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Optimal Lockdown and Social Welfare

Abstract

This paper reexamines the design of the optimal lockdown strategy by paying attention to its robustness to the postulated social welfare criterion. We first characterize optimal lockdown under utilitarianism, and we show that this social criterion can, under some conditions, imply a COVID-19 variant of Parfit's (1984) Repugnant Conclusion: for any non-maximal lockdown saving lives at the cost of reducing average utility at a given period, there exists always a stricter lockdown, which further reduces average utility, but leads to a larger aggregate welfare. The optimal lockdown under utilitarianism is also shown to deteriorate the situation of the worst-off, against Hammond Equity. In order to do justice to Hammond Equity, we characterize optimal lockdown under the ex post egalitarian criterion, which gives absolute priority to the worst-o¤ ex post. Under general conditions, the ex post egalitarian optimum involves a zero lockdown. Varying between zero and its maximal level, the optimal lockdown policy is not robust to the postulated ethical criterion.

JEL-Codes: I180, I310, J180.

Keywords: Covid-19, lockdown, optimal policy, social welfare.

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1 Introduction

In order to battle against the COVID-19 pandemic and to save lives, governments around the world relied massively on lockdown strategies during the Spring 2020. At the beginning of April 2020, about 3.9 billion humans – that is, more than half of humanity – were asked or ordered to stay at home to prevent further expansion of the pandemic.[1]

Those (more or less strict) lockdown strategies saved lives, but at the cost of causing major macroeconomic slowdown and mass unemployment. According to Deb et al (2020), the Great Lockdown reduced the number of fatalities by about 90 %, in comparison to a baseline with no containment policies. But at the same time, the lockdown had also a major impact on economic performance. According to the OECD (2020), the scale of the decline in the level of output is equivalent to about 2 percentage points of GDP growth lost for each month of strict lockdown. As a consequence, the 3 months of strict lockdown in the Spring 2020 imply an annual GDP growth that will be, for 2020, lowered by about 6 percentage points, and thus unambigously negative, i.e. a severe contraction of economic activity.[2] The macroeconomic impact of COVID-19 is studied in more details in Atkeson (2020) and Eichenbaum et al (2020).

The design of optimal lockdown requires to weight the gains and losses from maintaining the economy under more or less strong sanitary constraints. The economics literature on optimal lockdown has substantially grown in the last few months. Recent papers by Acemoglu et al (2020), Alvarez et al (2020) and Gollier (2020) examined, using various theoretical setting, the optimal lockdown strategy within dynamic economic models including the (potentially amended) SIR structure of epidemiological frameworks, the population being divided into three groups: susceptible individuals (S), infected individuals (I) and recovered individuals (R). Those papers focused not only on the optimal extent of the lockdown, but, also, on the optimal timing of the lockdown.[3]

The goal of this paper is to focus on another aspect of the optimal lockdown problem: its robustness to the postulated social welfare criterion. The research question that we would like to address in this paper is to know how robust the optimal lockdown strategy is to the postulated ethical criterion.

Our research question is motivated by the fact that the design of an optimal lockdown strategy is an inherently *prescriptive* task. Deriving an optimal lockdown is, by nature, normative, in the sense that this tells us something about what governments or national health agencies *should do*. As emphasized by Moore (1903), a normative proposition - whatever it is - cannot be deduced from positive premises only, but requires necessarily, among the premises, at least one normative proposition. Any policy can only be "optimal" with respect to some pursued goal, which is normative in nature. What is true in general is

[1] See Euronews (2020).

[2] Obviously, those figures will have to be updated, in the light of what takes place at the end of 2020, where the COVID-19 epidemic is still active.

[3] Other recent papers on optimal size and timing of the lockdown include Bosi et al (2020), Garriga et al (2020) and Piguillem and Shi (2020).

also true in the times of COVID-19: the characterization of optimal lockdown does not escape from this general rule: any “optimal” lockdown can only be “optimal” given some pursued goal. As a consequence, the study of the optimal lockdown cannot avoid a discussion on its normative foundations.

During the COVID-19 crisis, governments gave, at some point, the impression that the pursued goal was to "save as many lives as possible". Whereas further research would be needed to try to "rationalize" government's chosen strategies during the COVID-19 crisis, one can raise serious doubts about a social objective that would consist only in saving as many lives as possible. Obviously, “saving lives” cannot be regarded, on its own, as a goal to be pursued, since such a normative objective would amount to ignore all other aspects of life, and, as such, would be too restrictive. Ideally, a social objective should incorporate and weight all aspects of individual interests in the population under study. This paper proposes to explore the implications of several distinct social welfare criteria for the design of optimal lockdown strategies.

In order to address that issue, this paper develops a dynamic model of the human lifecycle with risky lifetime. In our model, an epidemic, which has its own dynamics, reinforces the strength of mortality and reduces the proportion of old individuals in the population. In that economy, the government can reduce the mortality due to the epidemic by adopting a lockdown strategy, which slowdowns the rise of prevalence of the epidemic, but at the cost of reducing consumption possibilities and causing direct disutility to individuals. We examine the solution of the optimal lockdown problem under various social welfare criteria.

Anticipating on our results, we first characterize the optimal lockdown under the standard utilitarian social objective, and we show that this social criterion can, under some conditions, lead to a COVID-19 variant of Parfit's (1984) Repugnant Conclusion: for any strict lockdown saving lives at the cost of reducing average welfare at a given period, there exists always a stricter lockdown, which reduces average welfare even more, but which leads to a higher aggregate welfare level. The utilitarian solution is also shown to deteriorate the situation of the worst-off, against Hammond Equity (Hammond 1979). In order to do justice to Hammond Equity, we then characterize the optimal lockdown under the ex post egalitarian social criterion, which gives absolute priority to the worst-off ex post. It is shown that, under general conditions, the ex post egalitarian optimum involves a zero lockdown. In the light of all this, it can be concluded that the optimal lockdown strategy is not robust to the postulated social welfare criterion. Moreover, our results seem to point to a general ethical dilemma between, on the one hand, saving lives, and, on the other hand, improving the situation of the worst-off individuals in the society. Preventive policies like the lockdown contribute to achieving the first goal, but at the cost of deteriorating the situation of the most disadvantaged in the society.

The rest of the paper is organized as follows. Section 2 presents the model. The optimal lockdown is then derived under the utilitarian social criterion in Section 3. Section 4 identifies the condition under which the utilitarian criterion leads to a COVID-19 variant of Parfit's Repugnant Conclusion. The ethical dilemma between saving lives and Hammond Equity is studied in Section 5. Section 6 characterizes the optimal lockdown strategy under the ex post egalitarian criterion, which gives absolute priority to the worst-off ex post. Concluding remarks are drawn in Section 7.

