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COVID-19: mortality, future years lost, and demographic structure

Italy and Kenya compared

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Abstract: COVID-19 causes extremely high mortality among the old. This motivates a comparison of the losses of future lifetime years and future lifetime years of work ensuing from a hypothetical 25,000 excess deaths in Italy, whose affluent population is one of the world's oldest, with those in Kenya, whose population is one of the most youthful and poor. If Italy's excess mortality profile were scaled up three-fold and then came to pass in Kenya, the aggregate loss of future lifetime working years would be slightly higher than Italy's, whereas the aggregate number of deaths and the loss of future lifetime years would be only about one third of Italy's—with all aggregate losses scaleable. Italy's profile implies a loss of 9.9 years of expected future life for each death and 1.8 years of expected working life, both scale-invariant within wide limits. For Kenya, the corresponding estimates are 14.0 and 8.2 years. Vaccines and debt relief apart, these findings suggest that donors might do better to concentrate on the old enemies malaria, HIV/AIDS, and diseases of childhood.

Key words: age structure, COVID-19, future years lost, Italy, Kenya

JEL classification: J1, J10, J11, O57

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1 Introduction

The public debate about the damage wrought by the SARS-CoV-2 pandemic has revolved almost wholly around the number of deaths and the loss of GDP. The purpose of this paper is to examine its effects on two other, arguably equally important, demographic-economic measures, namely, the losses of future lifetime years and future lifetime working years, respectively, both in aggregate and for each death.[1] These measures depend not only on the total number of deaths, but also on how they are distributed over the population, the population's age structure, and the underlying levels of age-specific mortality. Infection with the SARS-CoV-2 virus, which results in the illness called COVID-19, causes extremely high mortality among the old, unlike HIV/AIDS and the so-called 'Spanish' influenza, whose victims are, and were, predominantly young adults and those in their prime years.

To illustrate the central role played by age structure, this paper provides preliminary, inevitably hypothetical, estimates of these measures for Italy and Kenya. Italy is an affluent country, with one of the world's oldest populations: 29 per cent are aged 60 or over, only 18 per cent are aged under 20 (see Table 1). Kenya is poor, with one of the youngest populations: 50 per cent are aged under 20 and just four per cent aged 60 or over. Age-specific mortality in Kenya is also far higher than in Italy throughout all age groups; among those under 20, a whole order of magnitude higher. Yet Kenya's population is so young that its crude death rate is little more than one half of Italy's (see Table 1). Their respective populations are 61 and 53 million.

The estimates rest on various simplifying assumptions. The key one is that the epidemic delivers an exogenous shock in the form of an upward shift in the pre-existing profile of age-specific mortality for just one year, whereafter the *status quo ante* profile is restored. The size of that shock, measured by the total number of deaths, will not be known for quite some time—for Kenya, perhaps never with much precision; but the estimates of future life years are, within limits, scaleable, leaving the associated per-death measures unchanged. They relate to a total of 25,000 excess deaths in Italy.

Modelling the shock as an endogenous event, whose consequences for mortality possibly last beyond one year, would be an undertaking of a quite different order. One ambitious study that combines a controlled SIR model with the costs arising from various interventions in OECD countries is Gros et al. (2020). The authors come down heavily in favour of strict and extended lockdowns. Walker et al. (2020) provide global estimates of mortality under various forms of intervention.

Three closing remarks are in order: first, the costs of morbidity arising from COVID-19, human and economic, are not considered here. They are evidently great. Secondly, the disruption in the labour market, which may leave many unemployed, is also neglected. Thirdly, no attempt is made to estimate the trade-off between demographic losses and output.

Section 2 lays out the measures of loss in a formal way, followed by a discussion to elaborate various points. Estimates of losses for Italy and Kenya, in three variations, are presented and discussed in Section 3. A closing discussion follows in Section 4.

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[1] The former measure, also called the loss of remaining life, has a central place in Goldstein and Lee's (2020) analysis of COVID-19 mortality in the US. A study that employs the broadly related measure of the statistical value of life years (Holden et al. 2020) provided an important part of the basis for the Norwegian government's decision to open kindergartens from April 20.

2 Measures of loss

Consider a population whose age pyramid is $\mathbf{n} = (n_0, \ldots, n_\omega)$, where n_k is the number of individuals aged k and ω is the maximal lifespan in years. The probability that an individual aged x dies before reaching $x+1$ is denoted by q_x, that of surviving to $x+1$ by $p_x = 1 - q_x$, where $p_\omega = 0$. The mortality profile is defined by the vector $\mathbf{q} = (q_0, q_1, \ldots, q_\omega)$. Let the instantaneous survival rate change linearly within each year and continuously across years. In a large population, the total number of years of life remaining to the cohort aged x is

$$n_x e_x = n_x \left(1/2 + p_x + p_x p_{x+1} + \ldots \prod_{k=x}^{k=\omega} p_k \right), \tag{1}$$

where e_x is the expected future lifetime of individuals who have reached the age of x.[2] The total number of years of future life for the whole population in the *status quo ante* setting is $\mathbf{n} \cdot \mathbf{e}$.

