Public and private incentives for self-protection

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Abstract

Governments sometimes encourage or impose individual self-protection measures, such as wearing a protective mask when going outside during an epidemic. However, by reducing the risk of being infected by others, more self-protection may lead each individual to go outside more often. In the absence of lockdown, this creates a "collective offsetting effect", since more people outside means that the risk of infection is increased for all. Yet, wearing masks also creates a positive externality on others, by reducing the risk of infecting them. We show how to integrate these different effects in a simple model, and we discuss when self-protection efforts should be encouraged (or deterred) by a social planner.

1 Introduction

This note considers an economy where citizens enjoy going outside, though this increases the risk of catching, and spreading, a disease. In this economy, we examine the impact on welfare of a compulsory self-protection regulatory measure, such as wearing a mask. In a society without any lockdown, one may argue that imposing that people wear masks is socially beneficial, as it may reduce infection rates (Abaluck et al. 2020). Indeed, several countries

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have made it mandatory to wear masks in public in face of Covid-19.[1] This note calls for a more detailed analysis.

One may first wonder why governments interfere in self-protection decisions that are normally left to each individual sovereignty. Therefore, the first issue to be clarified is the dual role of a mask: it protects the wearer from being infected by others, but it may also protect others from being infected by the wearer. The latter is a positive externality that justifies a public intervention.

A second step is to take into account that agents adapt their behavior to the regulatory measure. Indeed, since wearing a protective mask decreases the risk that an individual catches the disease, it may in turn incite this individual to go more often outside, or more generally to increase his exposure to risk. This offsetting effect refers to the well-known Peltzman (1975)'s article about car seatbelts. This effect by itself cannot reduce the individual's welfare since the risk exposure (e.g., the time spent outside, or the driving speed) is optimally chosen by the individual.

Things become even more complex when taking into account the collective nature of an epidemic. Indeed, the probability that an agent becomes infected depends not only on the time he spends outside, but also on how much time other agents spend outside. This generates a "collective offsetting effect": since *everybody* has an extra incentive to go outside when wearing a mask, it becomes theoretically possible that such a compulsory increase in individual self-protection eventually hurts welfare (even if masks are costless), once these behavioral responses are taken into account.

We develop a model to evaluate these different effects, in the spirit of Hoy and Polborn (2015) (see the related literature below). A key role is played by the probability of being infected, which depends on four variables: the agent's choice of risk-exposure (i.e., how much time spent outside), the agent's compulsory level of self-protection, and the same two variables averaged on the general population.

We show that the collective offsetting effect may or may not increase the probability of infection, depending on the elasticity of risk-exposure with respect to the probability of getting infected. We also characterize when public incentives for self-protection exceed private incentives. This is the case

[1] In April 2020, such countries include Austria, Cameroon, Chad, the Czech Republic, Equatorial Guinea, Gabon, Luxembourg, Morocco, the Philippines, Singapore, Slovenia, Taiwan, and some provinces in China and Italy. During the 1918 flu pandemic, wearing a mask was made compulsory in some parts of the US.

in particular when the above elasticity is not too high (so that the collective offsetting effect is not too strong), and self-protection is asymmetrical, i.e. the benefits from wearing a mask are borne by other agents more than by the wearer.

We finally note that these results may help to evaluate the impacts of other self-protection devices such as seatbelts in transport, helmets in sports (Schelling 1973), or anti-infection drugs (such as the PrEP for HIV) in health for instance.

1.1 Related literature

Peltzman (1975) finds that people adjust their behavior in response to the perceived level of risk, becoming less careful if they feel more protected. He shows empirically that imposing seatbelts to drivers led to an increase in the number of car accidents, thus offsetting the benefit of the reduction in accident severity. Similarly, Viscusi (1984) examined the impact of a Food and Drug Administration (FDA)'s regulation imposing child resistant packaging on drugs, and provided evidence that parents reacted by increasing children's access to drugs. In a recent contribution, Chong and Restrepo (2017) review the empirical literature on the Peltzman effect.