2 The model

Let us consider a simple model of the human lifecycle in the presence of an epidemic. Time is discrete, and goes from $t = 0$ to $t = +\infty$. The model is a two-period overlapping generations economy: there are two ages of life - the young age and the old age - and the duration of each period of life is normalized to unity.[4] Young individuals are active, while old individuals are retired. The number of young adults is denoted by $N > 0$. For the sake of simplicity, we assume that all cohorts are of the same size, equal to N (i.e. no population growth).

The survival process An epidemic takes place in the society, and increases the strength of mortality. Let us denote by $0 \leq S_t < 1$ the probability to survive to the old age at time t. Abstracting from infant and childhood mortality, life expectancy at birth in our economy is thus equal to $1 + S_t$.

The probability of survival to the old age.is assumed to be decreasing with the degree of prevalence of the epidemic, denoted by $0 \leq I_t \leq 1$, and to be increasing with the strength of the lockdown policy chosen by the government, denoted by Z_t. The degree of lockdown can go from $Z_t = 0$ (no lockdown) to $Z_t = 1$ (full lockdown). We thus have:

$$S_t = S\left(I_t, Z_t\right) \tag{1}$$

In the absence of any epidemic (i.e. $I_t = 0$) and lockdown, we have $S_t = S(0,0) = \bar{S} < 1$. The first-order derivatives of $S\left(I, Z\right)$ satisfy: $S_I < 0$, $S_Z > 0$ when $I_t > 0$ and $S_Z = 0$ when $I_t = 0$.

Using the Law of Large Numbers, the number of old individuals at time t is given by:

$$NS\left(I_t, Z_t\right) \tag{2}$$

Note that the strength of the pandemic only affects the number of old individuals in the society, but not the number of young individuals. This feature of the model captures an important asymmetry concerning the impact of the COVID-19 epidemic on mortality: the epidemic has strongly increased the mortality of the old, while the mortality of the young has remained low and only marginally affected.

The prevalence of the epidemic The prevalence of the epidemic at time t depends on past prevalence at time $t - 1$, and on the degree of lockdown

[4] For the sake of simplicity, we abstract here from childhood, and we divide adulthood in only two parts: active life and inactive life.

imposed by the government at time $t-1$, according to the following law:

$$I_t = \frac{M + I_{t-1}}{1 + I_{t-1} + Z_{t-1}} \tag{3}$$

where $0 < M < 1$. That simple dynamic law ensures that the prevalence of the epidemic I_t belongs always to the $[0,1]$ interval, is increasing in the past prevalence I_{t-1}, and is decreasing in the strength of the lockdown imposed by the government Z_{t-1}.

We have:

$$\Delta I_t \equiv I_t - I_{t-1} = \frac{M - I_{t-1}^2 - I_{t-1}Z_{t-1}}{1 + I_{t-1} + Z_{t-1}} \tag{4}$$

Hence, in the absence of lockdown ($Z_{t-1} = 0$), the prevalence of the epidemic grows (i.e. $\Delta I_t > 0$) when $M > I_{t-1}^2$. That condition is quite weak when the prevalence of the epidemic is initially low, as it is always the case with epidemics in the real world. On the contrary, the prevalence declines (i.e. $\Delta I_t > 0$) in the absence of lockdown when $M < I_{t-1}^2$, which can only be achieved when the prevalence is quite high.

Once there is a lockdown $Z_{t-1} > 0$, this reduces the growth of the prevalence of the epidemic. The growth of the prevalence remains strictly positive when $M > I_{t-1}^2 + I_{t-1}Z_{t-1}$, and declines when $M < I_{t-1}^2 + I_{t-1}Z_{t-1}$. Thus imposing a lockdown tends to reduce the growth of the prevalence of the epidemic, and can also, if the lockdown is sufficiently strict, lead to a reduction of the prevalence of the epidemic.

The production process The output is denoted by $Y_t > 0$. For simplicity, production involves only labor. Young individuals supply one unit of labor inelastically. The output obtained from a given quantity of labor depends on the extent of the lockdown policy decided by the government. The stronger the lockdown is, and the lower the output is, for a given quantity of labor.

The production process is described by the following production function:

$$Y_t = F(N, Z_t) \tag{5}$$

where $F_N > 0, F_{NN} < 0$ (decreasing marginal productivity of labor), as well as $F_Z < 0$.

We assume also that, for any level of labor, the output remains strictly positive even when the lockdown chosen by the government takes its maximal value, that is, that: $F(N, 1) = \hat{Y} > 0$.

The resource constraint At any period of time, the production is consumed by the population. Let us denote by $c_t \geq 0$ the consumption of each young adult at time t. Let us assume that each old adult receives a defined benefit Pay-As-You-Go pension $b_t \geq 0$.[5] Thus the following resource constraint

[5] Note that our results would not be affected if we were assuming a PAYGO system with defined contributions instead of defined benefits.

holds in the economy at any period of time:

$$F(N, Z_t) = Nc_t + NS(I_t, Z_t) b_t \tag{6}$$

The lelf-hand side (LHS) is equal to the total production at time t, whereas the right-hand side (RHS) denotes the total consumption, either of young adults (first term), or old adults (second term). Note that the extent of the lockdown policy chosen by the government affects the economy's resource constraint on the two sides. On the one hand, a stronger lockdown reduces the available output (LHS); on the other hand, the degree of the lockdown also increases the proportion of old individuals alive in the population, which increases aggregate consumption of the old.

Rewriting the consumption of each young adult as follows:

$$c_t = \frac{F(N, Z_t)}{N} - S(I_t, Z_t) b_t \tag{7}$$

it appears that the lockdown imposes a double pressure on the consumption of the young, by reducing output per worker (first term of RHS) and by increasing the transfer of each worker to the elderly.

Preferences Individuals are assumed to have preferences over lotteries of life that satisfy the expected utility hypothesis. Expected lifetime well-being for a young adult at time t is given by:[6]

$$EU_t = u(c_t) - vZ_t + S(I_t, Z_t)\left[u(b_{t+1}) - vZ_{t+1}\right] \tag{8}$$

where the utility function $u(\cdot)$ is increasing and concave in consumption. The parameter $v \geq 0$ captures the pure disutility from the lockdown.