Suppose there is a temporary mortality shock at time t, which yields the mortality profile $\mathbf{q}_t = (q_0 + d_0, q_1 + d_1, \ldots, q_\omega + d_\omega)$, $d_x \geq 0 \; \forall x$, in that year only, with $\mathbf{q}$ restored thereafter. Then the shock generates $D = \mathbf{d} \cdot \mathbf{n}$ excess deaths (by assumption, in year t only) and a loss of future lifetime years in the whole population in the amount

$$L_d = \sum_{x=0}^{x=\omega} d_x n_x e_x. \tag{2}$$

Associated with this aggregate measure is the loss per death, denoted by $\lambda_d = L_d/D$, which is a weighted average of the e_x, the weights being each cohort's share in the number of excess deaths, $d_x n_x/D$.

Turning to the economically active population, let entry into the labour force begin at age ℓ with retirement at r. Then, assuming unchanged fertility, the total number of working years lost will be

$$L_w = \sum_{x=\ell}^{x=r-1} d_x n_x \left(1/2 + p_x + p_x p_{x+1} + \ldots \prod_{k=x}^{k=r-1} p_k \right). \tag{3}$$

Additional to this sum is the loss of future working years arising from the deaths of those under the age of ℓ at time t, some of whom would have died before reaching ℓ after the shock has passed. The entire future loss is

$$L_a = L_w + \sum_{x=0}^{x=\ell-1} d_x n_x \left(\prod_{j=x}^{j=\ell-1} p_j \right) \left(1/2 + p_\ell + p_\ell p_{\ell+1} + \ldots \prod_{k=\ell}^{k=r-1} p_k \right). \tag{4}$$

Associated with this aggregate measure is the loss per death, denoted by $\lambda_a = L_a/D$.

Evaluating changes in welfare when time is involved necessitates a choice of discount rate. There is no discounting in the above measures of future losses. Formally, one could regard L_a and λ_a as special cases of L_d and λ_d, respectively, in which the former follow from the latter by applying an infinite discount rate to all future life years accruing in retirement. Such a drastic position is neither defensible nor advocated, of course: the measures involve separate considerations and are to be treated as such.

Suppose there is agreement about the rate, which may vary with x, at which life years should be discounted. Setting the date of the shock at year $t = 0$, let the discount factor for year t be denoted by

[2] Each and every member of the cohort x survives, on average, until the middle of the year in question, thus contributing 0.5 of a year to expected future life at its start. The fraction p_x survives into the following year. Each of them contributes, on average, half a year in both years, and thus p_x years to e_x. The sequence continues until the close of the year $\omega - x$ years after the start, at which point in time the last survivors of the cohort x will have died.

$\beta_t \equiv \left(\prod_{\tau=1}^{t}(1+\delta_\tau)\right)^{-1}$, where δ_τ is the discount rate for year τ. Then, discounting the components of $n_x e_x$, (1) becomes

$$n_x e_x(\boldsymbol{\delta}) = n_x \left(1/2 + \beta_1 p_x + \beta_2 p_x p_{x+1} + \ldots \beta_\omega \prod_{k=x}^{k=\omega} p_k \right). \tag{5}$$

The discounted loss of future lifetime years in the whole population becomes

$$L_d(\boldsymbol{\delta}) = \sum_{x=0}^{x=\omega} d_x n_x e_x(\boldsymbol{\delta}). \tag{6}$$

The measures L_w and L_a are modified in the same way, thus completing the formal accounting for the purposes of this paper.

It should be remarked that the foregoing measures of loss are themselves special cases of two others that are well known in the literature. The first is the disability-adjusted life year, or DALY, which is a measure of the burden of disease (Murray and Lopez 1996). This can be thought of as one lost year of healthy life or a certain period lived with disability, where the length of the period is adjusted for the severity of the disability, and the weights attached to various disabilities are based on the valuations tendered by households in surveys designed for this purpose (WHO 2003).[3] For whole populations, one can appeal to the law of large numbers, and so use age-specific death and disability rates to yield the stream of DALYs for each age group from the present onwards. These streams may be discounted and weighted by age.

A closely related alternative to the DALY involves weighting the losses of life years by the individual's productivity, as measured by his or her wage rate or earnings from labour, at each point over the span of years in question. This yields what can be called the expected lifetime earnings measure, which Jamison et al. (2001) employ to assess the economic costs of the AIDS epidemic in sub-Saharan Africa.[4]

2.1 Discussion

The following points arise:

1. The current, almost exclusive, concern in public discourse is to save lives, that is, to reduce D. Ethically, however, one can make the case that the losses L_d and λ_d also demand at least equally serious consideration. Both involve the population's age structure and the profile of the shock $\mathbf{d}$. One judgement is that a life year saved is equally valuable, whatever be the age of the beneficiary, so that the aggregate L_d is the appropriate measure of loss. Although death, especially a premature one, is always an individual tragedy, one serious argument against this position is that the old have already had a full life, whereas those in young adulthood and their prime years normally still have much before them.[5] Granted as much, the measure λ_d comes strongly into the reckoning, quite aside from the fact that deaths among the old have no effect on the supply of working life years.