Hoy and Polborn (2015) study the impact of a better self-protection technology in a general strategic model with externalities. They derive conditions on the model's primitives under which an improved technology increases or decreases players' equilibrium utilities. We extend their analysis by comparing private and public incentives to self-protect, and by considering that self-protection may also help protect others (as is the case with masks). Gossner and Picard (2005) also study the value of an improvement risk protection (i.e. road safety) in the presence of an offsetting effect. However, in their model, the interaction across agents does not come from individual self-protection efforts, but from a financial externality through the insurance market.

Finally, several papers (e.g., Shogren and Crocker 1991, Muermann and Kunreuther 2008, Lohse et al. 2012) examine a collective self-protection model where the probability that an agent faces a damage depends on his own as well as others' actions as a result of a Nash equilibrium. However, these papers do not specifically study how a better self-protection technology affects this probability, and in turn affects the agents' behavioral response and welfare.

2 A simple model

Preferences For a representative individual, the basic trade-off is between spending time x outside, with utility $u(x)$, and reducing the probability p of being infected, with a utility cost that we normalize to one. The self-protection level a allows to reduce this probability, but it is costly. Overall, an agent's preferences are represented by the following function of four variables:

$$u(x) - c(a) - p(x, X, a, A).$$

We assume that u is strictly concave, and that c is weakly convex, with suitable Inada conditions. The key role is played by the probability function p. It is assumed twice differentiable. It increases with the choice of risk-exposure x, and also with the other agents' choice X of the same variable. Similarly, it is reduced by the self-protection effort a, and also by the other agents' self-protection efforts A. Later on, we shall specialize this function as follows:

Assumption 1 *Let* $p(x, X, a, A) = x^{\beta+1} X^{\gamma} q(a, A)$, *with* $\beta, \gamma \geq 0$, *and function* q *decreasing in both arguments.*

One justification is as follows. The variables x and X determine the number of meetings, or interactions, between the agent under consideration, and the other agents. A multiplicative form is natural, as is assumed in simple epidemiological models such as the S-I-R model. The latter model typically focuses on the linear case when $\beta = 0$ and $\gamma = 1$, and we slightly generalize it to allow for non-linearities. The function q is not necessarily symmetrical: one may protect others by wearing a mask, without being protected from others' infections.[2] The relative importance of these two effects will be measured by the ratio q_A/q_a.

Individual decisions Given his environment, as characterized by the values of A and X, an agent chooses a and x by maximizing utility, with first-order conditions (subscripts denote partial derivatives)

$$u'(x) = p_x(x, X, a, A) \qquad - c'(a) - p_a(x, X, a, A) = 0.$$

[2] Note that the degree of self-protection is modeled as a continuous variable. For masks, one may think about the proportion of time when a mask is worn, or about an approximation for the existence of various types of masks (e.g., home made cloth masks, surgical masks or N95 respirators). Note that in general when a mask is more protective to the wearer, it is also more protective to other agents.

The first condition defines a choice x as a function of a; this function is increasing under Assumption 1. This is the Peltzman (1975)'s effect: a higher level of self-protection the agent increases his risk-exposure when the environment becomes safer. This also invites us to define ε as the elasticity of the risk-exposure x with respect to the probability of infection, by the usual equality:[3]

$$\varepsilon = -\frac{u'(x)}{xu''(x)}.$$

The second condition is active only when a is not a compulsory requirement. It will be used to compare private and public incentives for self-protection.

Policy and equilibrium Consider a continuum of identical agents, with the above preferences. A social planner imposes the value of a, so that $A = a$. Each agent reacts accordingly by choosing x, as explained above. Because each such choice depends on the other agents' average choice X, one has to characterize a Nash equilibrium. Under standard regularity assumptions, and in particular under Assumption 1, there exists a unique Nash equilibrium $x(a)$ for each value of a, and it is characterized by the following equality:

$$u'(x(a)) = p_x(x(a), x(a), a, a).$$

It is easily checked that under Assumption 1, $x(a)$ is increasing with a. This is the collective offsetting effect: when everybody wears a mask, everybody is tempted to go outside more often, and the equilibrium organizes all these decisions in a consistent way.