Note that the postulated utility function treats all premature deaths in a similar way, whatever their cause is (epidemic or not). The underlying intuition is that the damage due to a premature death lies mainly in the opportunity cost of that death (i.e. all the things that would have been lived provided the premature death had not taken place), rather than in the circumstances of the death.

Moreover, the above utility function deliberately abstracts from pure time preferences. Actually, the survival probability $S(I_t, Z_t)$ can be interpreted as a biological discount factor.

Steady-state prevalence of the epidemic Let us study the long-run dynamics of the prevalence of the epidemic. The prevalence of the epidemic follows the dynamic law:

$$I_t = \frac{M + I_{t-1}}{1 + I_{t-1} + Z_{t-1}}$$

[6] The utility of being dead is normalized to 0.

In the absence of any lockdown policy (i.e. $Z_{t-1} = 0\ \forall t$), the prevalence of the epidemic follows the law:

$$I_t = \frac{M + I_{t-1}}{1 + I_{t-1}} \tag{9}$$

so that the steady-state prevalence $I_t = I_{t-1} = I$ is given by:

$$I = \sqrt[2]{M} < 1 \tag{10}$$

Thus, in the absence of lockdown, the prevalence of the epidemic will, in the long-run, stabilize at a level equal to $\sqrt[2]{M}$. We then have, in the long-run: $S_t = \lim_{I \to \infty} S\left(\sqrt[2]{M}, 0\right) = \breve{S}$ with $0 < \breve{S} < 1$.

Let us now assume that a constant positive lockdown $Z_{t-1} = Z > 0$ takes place. The steady-state prevalence of the epidemic is now given by:

$$I = \frac{-Z + \sqrt[2]{Z^2 + 4M}}{2} > 0 \tag{11}$$

The steady-state prevalence of the epidemic under a positive lockdown is smaller than in the absence of lockdown. This can be seen by noticing that the steady-state prevalence is decreasing in the size of the lockdown Z imposed by the government.

Note also that the absolute value of the derivative of the prevalence dynamic equation at the steady-state satisfies the condition:

$$\left|\frac{\partial I_t}{\partial I_{t-1}}\right| = \frac{1 + Z - M}{\left(1 + Z + \frac{-Z + \sqrt[2]{Z^2+4M}}{2}\right)^2} < 1$$

so that the steady-state prevalence is locally stable.

3 Optimal lockdown under utilitarianism

Let us now consider the design of a socially optimal lockdown policy. For that purpose, this section adopts the standard utilitarian ethical criterion. Introduced by Bentham (1789) and by Mill (1863), utilitarianism recommends to implement policies that satisfy the Principle of Utility, or the Principle of the Largest Happiness for the Largest Number. Under utilitarianism, social ethics is reduced to a large calculus of pleasures and pains. Under that ethical criterion, the question of the optimal lockdown can be reduced to characterizing the degree of lockdown that leads to the largest social welfare, defined as the sum of individual utilities.

Let us consider a utilitarian social planner, who chooses the consumption per young adult c, the PAYGO benefit b and the degree of lockdown Z in such a way as to maximize the sum of individual utilities prevailing at the steady-state equilibrium, while satisfying the economy's resource constraint, and while assuming that the prevalence of the epidemic takes its steady-state level.

The problem of the utilitarian social planner can be written as:

$$\begin{aligned}
\max_{c,b,Z} & \quad N\left[u(c) - vZ + S\left(I,Z\right)\left[u(b) - vZ\right]\right] \\
\text{s.t. } c &= \frac{F\left(N,Z\right)}{N} - S\left(I,Z\right)b \\
\text{s.t. } I &= \frac{-Z+\sqrt[2]{Z^2+4M}}{2} \\
\text{s.t. } Z &\geq 0 \text{ and } 1-Z \geq 0
\end{aligned}$$

The last two conditions insure that $0 \leq Z \leq 1$, that is, the lockdown is between 0 (no lockdown) and 1 (full lockdown).

Substituting for the first two constraints, the utilitarian social planner's problem can be rewritten as the following Lagrangian:

$$\max_{b,Z} N \left[\begin{array}{c} u\left(\frac{F(N,Z)}{N} - S\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)b\right) - vZ \\ +S\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)\left[u(b) - vZ\right] \end{array} \right] + \lambda Z + \mu(1-Z)$$

where λ and μ are two Lagrange multipliers.

First-order conditions (FOCs) are:

$$-S\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)u'(c) + S\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)u'(b) = 0 \quad (12)$$

and

$$N\left[u'(c)\left(\frac{F_Z\left(\cdot\right)}{N} - S_Z\left(\cdot\right)b\right) - v + S_Z\left(\cdot\right)\left[u(b) - vZ\right] - S\left(\cdot\right)v\right] + \lambda - \mu = 0 \quad (13)$$

where $S_Z\left(\cdot\right)$ denotes the derivative of the steady-state survival function $S\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)$ with respect to Z, as well as:

$$\begin{aligned}
\lambda &\geq 0, Z \geq 0 \quad (14) \\
\mu &\geq 0, 1-Z \geq 0 \quad (15)
\end{aligned}$$

with complementary slackness.

The first FOC can be simplified to:

$$u'(c) = u'(b) \quad (16)$$

that is, it is socially optimal, from a utilitarian perspective, to smooth consumption along the life cycle. The consumption of the young adult is thus exactly equal to the level of the PAYGO benefit enjoyed at the old age. We thus have:

$$c = b = \frac{F\left(N,Z\right)}{N\left(1 + S\left(I,Z\right)\right)} \quad (17)$$

Consumption possibilities at the steady-state are thus decreasing with the extent of the lockdown.

Let us now focus on the socially optimal lockdown level under utilitarianism. The second FOC simplifies to:

$$u'(c)\left(\frac{F_Z(\cdot)}{N} - S_Z(\cdot)\, b\right) - v + S_Z(\cdot)\left[u(b) - vZ\right] - S(\cdot)\, v + \lambda - \mu = 0 \quad (18)$$

The first term on the LHS reflects the negative effect of the lockdown policy on the welfare obtained from consumption at the young age, through reducing output per worker and increasing the aggregate consumption of the old. The second term of the LHS captures the pure disutility of the lockdown for young adults. The third term of the LHS reflects the marginal welfare gain from increasing the survival of the elderly thanks to the lockdown, while the fourth term captures the pure disutility of the lockdown for old adults.