2. Independently of any considerations of age-specific weighting or productivity, the vexing question of whether it is justified to discount future outcomes must be addressed. Ramsey (1928) argued strongly against discounting the welfare of future generations simply because they arrive on the scene later, that is to say, it is ethically indefensible to evaluate outcomes using a positive rate of

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[3] The procedure involves the contingent valuation method, which is far from uncontroversial.

[4] For Botswana, they calculate the expected lifetime income of a 22-year old male with 12 years of education as $\sum_\tau \left[{}_\tau p_{22} w(12,t)(1+r)^{-\tau} \right]$, where ${}_\tau p_{22}$ is the probability of surviving τ years from the age of 22, $w(12,t)$ is the age-earnings function with 12 years of education, and r is a constant discount rate. While the losses of income due to morbidity do not appear in this formula, they can be readily introduced—although whether the corresponding data are available is another matter.

[5] Maestad and Norheim (2009), for example, take this position in their study of age weights. In effect, they argue that $\delta_\tau > 0$.

pure impatience, in Ramsey's setting, for consumption. This does not, however, imply that the social discount rate is zero. According to the standard definition, the social discount rate is the rate at which the value of the numéraire is falling through time. This definition appears to pose no fundamental difficulties, in principle, if the numéraire is aggregate or per capita consumption, or, as common in cost-benefit analysis, public income. It is not clear what apparatus can be used to apply such a definition to lifetime years or DALYs so as to extract an associated discount rate. This conundrum will intrude again in Section 3.

Although losses of future lifetime years of work can be fitted into the framework of standard optimal growth theory, there is more than one way of doing so. In the simplest variant, there is an immortal representative agent, who may well be impatient, with a constant rate thereof. Reinterpreting the latter as his or her instantaneous mortality rate is neither conceptually appealing nor compatible with the actual age-specific profile of human populations.

Putting this difficulty aside, suppose the maximand is the discounted sum of all individuals' streams of utility and that all individuals are identical ex ante. Each death reduces the said sum by an amount that depends on the point in the life cycle at which the individual in question dies and the discount rate, where the latter depends on the rate of growth of consumption and the elasticity of the marginal utility of consumption, both of which may vary over time.[6] An alternative formulation of utilitarian doctrine is that the number of individuals has no place in the evaluation of well-being. At each point in time, the available aggregate is divided equally among the (identical) living, and the maximand is defined as the discounted sum of the stream of the utilities yielded by the resulting stream of averages. If, at every point in time, each individual claims exactly what he or she contributes, his or her death has no effect on the sum in question. The 'value' of the loss of future lifetime years of work is then zero. In practice, those in the workforce consume less than their incomes: they pay taxes, rear their children, and may save for retirement in a form that permits bequests. Yet the two variants of utilitarianism yield very different values of the welfare losses arising from given losses of working years, even when there is agreement about the discount rate to be used.

3. The economic loss L_a ensuing from any given profile $\mathbf{d}$ may well affect the mortality profile that rules after t. Although it is ruled out by assumption in the above scheme, an adverse effect is probable; for the reduction in future working years will result in both lower tax revenues and family incomes, out of which future expenditures on health must be financed.

4. In actual fact, the shock $\mathbf{d}$ is not exogenous, for it depends, *inter alia*, on what policy measures, if any, are taken to combat the epidemic. Some measures aimed at reducing D augment the loss L_a. Lockdowns, which inevitably reduce economic activity, are the prime example. Not only are most categories of workers prevented from doing their jobs during this phase, but there is some evidence that unemployment and the resulting losses of income result in higher morbidity and mortality beyond the short run. One mitigating factor in all this is that lockdowns are clearly reducing air pollution, especially of nitrogen dioxide. Over the medium to long run, one would expect consequently lower levels of morbidity and mortality, especially among the inhabitants of large cities in poor and middle-income countries. On the face it, lockdowns would seem to influence D largely by reducing mortality among the old: the profile $\mathbf{d}$ is not simply scaled down, but rather its structure is changed. This point will be taken up in Section 3.

5. Measures or no measures, the SARS-CoV-2 virus is causing vastly heavier mortality among the old than among the young. For given profile $\mathbf{d}$ of this kind, a society with a youthful population

[6] For cogent arguments against the ubiquitous assumption that the said elasticity is constant, see Bliss (2007: 52–4 and Appendix 4.1).

will suffer fewer deaths, *cet. par.* As remarked above, it is otherwise—and distressingly grim—with HIV/AIDS, which is chiefly a disease of young adults and those in their prime years.