Effect of the policy on the equilibrium probability of infection The equilibrium probability of infection

$$p^*(a) \equiv p(x(a), x(a), a, a)$$

depends on the policy a, as follows:

$$p^{*\prime}(a) = (p_a + p_A) + (p_x + p_X)x'(a).$$

[3]More precisely, this is the elasticity of risk-exposure with respect to the marginal probability of infection for an additional unit of time spent outside, i.e. p_x. From the first-order condition, we can indeed write the demand function D defined by $u'(D(z)) = z$, where z plays the role of p_x. We then get $\varepsilon = -\frac{zD'}{D} = -\frac{z}{Du''}$.

The first term in parenthesis is negative: it is the direct effect of imposing a to all agents. But the second term is the collective offsetting effect, and it goes in the opposite direction. In general, the comparison is ambiguous, but we can provide a more clearcut result, as follows:[4]

Proposition 1 *Under Assumption 1, the equilibrium probability of infection p^* decreases with the compulsory self-protection effort a if and only if the elasticity of risk-exposure with respect to the probability of infection is less than one, i.e. $\varepsilon < 1$.*

The result is intuitive: if people's reaction to an increase in a in terms of risk-exposure is sufficiently strong then it may more than offset the impact of a so that the probability of infection may eventually increase in the economy. Importantly, note that the result only depends on a single parameter, ε.[5] Hence, even if others' behaviors do not affect the probability of infection, i.e. $\gamma = 0$, the result still depends on the same condition on ε capturing the individual reaction to a change in a. This proposition raises the question of how to estimate in practice the elasticity of risk-exposure with respect to the probability of infection.

Public vs. private incentives for self-protection In a welfarist vision of the world, a public policy should be maximizing welfare, which is in general not equivalent to minimizing the probability of infection. Here, welfare is

$$W(a) = u(x(a)) - c(a) - p(x(a), x(a), a, a),$$

so that, thanks to the envelope theorem:

$$W'(a) = -c'(a) - p_a - p_A - p_X x'(a).$$

The first two terms measure the private incentive for self-protection, as observed in the paragraph on individual decisions. The public policy should support or deter self-protection, according to the sign of the remaining terms. The direct effect $(-p_A)$ is positive: this is the positive externality of wearing a mask, normally justifying a public policy. But the collective offsetting effect

[4] The Propositions are demonstrated in the appendix.

[5] The knife-edge case $\varepsilon = 1$ corresponds to $u(x) = \log x$, for which a change in a has no impact on the probability of infection.

goes once more in the opposite direction: masks lead people to increase their risk-exposure.

To go further, we use our assumption regarding the shape of the probability. We obtain:

Proposition 2 *Under Assumption 1, public policy should support self-protection if and only if the following inequality holds:*

$$\frac{\gamma}{\beta + 1/\varepsilon} < \frac{q_A}{q_a}(a, a).$$

The left-hand side is a measure of the elasticity of behavior. In particular, when the probability of infection is simply proportional to x (i.e., $\beta = 0$) and X (i.e., $\gamma = 1$), then this term reduces to the elasticity ε. The right-hand side is the ratio of the strength of the positive externality q_A, to the strength of the self-protection effect q_a. In a symmetrical case, the two effects are equivalent, and then we would be back to the inequality $\varepsilon < 1$. To illustrate the inequality, we further discuss a few simple cases.

The case when individuals do not react When risk-exposure is fixed, approximated here by $\varepsilon \to 0$, then the positive externality alone ($q_A < 0$) justifies a public support to self-protection. More generally, a decrease in ε increases public support.

The case when the offsetting effect is purely individual This case corresponds to a probability of infection that does not depend on X, i.e. $\gamma = 0$. In that case, a public policy is also justified. The effect on the probability of infection still depends on the same comparison of ε to 1. More generally, a decrease in γ increases public support.