That condition for optimal lockdow can be rewritten as follows:

$$S_Z(\cdot)\left[u(b) - vZ\right] = v(1 + S(\cdot)) - u'(c)\left(\frac{F_Z(\cdot)}{N} - S_Z(\cdot)\, b\right) - \lambda + \mu \quad (19)$$

The LHS is the marginal gain in social welfare from allowing more elderly people to survive thanks to larger lockdown, whereas the RHS is the marginal loss in social welfare due to a stronger lockdown, which includes, on the one hand, a direct utility loss from the lockdown (for the young and the old) (first term of RHS), and, on the other hand, a reduction of consumption possibilities due to the fall of output per worker and the additional pressure on resources due to a larger number of elderly persons (second term of RHS).

Note that, in the absence of epidemic, we would have $S_Z(\cdot) = 0$, implying that the optimal lockdown would be equal to zero, since in that case the marginal welfare gains from a positive lockdown would be equal to zero, while the associated costs on the RHS would be strictly positive, so that we must have $\lambda > 0$ and $\mu = 0$, that is, $Z = 0$.

Let us now examine the condition under which the optimal lockdown is zero in the presence of an epidemic. Lagrange multipliers take the values $\lambda > 0$ and $\mu = 0$. This case occurs when, if $Z = 0$, the marginal welfare gain from a rise in the intensity of the lockdown is lower than the marginal welfare loss associated to such a rise. Denoting the steady-state consumption in the absence of lockdown as:

$$\hat{c} \equiv \frac{F(N, 0)}{N\left(1 + S\left(\sqrt[2]{M}, 0\right)\right)}$$

the necessary and sufficient condition for a zero optimal lockdown level is:

$$S_Z\left(\frac{-Z + \sqrt[2]{Z^2 + 4M}}{2}, Z\right)\Bigg|_{Z=0}\left[u(\hat{c}) - u'(\hat{c})\hat{c}\right] \leq v(1+\breve{S}) - u'(\hat{c})\left(\frac{F_Z(\cdot)}{N}\Bigg|_{Z=0}\right) \quad (20)$$

Since the derivative of steady-state survival function at $Z = 0$ is strictly positive, and assuming $u(\hat{c}) - u'(\hat{c})\hat{c} > 0$, the LHS of the condition is strictly positive. The first term of the RHS is strictly positive, and the second term of the RHS is also strictly positive. We can see that, the higher the pure marginal disutility of the lockdown is, and the more likely it is that the optimal lockdown is zero. Another key determinant of that condition is the level of the marginal output loss due to a marginal rise in the degree of lockdown when $Z = 0$.

Note that, if the pure marginal disutility of the lockdown is low (i.e. $v \simeq 0$), and if the output reacts little to a marginal rise of the degree of lockdown (i.e. $F_Z(\cdot) \simeq 0$ at $Z = 0$), then the RHS of the above condition is close to 0, so that this condition is unlikely to be satisfied. The necessary and sufficient condition for a strictly positive optimal lockdown is:

$$S_Z\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)\Bigg|_{Z=0}\left[u\left(\hat{c}\right)-u'\left(\hat{c}\right)\hat{c}\right] > v(1+\breve{S})-u'\left(\hat{c}\right)\left(\frac{F_Z\left(\cdot\right)}{N}\Bigg|_{Z=0}\right) \tag{21}$$

Proposition 1 summarizes our results.

Proposition 1 *Consider the utilitarian social optimum. The optimal lockdown is strictly positive if and only if*

$$S_Z\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)\Bigg|_{Z=0}\left[u\left(\hat{c}\right)-u'\left(\hat{c}\right)\hat{c}\right] > v(1+\breve{S})-u'\left(\hat{c}\right)\left(\frac{F_Z\left(\cdot\right)}{N}\Bigg|_{Z=0}\right)$$

Proof. See above. ■

Proposition 1 provides the necessary and sufficient condition on the structural parameters and functional forms such that the utilitarian optimum involves a strictly positive lockdown level $Z > 0$. As stated above, that condition is relatively weak, especially when the direct disutility of the lockdown is low. The intuition behind that statement is that the survival function is likely to be extremely sensitive to a marginal rise in the extent of the lockdown when the initial lockdown level is zero. Thus, the first factor of the LHS of the condition in Proposition 1 is likely to be quite high, implying that the LHS exceeds the RHS, leading thus to a strictly positive optimal lockdown level.

In the light of Proposition 1, it appears that, under mild conditions, it is possible to rationalize, on utilitarian grounds, the existence of a strictly positive lockdown in the presence of an epidemic like COVID-19. Note, however, that the degree of strictness of the optimal lockdown under utilitarianism is more complex to characterize, since this optimal degree (i.e. the level of optimal Z) is the outcome of a complex calculus of pleasures and pains, where various forces are at work, as we discussed above. Having stressed this, we can nonetheless identify some conditions under which the optimal lockdown would, under utilitarianism, take its maximal level ($Z = 1$).

4 A COVID-19 Repugnant Conclusion

The utilitarian social criterion is a standard benchmark in consequentialist ethics, and in public economics. However, it should be stressed that, when applied to the context of an economy with a pandemic, the utilitarian social criterion can have quite counterintuitive implications.

A first, particularly counterintuitive, implication, consists of its tendency to imply, under some conditions, a variant of Parfit's (1984) Repugnant Conclusion. In a seminal work in population ethics, Parfit showed that classical utilitarianism suffers, under mild conditions, from the Repugnant Conclusion, in the sense that for any large population of individuals having a low utility level, it is always possible to find another, even larger, population, where each individual enjoys an even lower welfare level, but where aggregate welfare is larger (see Blackorby et al 2005).

Within the context of an economy with a pandemic, utilitarianism can lead to some form of Repugnant Conclusion. Actually, under some conditions, the society is, under utilitarianism, locked in a kind of COVID-19 variant of the Repugnant Conclusion: for any non-maximal lockdown with a low level of average well-being at a given period, there exists a higher degree of the lockdown reducing average welfare even more, but which leads to a higher aggregate welfare. A utilitarian society would thus, under some conditions, be condemned to maximal lockdown leading to a low average welfare at any time period.