6. Given any such a profile **d**, a youthful population will suffer an absolutely larger number of deaths among the young and those of working age than an older population of the same size. The youthful population will therefore suffer larger losses per death, λ_w and λ_a, again *cet. par.*; but whether this effect will so offset the loading of **d** as to result in lower aggregate losses L_d and L_a seems rather implausible. This possibility will also be taken up in Section 3.

7. Poorer countries have higher age-specific mortality rates **q**. Superimposing the same **d** on different profiles **q** may have ambiguous comparative effects not only on L_w and L_a, but also on λ_w and λ_a. If, instead, both the total number of deaths D and the mortality profile **d** are held constant, then L_w and L_a will be lower for youthful populations.

8. The demographic accounting set out above rests on the implicit assumption that the members of each age group are equally likely to succumb to COVID-19. In fact, those with pre-existing medical conditions, who are quite often infirm and have weakened immune systems, suffer much higher mortality, conditional on getting infected. The measures L_d and, to a lesser extent, L_w and L_a, will therefore overstate both losses. The measure D, being confined to a single year, will involve a much smaller overstatement.

   Consider, for example, the extreme case in which all those who die as a consequence of the shock **d** in year t would have died in the following year in its absence. Then the said mortality shock will be followed by the excess survival shock $-\mathbf{d}$ in year $t+1$, thus resulting in the mortality profile $\mathbf{q}_{t+1} = \mathbf{q} - \mathbf{d}$ in that year, to be followed by **q** thereafter. In this special case, there will be no excess mortality over the years t and $t+1$ taken together, and the total loss of future life years will be D.

3 Italy and Kenya: a hypothetical comparison

At this time of writing, the official count of COVID-19 related deaths in Italy has just exceeded 25,000, but there are clear signs that the epidemic there is slowing considerably. For the purposes of this comparison, let excess mortality be 25,000 deaths, that is, just under 0.39 deaths per 1,000 persons. The full distribution of these posited deaths by age is reported in column 1 of Table 1, whereby it is assumed that the proportions are correct, even if the scale is not.[7] Some 86 per cent of the victims are aged 70 and over. Applying these numbers to the population age pyramid, reported as the (normalized) vector **n** in column 2, we obtain the associated excess mortality profile **d** in column 4. This COVID-19 related rate is 3.67 per cent of the population crude mortality rate of 10.566 per 1,000 for the year 2019 (Macrotrends 2020), which is taken to be the underlying rate for 2020. Recall that all of the following aggregate estimates are, within quite wide limits, scaleable; those per death are invariant.

[7] The age-specific proportions given in Statista (2020) add up to less than 100. They yield the resulting total of 23,550, which is the operative total for the purposes of the present analysis.

Table 1: Measures of loss: Italy and Kenya compared

	COVID-19[a] (1)	$\mathbf{n}^b$ (2)	$\mathbf{q}^c$ (3)	$10^3 \cdot \mathbf{d}$ (4)	L_d^d (5)	L_a^d (6)	λ_d (7)	λ_a (8)
Italy								
Age group								
0–9	25	8.4	0.0038	0.005	1995	1189	79.8	47.5
10–19	0	9.5	0.0021	0.000	0	0	70.2	45.1
20–29	25	10.1	0.0048	0.004	1507	1196	60.3	47.8
30–39	100	11.8	0.0072	0.014	5037	3790	50.4	37.9
40–49	225	15.3	0.0155	0.024	9110	6305	40.5	20.8
50–59	600	15.7	0.0402	0.063	18447	10966	30.7	18.3
60–69	2250	12.3	0.1014	0.302	47898	19844	21.3	8.8
70–79	5850	9.8	0.2538	0.986	72941	–	12.5	0
80+	14475	7.3	0.7172	3.275	75107	–	5.2	0
Total	23550	100	0.0106	0.388	232042	43289	9.9	1.8
Kenya								
Age group								
0–9	70	26.7	0.0619	0.005	4468	1976	63.9	36.6
10–19	0	23.9	0.0180	0	0	0	54.8	34.2
20–29	37	17.8	0.0343	0.004	1693	1478	45.5	39.7
30–39	100	13.8	0.0494	0.014	3638	3062	36.4	30.6
40–49	112	8.9	0.0739	0.024	3103	2456	27.6	21.9
50–59	166	5.0	0.1150	0.063	3216	2262	19.4	13.7
60–69	429	2.7	0.2198	0.302	5147	2677	12.0	6.2
70–79	518	1.0	0.4609	0.986	2987	–	5.8	0
80+	344	0.2	0.8512	3.275	531	–	1.5	0
Total	1776	100	0.0058	0.034	24782	14493	14.0	8.2

Sources: [a] for Italy, Statista (2020); for Kenya, apply **d** to **n**. [b] PopulationPyramid.net (2020). [c] Calculated from WHO (2018). The value of q for the group 80+ is the quinquennial rate for the group 80–84 followed by the annual rate for that aged 85 and over applied to five additional years, thus making a decadal rate for consistency. Details available upon request. [d] Calculated from (2)–(4) using the statistic Tx in WHO (2018). Details available upon request.

