

- GDP vs. consumption
- Capital bequeathed to survivors
- Lost leisure during social distancing
- Leisure varying by age
- Competing hazards
- The poor burying the brunt of the consumption loss
References