In order to understand that - somewhat counterintuitive - result, let us turn back to the condition for optimal lockdown under utilitarianism:

$$S_Z(\cdot)\left[u(b) - vZ\right] = v(1 + S(\cdot)) - u'(c)\left(\frac{F_Z(\cdot)}{N} - S_Z(\cdot)\, b\right) - \lambda + \mu$$

Let us now consider the condition under which the optimal lockdown is the maximal lockdown $Z = 1$. In that case, the Lagrange multipliers take the levels $\lambda = 0$ and $\mu > 0$. Denoting consumption under maximal lockdown as:

$$\bar{c} \equiv \frac{F(N, 1)}{N\left(1 + S\left(\frac{-1+\sqrt[2]{1+4M}}{2}, 1\right)\right)}$$

as well as the probability of survival to the old age under maximal lockdown as:

$$\bar{S} = S\left(\frac{-1 + \sqrt[2]{1 + 4M}}{2}, 1\right) < 1$$

The necessary and sufficient condition for the maximal lockdown to be socially optimal is:

$$S_Z\left(\frac{-Z + \sqrt[2]{Z^2 + 4M}}{2}, Z\right)\Bigg|_{Z=1}\left[u(\bar{c}) - u'(\bar{c})\bar{c} - v\right] > v\left[1 + \bar{S}\right] - u'(\bar{c})\left(\frac{F_Z(\cdot)}{N}\Bigg|_{Z=1}\right) \tag{22}$$

That condition depends on how reactive the survival function $S(\cdot)$ is to a variation of Z when lockdown is at its maximal level. If that reactivity is low (i.e. $S_Z(\cdot) \simeq 0$), then the above condition is never satisfied. However, there is no reason to impose that assumption. There is no obvious reason why small deviations from maximal lockdown should have a negligible effect on survival to the old age. It is actually quite plausible that the survival function is sensitive to Z even at the maximal lockdown level. If so, the above condition may be satisfied, especially in economies where the pure disutility from lockdown is low.

Under that condition, a level of lockdown less than the maximal lockdown is never socially optimal. There is always a gain in social welfare from shifting from Z to $Z' > Z$.

Obviously, such a shift from Z to $Z' > Z$ has a cost in terms of the average welfare level prevailing in the population at a given time period. To see this, note that average welfare at time t is:

$$\frac{N\left(u(c) - vZ\right) + NS\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)\left(u(c) - vZ\right)}{N\left(1 + S\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)\right)} = u(c) - vZ \tag{23}$$

which is decreasing in the extent of the lockdown Z. Hence, when shifting from Z to $Z' > Z$, there is always a loss in average welfare at time t, but a gain in social welfare.

Hence, under some conditions, utilitarianism leads to a form of Repugnant Conclusion, since this leads societies to sacrifice average welfare within the population alive at a given point in time on the grounds of promoting aggregate welfare. Proposition 2 summarizes our results.

Proposition 2 *Consider the utilitarian social optimum. If*

$$S_Z\left(\frac{-Z+\sqrt[2]{Z^2+4M}}{2}, Z\right)\Bigg|_{Z=1}\left[u(\bar{c}) - u'(\bar{c})\bar{c} - v\right] > v\left[1+\bar{S}\right] - u'(\bar{c})\left(\frac{F_Z(\cdot)}{N}\Bigg|_{Z=1}\right)$$

then for any non-maximal lockdown $Z < 1$ leading to a low level of average welfare at time t, there exists always a stricter lockdown $Z' > Z$ leading to an even lower average welfare, but such that aggregate welfare takes a higher level.

Proof. See above. ■

Proposition 2 provides a condition under which any non-maximal lockdown level is not optimal from a utilitarian perspective. When the condition of Proposition 2 is verified, the economy is trapped in a situation that could be called a COVID-19 variant of Parfit's (1984) Repugnant Conclusion. In a seminal work, Parfit showed that classical utilitarianism suffers, under mild conditions, from the Repugnant Conclusion, in the sense that for any large population of individuals having a low utility level, it is always possible to find another, even larger, population, where each individual enjoy an even lower welfare level, but such that total welfare is larger. When the condition of Proposition 2 prevails, the society is locked in a kind of COVID-19 variant of the Repugnant Conclusion: for any non-maximal lockdown with a low average well-being, there exists a higher degree of the lockdown reducing average well-being even more, but which leads to a higher aggregate well-being.

Within the population ethics literature, the Repugnant Conclusion has been regarded as a counterintuitive implication of the classical utilitarian criterion, and, as such, as some result that disqualifies the reliance on that ethical criterion for population issues. The reason why that Repugnant Conclusion was regarded as "repugnant" lies in the fact that utilitarianism justifies a substitution of *quality* of lives by *quantify* of lives, in the sense that the Repugnant Conclusion amounts to replace lives with a high quality by a larger number of born individuals enjoying poor lives (see Arrhenius 2013).

Concerning the COVID-19 variant of the Repugnant Conclusion studied here, the utilitarian criterion justifies another type of substitution: a substitution between average welfare at a given time period and the quantity of life for a given number of born individuals. Thus we escape here from the standard form of the substitution between number of born individuals (here constant) and the utility per life. However, utilitarianism still implies, under the condition of Proposition 2, a kind of substitution that is quite counterintuitive: from the quality of each life-period to the total number of life-periods. Indeed, increasing the extent of the lockdown Z is, under the condition of Proposition 2, always socially desirable, but this is made at the cost of reducing the average welfare prevailing at any period of time.

5 Saving lives *versus* equity

Another counterintuitive implication of the utilitarianism in the present context concerns its violation of Hammond Equity (see Hammond, 1979). Hammond Equity regards as socially desirable any transfer of well-being from a more advantaged person to a less advantaged person, whatever the sizes of the welfare loss for the former and of the welfare gain for the latter. In some sense, Hammond Equity consists of giving absolute priority to the worst-off in the society.

It can be shown that the utilitarian optimum leads, in the context of selecting an optimal lockdown under a pandemic, to a violation of Hammond Equity. To see this, let us first calculate the welfare levels of all individuals in the society. Focusing on the steady-state, there exist only two types of persons: on the one hand, short-lived individuals, who died before reaching the old age, and, on the other hand, long-lived individuals, who could survive to the old age.

The realized or ex post lifetime well-being of the short-lived is, at the utilitarian optimum, given by:

$$U^{SL} = u\left(\frac{F(N,Z)}{N(1+S(I,Z))}\right) - vZ \tag{24}$$

The realized or ex post lifetime well-being of the long-lived is, at the utilitarian optimum, given by:

$$U^{LL} = u\left(\frac{F(N,Z)}{N(1+S(I,Z))}\right) - vZ + u\left(\frac{F(N,Z)}{N(1+S(I,Z))}\right) - vZ \tag{25}$$

Assuming that a life is worth living, that is, that the utility of being alive at a given time period is higher than the utility of being dead (normalized to 0), that is:

$$u\left(\frac{F(N,Z)}{N(1+S(I,Z))}\right) - vZ > 0 \tag{26}$$

we can see that, at the utilitarian optimum, there exists an inequality in lifetime well-being between the short-lived and the long-lived. At the utilitarian optimum, persons who have a short life are clearly worst-off than persons who enjoy a long life.