Using **d**, **n**, and the statistic Tx[8] in WHO (2018) in equations (2) and (4), we obtain the associated losses L_d and L_a: these are 232,042 and 43,289 person years, respectively, whose age-specific distributions are reported in columns 5 and 6. Expressed in relation to D, these imply, on average, $\lambda_d = 9.9$ years of future life lost for each death, and just $\lambda_a = 1.8$ years of working life so lost (see columns 7 and 8). This striking difference stems from Italians' substantial longevity conditional on reaching age 70 and the nature of the mortality shock in the form of the profile **d**. Not only are the overwhelming majority of the victims those in retirement, but they are also meeting what must be considered an untimely death. Those in their seventies lose, on average, 12.5 years, and those aged 80 and over a still notable 5.2 years. It should be recalled, however, that those already in poor health are much more likely to succumb to COVID-19 if they suffer the misfortune to get infected, the probability of which has been especially high in old-age homes.

The epidemic in Kenya is in its early stages. Testing is very limited and likely to remain so. As a thought experiment, therefore, suppose the epidemic develops in such a way that it inflicts the same mortality shock **d** on Kenya's population as that on Italy's. With such a young population, there will be far fewer deaths in Kenya—just 1776, in fact, distributed as given in column 1 in the lower panel of Table 1. Scaling up to allow for Italy's somewhat larger population yields an adjusted total of 2037, or not quite 9 per cent of Italy's hypothesized 23,550. The adjusted values of L_d and L_a are also much smaller, at 28,424 and 16,623 person years, respectively; that is to say, 12.2 and 38.4 per cent of the levels of their

[8] Since the age grouping in the available data is fairly coarse, this statistic yields some desirable smoothing in relation to e_x.

Italian counterparts. Expressing these aggregate losses in relation to D, λ_d and λ_a are, respectively, 14.0 years of future life lost for each death, and 8.2 years of working life so lost, both appreciably higher than in Italy, in keeping with Kenya's much younger population. By all three aggregate measures, then, the hypothesized common shock **d** in Table 1 wreaks far heavier damage in Italy than in Kenya. In contrast, the associated losses per death are decidedly higher in Kenya.

3.1 Two variations

This conclusion concerning aggregate losses is open to the objection that if the epidemic's course in Kenya were to follow that in Italy, it would almost surely not generate the same **d** as in Italy; for Kenya's population is less well nourished, beset by a more hostile disease environment, and served by a system of health care that is wanting in so many ways. There is also the general consideration that underlying mortality is correspondingly a good deal higher in Kenya, so that Italy's **d** implies a smaller *proportional* shock in Kenya. Suppose, therefore, that **d** were scaled up by a factor of three. Then the above aggregate measures would also increase threefold. Whereas the aggregate loss of working years would now be slightly higher than that in Italy, the levels of D and L_d would still be about one-third of their Italian levels.

Another consideration is the relationship of the shock **d** to the *status quo ante* mortality profile **q**. The vector of age group-specific ratios in Table 1, d_x/q_x, is $\boldsymbol{\rho} = (1.307, 0, 0.845, 1.955, 1.568, 1.570, 2.980, 3.884, 4.555)/10^3$. Even allowing for the sampling fluctuation arising from the small number of deaths among Italy's young, it is hard to maintain that **d** is a scalar multiple of **q**. According to the data in Statista (2020), therefore, COVID-19 is carrying off disproportionately large numbers of Italy's old, relative to the underlying profile **q**.

This pattern may not hold more widely. Spiegelhalter (2020) examines mortality in England and Wales in the week March 21–27, and concludes, in contrast to the $\boldsymbol{\rho}$ above, that the increased risk for that population was indeed very close to an equiproportional one. Goldstein and Lee (2020) arrive at a similar finding for Italy, France, Spain, South Korea, and, though less closely, the US. In keeping with this finding, consider the alternative shock $\mathbf{d} = 0.338 \cdot \mathbf{q}/10^3$, which is reported in column 4 of Table 2. It yields the same total number of deaths, but now distributed by age group as given in the upper panel of column 1. Since fewer deaths among the old are now matched by an equal number more among those aged under 60, all other measures of loss will rise: L_d is 26.4 per cent larger, L_a doubles. The normalized measures λ_d and λ_a necessarily increase in the same proportions, respectively, since **d** is a now scalar multiple of **q** .