The case when self-protection does not protect others In standard self-protection cases, such as for seatbelts or helmets, there is no positive externality associated with self-protection, i.e. $q_A = 0$.[6] In those cases, public policy should not support individual self-protection, but rather deter it in fact. This holds as soon as there is a strictly positive collective offsetting effect through $\gamma > 0$, which makes everyone increasing risk exposure at an over-optimal collective level.

[6] We exclude here the externalities passing through the health system.

3 Conclusion

We have discussed whether individual self-protection measures should be publicly encouraged in a situation where self-protection induces both externalities and offsetting effects. We have shown that this should be the case when the collective offsetting effect is not too strong. We have also shown that this depends on the respective strength of the two-sided impact of self-protection: protecting oneself and protecting others.

We finally emphasize several assumptions of our analysis that limit its practical policy relevance in face of an epidemic such as Covid-19. First, we assume that the government can control individual self-protection measures such as wearing a mask in public but cannot control individual risk-exposure such as the time spent outside by citizens. Hence, we essentially consider a post-lockdown economy where people can go outside freely, and in which (costly) masks are made available and possibly compulsory for everyone.

Second, we assume that individuals correctly perceive the risks. Yet, if the public for instance overestimate the efficacy of the mask as a protective technology, individuals may mistakenly over-expose themselves to the risk because of a "feeling of safety". This may call for public intervention (Salanié and Treich, 2009).

Third, as in Hoy and Polborn (2015), we consider a continuum of identical agents. In particular, we do not keep track of the health status (susceptible or infected) of agents. Embedding the analysis in a fully dynamic epidemiological model would be much more complex.[7]

Finally, there are certainly other (positive) externalities associated with going outside during an epidemic. The deployment of masks in public areas and workplaces may help the global economy restart with benefits for all (Polyakova et al. 2020). Hence, our study only enlightens a few specific facets of a much broader and complex economic problem.

[7]See Geoffard and Philippon (1996) for how to identify the impact of self-protection efforts on the dynamics of an epidemic.

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Proof Appendix:

The proofs of Propositions 1 and 2 simplify the general equations in the text, by applying Assumption 1. The Nash equilibrium outcome $x(a)$ is characterized by

$$u'^{\beta+\gamma}q(a,a),$$

so that the derivative $x'(a)$ is given by:

$$x'(a)\left[u'' - (\beta+1)(\beta+\gamma)x^{\beta+\gamma-1}q\right] = (\beta+1)x^{\beta+\gamma}(q_a+q_A).$$

Now, from the definition of ε and the first-order condition, one has

$$u'' = -\frac{u'}{x\varepsilon} = -\frac{p_x}{x\varepsilon} = -\frac{1}{\varepsilon}(\beta+1)x^{\beta+\gamma-1}q,$$

so that

$$x'(a)\left[-\frac{1}{\varepsilon} - (\beta+\gamma)\right] = x\frac{q_a+q_A}{q}.$$

Because q is decreasing with both arguments, this shows that $x(a)$ is increasing. The derivative of the probability p^* with respect to a is

$$x^{\beta+1+\gamma}(q_a+q_A) + x'^{\beta+\gamma}q$$

and has the same sign as

$$x(q_a+q_A)(\frac{1}{\varepsilon}+\beta+\gamma) - (\beta+1+\gamma)qx\frac{q_a+q_A}{q}$$

which has the same sign as

$$\beta+1+\gamma-(\frac{1}{\varepsilon}+\beta+\gamma) = 1-\frac{1}{\varepsilon}.$$

This shows Proposition 1. For Proposition 2, the difference between public and private first-order conditions equals

$$-p_A - p_X x'^{\beta+\gamma}[-xq_A - \gamma q x']$$

which has the same sign as

$$-q_A + \frac{\gamma}{\frac{1}{\varepsilon}+\beta+\gamma}(q_a+q_A)$$

from which we get the inequality in the Proposition.