Does the utilitarian criterion satisfy Hammond Equity? In other words, does the utilitarian optimum give priority to the worst-off ex post, who is the short-lived?

The answer to that question is, in general: No. To understand why the utilitarian criterion violates Hammond Equity, let us remind that, under the condition of Proposition 1, the utilitarian optimum involves a strictly positive level of the lockdown $Z > 0$. It should be stressed, however, that the level of well-being of the short-lived is decreasing with the strength of the lockdown. Indeed, we have:

$$\frac{\partial U^{SL}}{\partial Z} = u'\left(\frac{F(N,Z)}{N(1+S(I,Z))}\right) \frac{F_Z(N,Z)\,N(1+S(I,Z)) - F(N,Z)\,NS_Z(I(Z),Z)}{(N(1+S(I(Z),Z)))^2} - v < 0$$

Thus the strength of the lockdown necessarily reduces the realized welfare level for individuals who are short-lived.

Therefore, if one wants to satisfy Hammond Equity, and to give priority to the worst-off, one needs here to set the lockdown level Z to zero, in such a way as to maximize the lifetime well-being of the short-lived, U^{SL}. This is clearly not the case under utilitarianism in general. The following proposition summarizes our results.

Proposition 3 *Hammond Equity requires to set the lockdown level to $Z = 0$. Under the condition of Proposition 1, the utilitarian criterion leads to a strictly positive lockdown, $Z > 0$, thus violating Hammond Equity.*

Proof. See above. ■

Proposition 3 states that utilitarianism violates Hammond Equity, since it fails to give priority to the worst-off ex post. Such a failure is quite problematic: within our economy, being long-lived or short-lived is a pure matter of luck, a pure matter of circumstances. Hence, well-being inequalities due to unequal lifetimes are arbitrary, and the short-lived are victims of circumstances. Hence, if a government wants to be fair with respect to those short-lived individuals, it should, in line with Hammond Equity, implement zero lockdown. Utilitarianism, by recommending a strictly positive lockdown level, clearly fails at satisfying Hammond Equity.

At this stage, it is worth explaining the fundamental reason why utilitarianism applies a positive lockdown. Actually, as shown above, the average welfare at a given point in time is decreasing in the extent of the lockdown. Moreover, the well-being of the worst-off (the short lived) is decreasing with the strength of the lockdown. Hence, why does utilitarianism lead to a positive lockdown level under mild conditions? Which part of the calculus of pleasures and pains leads to impose a strictly positive lockdown? The answer to that question can be found by going back, once again, to the FOC characterizing the optimal lockdown level under utilitarianism:

$$S_Z(\cdot)\left[u(b) - vZ\right] = v(1 + S(\cdot)) - u'(c)\left(\frac{F_Z(\cdot)}{N} - S_Z(\cdot)\, b\right) - \lambda + \mu$$

The unique gain, in terms of social welfare, appears on the LHS of the condition: the unique social welfare gain associated to the lockdown comes from the fact that the lockdown strategy leads to increase the survival probability to the old age, and, hence, leads to *saving lives*. If that motive were absent (i.e. $S_Z(\cdot) = 0$), the utilitarian criterion would not legitimate any lockdown.

In the light of all this, it appears that there exists a fundamental dilemma between, on the one hand, Hammond Equity and, on the other hand, saving lives. Under the conditions of Proposition 1, utilitarianism implements a strictly positive lockdown and, hence, violates Hammond Equity. Under the conditions of Proposition 2, utilitarianism leads to maximal lockdown, and, hence, leads to save as many lives as possible. But when the condition of Proposition 1 are satisfied and not the ones of Proposition 2, utilitarianism leads to an interior lockdown, which violates both Hammond Equity and the goal of saving lives.

As formalized by Fleurbaey and Ponthiere (2013), a basic way to present the objective of saving lives takes the form of the Survivors Number Count Axiom. That axiom states that the certainty to save one life justifies a general rise of the preventive effort in the population, consumption levels being left unchanged. The Survivors Number Count Axiom does not give absolute priority to saving lives over any other concern. Indeed, this axiom is only an axiom for an interest in saving lives, but it does not justify sacrificing consumption possibilities for the sake of saving lives. It only justifies more prevention provided this leads to the certainty of saving one life, while consumption possibilities are left unchanged.

Does the utilitarian criterion satisfy the Survivors Number Count Axiom? To answer that question, let us consider the hypothetical choice of a lockdown level *ceteris paribus*, that is, the hypothetical choice of a lockdown level in an economy where the lockdown level does not affect consumption possibilities. In that hypothetical context, we would have $F_Z(\cdot) = 0$.[7] Under that assumption, the FOC for optimal lockdown becomes:

$$S_Z(\cdot)\left[u(c) - u'(c)c - vZ\right] = v(1 + S(\cdot)) - \lambda + \mu$$

[7] That assumption is not realistic, but is made here only for the sake of evaluating whether the utilitarian criterion would satisfy the Survivors Number Count Axiom.

We can see that, if

$$\left(\left. S_Z\left(\cdot\right)\right|_{Z=1} \right)\left[u(\bar{c}) - u'(\bar{c})\bar{c} - v \right] > v(1+\bar{S})$$

the utilitarian optimum would involve, in that hypothetical case, maximal lockdown, meaning that the certainty to save one more life would definitely justify as much prevention as possible. Actually, that condition is necessary and sufficient for the utilitarian criterion to satisfy the Survivors Number Count Axiom. Proposition 4 summarizes our results.

Proposition 4 *The Survivors Number Count Axiom requires to set the lockdown level to $Z = 1$ when lockdown does not affect consumption possibilities. The utilitarian criterion satisfies the Survivors Number Count Axiom if and only if:*

$$\left(\left. S_Z\left(\cdot\right)\right|_{Z=1} \right)\left[u(\bar{c}) - u'(\bar{c})\bar{c} - v \right] > v(1+\bar{S})$$

Proof. See above. ■

Thus, while the utilitarian criterion fails to satisfy Hammond Equity, it can, in some cases, satisfy the Survivors Number Count Axiom. Obviously, when there is no direct welfare loss due to the lockdown, the condition of Proposition 4 is necessarily satisfied, and the utilitarian criterion satisfies the Survivors Number Count Axiom. However, in cases where there is a high disutility of lockdown, this may not be the case.