Turning to Kenya, consider the combination of the three-fold scaling of **d** in the first variation with an equiproportional shock that yields the same number of deaths, namely, $3 \times 1776 = 5328$, but now distributed as given in the lower panel of column 1 of Table 2. In contrast to the two structures in Table 1, this pair in Table 2 are inverted opposites, with deaths among those under age ten accounting for 28 per cent of Kenya's total. Yet on the evidence, children infected by the virus are very unlikely to succumb to COVID-19. This particular feature of Kenya's projected death toll is, therefore, quite implausible. It stems from the fact that those under age ten comprise somewhat over one quarter of the whole population, and although the mortality rate among Kenya's infants and young children is high by international standards (${}_{10}q_0 = 0.0619$), it is not much higher than that among their compatriots in their thirties (${}_{10}q_{30} = 0.0494$), who number only half as many. It follows that an equiproportional mortality shock must bear very heavily, in absolute terms, on Kenyans under age 10, and the ensuing increase in their mortality rate is almost the same as that in aggregate (see column 4). Neither the resulting measures of aggregate losses reported in the lower panel of Table 2 nor their normalized counterparts $\lambda_d = 37.9$ years and $\lambda_a = 12.5$ years are to be taken seriously, although the age-specific measures for those older than 30 warrant attention. In this connection, it should be remarked that Spiegelhalter (2020) takes care to restrict his finding to those aged 15 and older. Goldstein and Lee (2020) shy away from any assertions about those under 40, on the ground that the current samples are too small. For the purposes of this paper, this restriction may not matter much for an old population like Italy's, but it certainly does so for Kenya's youthful one.

Table 2: Measures of loss: equiproportional increases in mortality

	COVID-19[a] (1)	$\mathbf{n}^b$ (2)	$\mathbf{q}^c$ (3)	$10^3 \cdot \mathbf{d}$ (4)	L_d^c (5)	L_a^d (6)	λ_d (7)	λ_a (8)
Italy								
Age group								
0–9	74	8.4	0.0038	0.0146	5922	3528	79.8	47.5
10–19	47	9.5	0.0021	0.0082	3308	2123	70.2	45.1
20–29	115	10.1	0.0048	0.0188	6924	5492	60.3	47.8
30–39	198	11.8	0.0072	0.0278	9997	7522	50.4	37.9
40–49	557	15.3	0.0155	0.0601	22545	15602	40.5	20.8
50–59	1483	15.7	0.0402	0.1580	45588	27100	30.7	18.3
60–69	2929	12.3	0.1014	0.3933	62358	25834	21.3	8.8
70–79	5843	9.8	0.2538	0.9847	72858	–	12.5	0
80+	13300	7.3	0.7172	2.7826	63818	–	5.2	0
Total	23546	100	0.0106	0.388	293319	87202	12.5	3.7
Kenya								
Age group								
0–9	1508	26.7	0.0619	0.1078	96346	55163	63.9	36.6
10–19	392	23.9	0.0180	0.0313	21479	13408	54.8	34.2
20–29	556	17.8	0.0343	0.0598	25300	22095	45.5	39.7
30–39	624	13.8	0.0494	0.0860	22705	19109	36.4	30.6
40–49	602	8.9	0.0739	0.1286	16622	13156	27.6	21.9
50–59	526	5.0	0.1150	0.2003	10226	7912	19.4	13.7
60–69	543	2.7	0.2198	0.3826	6521	3392	12.0	6.2
70–79	422	1.0	0.4609	0.8024	2431	–	5.8	0
80+	156	0.2	0.8512	1.4819	240	–	1.5	0
Total	5329	100	0.0058	0.1017	201868	133515	37.9	12.2

Sources: [a] for Italy, Statista (2020). The profile $\mathbf{q}$ is scaled by the factor 0.388 and then applied to $\mathbf{n}$, thus yielding, after rounding, 23,550 deaths in total. For Kenya, apply $\mathbf{d}$ to $\mathbf{n}$. [b] PopulationPyramid.net (2020). [c] Calculated from WHO (2018). The value of q for the group 80+ is the quinquennial rate for the group 80–84 followed by the annual rate for that aged 85 and over applied to five additional years, thus making a decadal rate for consistency. Details available upon request. [d] Calculated from (2)–(4) using the statistic Tx in WHO (2018). Details available upon request.

3.2 Discounting

One way of skirting the whole problem of discounting is to demonstrate that using a positive rate does not overturn the results obtained without discounting—provided the choice of rate is defensible. In the absence of any theory that could guide that choice where future lifetime years are concerned, there is still empirical convention. The constant rate of three per cent a year goes back to the seminal contribution on DALYs. After weighing a variety of considerations, Murray chooses what he himself terms the 'entirely arbitrary' rate of three per cent (Murray and Lopez 1996: 54).[9] There remains the question of whether this rate—that is, a halving every 24 years—if applied to either of Italy and Kenya, should also be applied to the other. It is hard to think of arguments why it should not be: the common rate, whatever its level, treats an individual's future years of life independently of where he or she happens to live. Accordingly, that is the position taken here. Some might argue, on the contrary, that ethical judgements involving age weights embody a cultural element; but if two societies are to be compared, using different

[9] Jamison et al. (2001) also choose three per cent, placed parenthetically and drawn out of thin air, in connection with their estimate of the expected lifetime earnings measure for Botswana.

weighting vectors rather distorts the picture where observable differences in outcomes are concerned, to say nothing of the difficulties of arriving at estimates of weights that reflect cultural factors.