Whereas the Survivors Number Count Axiom may be regarded as a quite mild way of formalizing the goal of "saving lives", that axiom is actually incompatible with Hammond Equity, as shown in Fleurbaey and Ponthiere (2013). This contradiction between those two ethical principles is a general result, which can be expressed also in an economy with a pandemic like the one studied here.

Indeed, Hammond Equity requires to set the lockdown level to $Z = 0$ even in the hypothetical case where the lockdown does not affect consumption possibilities (i.e. when $F_Z\left(\cdot\right) = 0$). The reason is that a strictly positive lockdown level would still reduce the welfare level of the worst-off (the short-lived), because of a strictly positive direct disutility of lockdown ($v > 0$). But at the same time, the Survivors Number Count Axiom requires, in that hypothetical case, to set $Z = 1$ (maximal lockdown), on the ground of the certainty to save one life. Those two implications being contradictory, there exists no ethical criterion that would satisfy both Hammond Equity and the Survivors Number Count Axiom, as stated in Proposition 5.

Proposition 5 *Assume a strictly positive disutility from lockdown $v > 0$. No ethical criteria can satisfy both Hammond Equity and the Survivors Number Count Axiom.*

Proof. See above. ■

Proposition 5 points to a fundamental dilemma between two social goals that look quite attractive: on the one hand, giving priority to the worst-off and, on the other hand, saving lives. A choice is to be made between those two social objectives. In the present setting, giving priority to the worst-off would imply zero lockdown, whereas the goal of saving lives would requite maximal lockdown.

The utilitarian criterion tends, under general conditions, to violate Hammond Equity, but can, under the conditions of Proposition 4, satisfy the Survivors Number Count Axiom. As such, the utilitarian criterion tends to give more priority to the goal of saving lives than to the improvement of the situation of the worst-off. One may criticize this priority, and opt for a social criterion that gives priority to the worst-off. A social objective of that kind is studied in the next section.

6 Optimal lockdown under ex post egalitarianism

Welfare inequalities due to unequal lifetimes are arbitrary. These are a pure matter of luck, and one may argue that such arbitrary welfare inequalities should be abolished by the government. One way to advocate for such an abolishment of welfare inequalities due to circumstances consists of referring to the Principle of Compensation (see Fleurbaey and Maniquet 2004, Fleurbaey 2009). According to the Principle of Compensation, welfare inequalities due to circumstances should be abolished.

Let us now assume an alternative social criterion, which does justice to the Principle of Compensation. Following Fleurbaey et al (2014), we consider here a social objective that is ex post egalitarian, that is, which gives absolute priority to the interests of the worst-off ex post.

Under the ex post egalitarian social objective, the problem of the social planner becomes:

$$\begin{aligned}
\max_{c,b,Z} & \quad \min\left\{u(c) - vZ, u(c) - vZ + u(b) - vZ\right\} \\
\text{s.t. } c &= \frac{F(N,Z)}{N} - S(I,Z)\,b \\
\text{s.t. } I &= \frac{-Z + \sqrt[2]{Z^2 + 4M}}{2} \\
\text{s.t. } Z &\geq 0 \text{ and } 1 - Z \geq 0
\end{aligned}$$

The objective function is not continuous, and so the objective is not differentiable. However, it is possible to rewrite that planning problem as the maximization of the welfare of the short-lived subject to the egalitarian constraint specifying that the long-lived and the short-lived are equally well-off, and subject to the resource constraint and the steady-state epidemic prevalence constraint. After some substitutions, the problem can be rewritten as follows:

$$\begin{array}{rcl} \max_{b,Z} & & u\left(\frac{F(N,Z)}{N} - S(I,Z)\,b\right) - vZ \\ \text{s.t.} & & u(c) - vZ = u(c) - vZ + u(b) - vZ \\ \text{s.t. } I & = & \frac{-Z + \sqrt[2]{Z^2 + 4M}}{2} \\ \text{s.t. } Z & \geq & 0 \text{ and } 1 - Z \geq 0 \end{array}$$

The first constraint consists of an egalitarian constraint. That constraint specifies that the long-lived persons and the short-lived persons must be equally well-off. That egalitarian condition can only be satisfied provided:

$$u(b) - vZ = 0 \iff b = u^{-1}(vZ)$$

Substituting for this and for the steady-state prevalence, the planning problem becomes:

$$\max_{Z} u\left(\frac{F(N,Z)}{N} - S\left(\frac{-Z + \sqrt[2]{Z^2 + 4M}}{2}, Z\right) u^{-1}(vZ)\right) - vZ + \lambda Z + \mu(1 - Z)$$

where λ, μ are two Lagrange multipliers.

The FOCs are:

$$u'(c)\left[\frac{F_Z(\cdot)}{N} - S_Z(\cdot)\,u^{-1}(vZ) - S(\cdot)\,\frac{1}{u' \circ u^{-1}(vZ)}\right] - v + \lambda - \mu = 0 \quad (27)$$

as well as:

$$Z \geq 0, \lambda \geq 0 \quad (28)$$

$$1 - Z \geq 0, \mu \geq 0 \quad (29)$$

with complementary slackness.

Note that, since the first, the second and the third term in brackets of the first FOC are all strictly negative, the above equality cannot prevail, except if $\lambda > 0$ and $\mu = 0$, which implies $Z = 0$. The optimal lockdown under the ex post egalitarian criterion is thus the absence of lockdown, that is, $Z = 0$. That result is in line with what we showed above: Hammond Equity requires a zero lockdown. As a consequence, the ex post egalitarian criterion, which gives absolute priority to the worst-off, implies also a zero lockdown.

Quite interestingly, this policy recommendation is in sharp contradiction with what the utilitarian criterion would recommend. Indeed, under the mild conditions of Proposition 1, utilitarianism implies a strictly positive lockdown level. This lockdown level may also take its maximal level under the conditions of Proposition 2. Those policy recommendations are hardly compatible with what the ex post egalitarian criterion recommends.

This is not the only point of divergence between the two social criteria in the context of a pandemic. There is also a substantial divergence concerning the shape of consumption profiles. As we have seen in Section 3; utilitarianism recommends a flat consumption profile, with young age consumption c being exactly equal to the old age pension benefit b. But such an equality does not hold at the ex post egalitarian optimum.

Indeed, the egalitarian constraint requires, at a zero lockdown level:

$$u(c) = u(c) + u(b) \iff b = \bar{b}$$

where $\bar{b} > 0$ denotes the consumption level that makes the person, in the absence of lockdown, indifferent between life and death. By definition, we have $u(\bar{b}) = 0$. We thus have that the old-age pension benefit is, in the light of the egalitarian constraint, reduced to the level $\bar{b}$.