As discussed in Section 2.1, attempts to accommodate future lifetime working years into received growth theory run into thorny problems. For the sake of uniformity, therefore, the rate of three per cent will also be applied to this measure.

There is a potentially important interplay between the discount rate and the mortality profile. Let ${}_kp_x = (1 - {}_kq_x)$ denote the probability that an individual will reach the age of $x+k$, conditional on surviving until age x. If the discount rate is constant, then $e_x(\boldsymbol{\delta})$ specializes to

$$e_x(\boldsymbol{\delta}) = 1/2 + \beta \cdot {}_1p_x + \beta^2 \cdot {}_2p_x + \ldots \beta^{\omega} \cdot {}_{\omega}p_x. \tag{7}$$

It is seen that although a common β scales all survival profiles $({}_1p_x, \ldots, {}_{\omega}p_x)$ in the same proportions, it has an absolutely larger effect on those exhibiting higher rates of survival, particularly if the individual concerned is young.

The results of applying the discount rate of three per cent to the base case are set out in Table 3, in which the baseline values are repeated in columns 1 to 4, with the survival profile $\mathbf{p}_0$ replacing $\mathbf{q}$ for ease of interpretation. Discounting at this annual rate will have only a limited effect on the loss of future lifetime years among those who are already advanced in years. For Italians in the age group 70–79, $\lambda_d(\boldsymbol{\delta})$ is 10.2 (discounted) years, just 2.3 years less than the simple expectation (see column 7 of both tables). It is quite otherwise at the start of life: the members of the age group 0–9 can expect to live, on average, another 79.8 years; but once the scythe of discounting has worked its way through the decades to come, they are left with a mere 30.3 years. The story in Kenya is similar, despite the much higher levels of underlying mortality. For the age group 70–79, $\lambda_d(\boldsymbol{\delta})$ is 5.0 (discounted) years, reduced from 5.8 years. For the numerous young in the age group 0–9 years, the respective expected values are 63.9 and 27.8 years. Comparing the very young in the two countries, it is clear that the ‘conventional’ three per cent a year is a formidable leveller, as indeed it must be when a life of 80 years and more is not an utterly remote possibility.

Table 3: Measures of discounted loss: Italy and Kenya compared

	COVID-19[a]	$\mathbf{n}^b$	$\mathbf{p}_0{}^c$	$10^3 \cdot \mathbf{d}$	$L_d^c(\boldsymbol{\delta})$	$L_a^d(\boldsymbol{\delta})$	$\lambda_d(\boldsymbol{\delta})$	$\lambda_a(\boldsymbol{\delta})$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Italy								
Age group								
0–9	25	8.4	0.9962	0.005	757	556	30.3	22.6
10–19	0	9.5	0.9941	0.000	0	0	29.2	25.3
20–29	25	10.1	0.9893	0.004	692	625	27.7	25.0
30–39	100	11.8	0.9822	0.014	2571	2210	25.7	22.1
40–49	225	15.3	0.9670	0.024	5195	4098	23.1	18.2
50–59	600	15.7	0.9282	0.063	11806	7845	19.7	13.1
60–69	2250	12.3	0.8341	0.302	34635	14583	15.4	6.5
70–79	5850	9.8	0.6224	0.986	59666	–	10.2	0
80+	14475	7.3	0.1760	3.275	68911	–	4.8	0
Total	23550	100		0.388	184235	29927	7.8	1.3
Kenya								
Age group								
0–9	70	26.7	0.9381	0.005	1947	1438	27.8	20.6
10–19	0	23.9	0.9212	0	0	0	27.0	24.5
20–29	37	17.8	0.8896	0.004	933	887	25.1	23,8
30–39	100	13.8	0.8456	0.014	2267	2098	22.7	21.0
40–49	112	8.9	0.7832	0.024	2206	1945	19.6	17.3
50–59	166	5.0	0.6931	0.063	2620	2083	15.8	12.6
60–69	429	2.7	0.5408	0.302	4027	1967	11.0	4.6
70–79	518	1.0	0.2915	0.986	2574	–	5.0	0
80+	344	0.2	0.0434	3.275	487	–	1.4	0
Total	1776	100		0.034	17736	10418	10.0	5.9

Sources: [a] for Italy, Statista (2020). For Kenya, apply **d** to **n**. [b] PopulationPyramid.net (2020). [c] Calculated from WHO (2018). The value of q for the group 80+ is the quinquennial rate for the group 80–84 followed by the annual rate for that aged 85 and over applied to five additional years, thus making a decadal rate for consistency. Details available upon request. [d] Calculated from (2)–(4) using the statistic Tx in WHO (2018). Details available upon request.