Hence, consumption at the young age satisfies:

$$c = \frac{F(N,0)}{N} - S\left(\sqrt[2]{M}, 0\right) u^{-1}(0) = \frac{F(N,0)}{N} - \breve{S}\bar{b} \tag{30}$$

Under general conditions, we have that $\frac{F(N,0)}{N} - \breve{S}\bar{b} > \bar{b}$, which implies that the ex post egalitarian optimum involves a decreasing consumption profile with the age. That policy recommendation is in sharp contrast with what utilitarianism recommends.

The intuition behind that policy recommendations goes as follows. The government has here, as an objective, to maximize the well-being of the worst-off ex post. Those worst-off individuals are, under mild conditions (see above), the persons who die prematurely, before reaching the old age. Those persons cannot be identified ex ante, because no one knows who will be long-lived or short-lived. Moreover, once individual durations of life are revealed, it is generally too late to compensate the disadvantaged (because he is already dead). However, despite those difficulties, it is possible for a government to improve the situation of the worst-off, by transferring resources at young ages of life, in such a way as to increase the consumption of all young individuals. By proceeding in that way, the government will also, indirectly, improve the lives of the persons who will turn out to be short-lived. Hence, consumption profiles decreasing with the age are part of a strategy in order to improve the situation of the worst-off (see Fleurbaey et al 2014).

Proposition 6 summarizes our results.

Proposition 6 *The ex post egalitarian social optimum involves zero lockdown $Z = 0$, as well as a decreasing consumption profile with the age: $c > b$.*

Proof. See above. ■

Proposition 6 points to two major reasons why the strong lockdown imposed during the COVID-19 epidemic violated Hammond Equity, against the interests of the worst-off.

First, giving priority to the worst-off recommends to impose zero lockdown, contrary to the policies carried out around the world in Spring 2020. Clearly, those policies aimed at saving lives, and as many lives as possible, but this objective goes against Hammond Equity, since leads to deteriorate the living standards of individuals at the young age, and who will turn out to be short-lived (because of the epidemic or because of other causes).

Second, giving priority to the worst-off requires to impose decreasing consumption profiles with age. However, the large economic crisis that followed the Great Lockdown had, as a major consequence, to reduce incomes and consumption possibilities *especially for young adults*. This goes against the interests of worst-off individuals, since reducing consumption possibilities at the young age also deteriorates the situation of individuals who will turn out to be short-lived.

7 Concluding remarks

During the Spring 2020, a large number of countries around the world implemented more or less strict lockdown policies, aimed at saving lives in the context of the COVID-19 pandemic. Whereas a large economic literature is dedicated to the measurement of the economic and social consequences of lockdown policies, this paper focused on a particular aspect of the design of lockdown policies: their robustness to the postulated social welfare criterion. We proposed here an exploration of possible normative foundations for lockdown policies in the times of COVID-19.

Using a dynamic model of the human lifecycle with risky lifetime, this paper characterized the optimal lockdown strategy under several distinct social welfare criteria. Our main result consists of the lack of robustness of the optimal lockdown strategy to the underlying ethical criterion. Utilitarianism recommends, under mild conditions, a strictly positive lockdown level, which reduces average welfare at a given period of time, but contributes to save lives, and, hence, to improve social welfare. We also showed that, under other, stricter conditions, the utilitarian criterion leads to some COVID-19 variant of Parfit's (1984) Repugnant Conclusion in population ethics: for any non-maximal lockdown that leads to a low average well-being at a given point in time, there exists always a stricter lockdown that reduces average well-being even more, but which raises aggregate welfare. Under some conditions, utilitarianism tends to rationalize maximal lockdown, even though it goes against the average welfare of the people living at any time period.

This paradoxical result is not the only problem faced by utilitarianism in the context of a pandemic. Actually, we showed that this social criterion does not satisfy Hammond Equity, that is, it leads to an allocation where the interests of the worst-off are not maximized. Actually, in the context of a pandemic, Hammond Equity would require zero lockdown, on the grounds of preserving the quality of life of the persons who turn out to be short-lived (either because of the epidemic or because of other causes). Thus Hammond Equity would recommend zero lockdown, against utilitarianism, and also against policies carried out around the world in the Spring 2020. The Great Lockdown has thus played against the interests of the worst-off.

Quite interestingly, there exists a fundamental dilemma between Hammond

Equity and the objective of saving lives, as formalized by the Survivors Number Count Axiom (Fleurbaey and Ponthiere 2013), which justifies a general rise in preventive efforts (like the lockdown) provided this contributes to save at least one life with certainty, while leaving material conditions unchanged. The Survivors Number Count Axiom would lead, in the hypothetical case where the lockdown would leave the production process unaffected, to the maximal lockdown, whereas Hammond Equity would, in that case, recommend zero lockdown, to avoid the utility loss of lockdown for the young individuals, who include the persons who will turn out to be short-lived. There exists a fundamental dilemma between saving lives and caring about the worst-off. That ethical dilemma is worth being underlined at the time where countries around the world keep on fighting against the COVID-19 epidemic.

Following the violation of Hammond Equity by utilitarianism, we gave up the utilitarian social criterion, and we characterized optimal lockdown under the ex post egalitarian criterion, which gives priority to the worst-off ex post, and, hence, does justice to Hammond Equity. We showed that the ex post egalitarian optimum involves no lockdown, contrary to what utilitarianism recommends. But that alternative social optimum involves also decreasing consumption profiles with age, in such a way as to minimize the welfare loss due to a premature death. This last result points to a strategy against the epidemic that has not been explored: modifying consumption profiles in such a way as to improve the situation of the unlucky individuals who will turn out to die prematurely.

All in all, this paper highlights the difficulty to find solid ethical foundations for lockdown policies. True, those policies can save lives, which makes these appealing in the context of a serious epidemic like COVID-19. But at the same time, lockdown policies reduce consumption possibilities, and involve direct disutility for the population. Whereas it is tempting to regard those other aspects as "second-order" aspects, these are actually quite fundamental, since both consumption possibilities and direct disutility of lockdown determine the lifetime welfare of individuals who will die prematurely, because of the pandemic or because of other causes. Without any doubt, the weight assigned to the worst-off determines the extent to which a lockdown is socially desirable, and, if yes, how large it should be. This paper, by highlighting the lack of robustness of optimal lockdown to the underlying ethical criterion, underlines that the design of lockdown policies remains, even in periods of crises, a matter of social choice. Normative foundations behind those policies are far from obvious, and these should definitely be more discussed within the public debate.

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