The effect of this (accounting) compression of the expected loss of future lifetime years on the corresponding aggregate loss depends on the population's age structure. The very young of Italy comprise only 8.4 per cent of its population, so that whereas their compression from 79.8 to 30.3 years is much sharper that that of very young Kenyans, both absolutely and relatively, young Kenyans account for 26.7 per cent of its population. If the excess mortality profiles **d** are the same, as assumed in the baseline, the ratio of three to one in population shares will overwhelm the compression effect of discounting. It is seen from column 5 that $L_d(\boldsymbol{\delta})$ for the age group 0–9 in Kenya, at 1947 person years, is 2.57 times that of the same group in Italy. In the absence of discounting, the corresponding aggregate figures are 4468 and 1995 person years, respectively, implying a ratio of 2.24.

The said compression through discounting is modest for the age groups at the other end of the life span; but whereas those aged 70 and over comprise 17.1 per cent of Italy's population, their counterparts in Kenya make up a mere 1.2 per cent of theirs. The sum of their undiscounted losses are 148,048 and 3,518 person years, respectively, a ratio of 42 to 1 (see column 5 of Table 1). Discounted at three per cent, these become 128,577 and 3,056 person years, respectively, implying essentially the same ratio. For the groups in between, the relative population weights are more strongly in play for the young, with the ratio inverting between the age groups 20–29 and 30–39. In aggregate, $L_d(\boldsymbol{\delta})$ for Italy is 79.4 per cent of its L_d level, whereas the corresponding proportion for Kenya is 71.6 per cent. Discounting over such a span at such a rate will inevitably prune this measure of loss more heavily when applied to the younger population.

Turning to discounted losses of future lifetime working years, $L_a(\boldsymbol{\delta})$, there is now no longer any role for Italy's numerous old citizens, whose losses of future lifetime years dominate L_d and $L_d(\boldsymbol{\delta})$. Italy's ratio of $L_a(\boldsymbol{\delta})$ to L_a is, accordingly, a more modest 0.691, whereas Kenya's is 0.719, and so virtually the same as its ratio of $L_d(\boldsymbol{\delta})$ to L_d .

4 Concluding discussion

In comparing Kenya with Italy, it is by no means the purpose of this paper to make light of the damage that the SARS-CoV-2 pandemic threatens to wreak upon poor countries. The heavy and effective lockdowns, coupled with social distancing, imposed upon the populations of developed countries are virtually unenforceable in the dense urban slums and the socially interwoven rural communities of poor ones. Nor is the apparatus of the state so developed that their governments can provide temporary support to all those in need by employing an adroit combination of monetary and fiscal policies in the present, with payment of the bill for this social insurance, in the form of higher taxes, deferred to a future date, when the whole shock has passed. In order to eat, the urban poor must work and villagers must continue to cultivate their fields and tend their flocks, thus propagating the virus. The one advantage they enjoy is that, as group, they are young, and where the hazard of SARS-CoV-2 is concerned, youth is arguably a better shield against an untimely death than the best that medics and medicine can currently offer.

It is also arguable that the graver threat to well-being in poor countries stems from the heavy blow the pandemic has dealt to the global economy through the sharp and deep recession it has induced in the group of developed economies. The contraction of world trade and the attendant collapse of commodity prices in the Great Depression inflicted great damage on the people and economies of poor countries. A rerun cannot be ruled out.

How, then, should aid be targeted? Addressing even particular aspects of this question fully lies well beyond the scope of the present paper, but a few remarks are in order. On the health front, the common interest lies in the development of an effective vaccine, available to all at a cost affordable to all, and—it is to be hoped—within a year. That task will be undertaken in rich countries, which have an interest in population immunity for the world as a whole. The trade shock can be mitigated by generous debt relief, and some initiatives are in the making.

In the meantime, the young populations of poor countries continue to be assailed by malaria, HIV/AIDS, and a bevy of other communicable diseases, all competing hazards. Over the long haul, promoting the formation and protection of human capital will normally put a poor economy on the path to sustained growth, and this involves targeting scarce resources to health and education in particular ways.[10] If, in addition to financing a vaccine and providing debt relief, donors want to promote well-being by granting additional aid at this time, then they should weigh additional funding for impregnated bed nets and other measures to combat malaria, stronger vaccination programmes, especially against the diseases of childhood, and the promotion of primary and secondary education, especially for girls—all as alternatives to the provision of personal protective gear, SARS-Cov-2 testing kits, and ventilators.

To close, a remark on discounting is called for. It has been argued above that arriving at the 'right' discount rate is problematic enough even for an economy viewed in isolation. That reservation surely applies *a fortiori* when the goal is to compare losses in economies that are at very different stages of development. For that reason, it seems desirable to present the unweighted estimates of the age-specific measures, leaving ethical judgements to be made free of such a straitjacket.

[10] Motivated by the HIV/AIDS epidemic, this problem is analysed extensively by Bell and Gersbach (2009).

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