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 in public during an epidemic. However, by reducing the risk of being infected by others, more self-protection may lead each individual to go outside the house 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. However, 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 the house, 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 public. While several countries

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have adopted such policies in the hope of limiting infection rates for the COVID-19, this note calls for a detailed analysis of these policies.

One may first wonder why governments interfere in self-protection decisions that are normally left to 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 the house, or the driving speed of the car) 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.

In this note, 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 across the general population.

Our paper uses a particular (but fairly general) parametrization of this probability of infection to characterize the risk and welfare consequences of a policy mandate that individuals adopt a level of self-protection. Superficially, it might seem obvious that: (i) mandating protection will lower aggregate risk; and (ii) because of the externalities, a mandate will, at the margin, improve welfare. The paper shows that neither (i) nor (ii) is true, in general.

More specifically, we obtain two main results. First, whether an increase in the mandatory level of self-protection reduces or increases the equilibrium probability of infection depends only on the value of the demand elasticity of risk-exposure with respect to the marginal probability of getting infected. The generality of this result is striking, and it vindicates the view that behaviors matter more than technologies. Indeed, the equilibrium effect on the probability of infection does not depend on the protection offered by a mask, to the mask wearer or to other agents, or on how frequently people meet when they spend time outside.

Second, we characterize when public incentives for self-protection exceed private incentives. This is the case 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.

A general conclusion is that a public policy that relies only on mandatory self-protection may turn out to be ineffective, or even counter-productive. This may explain why public policies against the current pandemic often rely both on mandatory mask wearing, and on social distancing (or lockdowns). We also 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 the use of condoms or anti-infection drugs (such as the PrEP for HIV) in health for instance.

1.1 Related literature

Peltzman (1975) provides support for the idea 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) examines the impact of a Food and Drug Administration (FDA)'s regulation imposing child resistant packaging on drugs, and provides 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 in 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 the house, 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. We make the following functional form assumption:

Assumption 1 *Let $p(x, X, a, A) = x^{\beta+1}X^{\gamma}q(a, A)$, with $\beta, \gamma \geq 0$, and function $q > 0$ 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 many matching models, or in simple epidemiological models such as the S-I-R model (see Garibaldi et al., 2020.) 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.[1] The relative importance of these two effects will be measured by the ratio q_A/q_a. This ratio may be high for masks, but it may take different values for other decisions such as wearing gloves (probably a low value for this ratio) or washing his hands (maybe a more symmetric case in which the ratio is close to one). We do not claim expertise here. Our contribution will be to show that this ratio plays a key role in the study of efficient policies.

Remarks on self-insurance vs. self-protection Under the general form

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

there is no distinction between self-insurance and self-protection. Indeed, p can be interpreted as the product between the probability of an accident and the loss in utility associated to this accident. Therefore, whether a multiplicative shock impacts the probability or the loss is irrelevant: the comparative statics exercise is formally identical.

A related remark is that the two decisions a and x play symmetrical roles, and in fact $(-x)$ can be seen as a costly self-protection effort.[2] We only depart from this symmetrical approach when we formulate Assumption 1, which is based on an analysis of infection probabilities, and not on an evaluation of damages; and when we consider that the policy imposes a mandatory level for a, and not for x.

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

$$u'(x) = p_x(x, X, a, A) \qquad - c'(a) - p_a(x, X, a, A) = 0. \tag{1}$$

[1] Note that the degree of self-protection a 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.

[2] We thank an anonymous referee for this remark.

The second first-order condition is active only when a is not a compulsory requirement, namely when a is a voluntary decision made by the individual. It will be used to compare private and public incentives for self-protection. The first condition defines a choice x as a function of a; this function is increasing. This emphasizes an individual offsetting effect: a higher level of self-protection makes the agent increase his exposure to risk (this effect is quite general and does not depend on the specific functional form in Assumption 1.) This condition also invites us to define ε as the elasticity of the risk-exposure x with respect to the marginal probability of infection p_x, by the equality:

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

3 Policy and equilibrium

Consider a continuum of identical agents, with the above preferences. A social planner imposes the value of the self-protection effort a to some mandate $\overline{a}$, so that $A = a = \overline{a}$.[3] 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:

$$u'(x(a)) = p_x(x(a), x(a), a, a). \tag{2}$$

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

[3] For the sake of simplicity, we do not allow the agents to go beyond the mandate by choosing $a > \overline{a}$. This avoids studying a system of two first-order conditions, and this allows us to reduce the number and complexity of assumptions. For the same reason, we do not study corner solutions, by assuming Inada conditions.

3.1 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:

$$\frac{dp^*}{da}(a) = (p_a + p_A) + (p_x + p_X)x'(a).$$

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. Using Assumption 1, we can provide a 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 idea that equilibrium infection rates are impacted by individual behaviors is intuitive: if behaviors react strongly to a mandate on masks, these rates may even increase. What is remarkable is that in equilibrium, only these behaviors matter, as captured by the elasticity ε. For example, in the knife-edged case $u(x) = log(x)$, so that $\varepsilon = 1$, the mandate has absolutely no effect on the equilibrium rates of infection. More generally, the equilibrium rates of infection do not depend on the cost of masks, on whether they are effective to protect oneself or others, or on the particularities of the meeting process, as captured by the values of β and γ. This result therefore underlines the fundamental role of behaviors, in contrast with technologies. It calls for more empirical investigations of the value of the elasticity ε.

3.2 Public vs. private incentives for self-protection

In a welfarist vision of the world, a public policy should aim at maximizing welfare, which is in general not equivalent to minimizing the probability of infection. Here, welfare is

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

[4] The proofs of the Propositions are given in the Appendix.

so that, thanks to the envelope theorem:

$$W'(a) = (-c'(a) - p_a) + (-p_A - p_X x'(a)). \tag{3}$$

The first two terms measure the private incentive for self-protection, as observed in the paragraph on individual decisions (see (1)). 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 (due to others' reaction) 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 mandatory 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 favors 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.[5] The effect on the

[5] It may seem strange at first that public policy is justified even if others' risk exposure does not affect its own infection probability. However, note that there are still externalities through others' self-protection choices A, justifying policy intervention.

probability of infection still depends on the same comparison of ε to 1. More generally, a decrease in γ increases public support. This case also emphasizes the opposing effect of γ and β, namely the parameters that control the impact of others' and its own risk exposure choices on the infection probability.

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.

3.3 The first-best case

We conclude the analysis with a remark about the first-best case, i.e., when the social planner can choose both a and x. This case is defined by maximizing over a and x the social objective

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

with the following two first-order conditions:

$$u'(x) - p_x - p_X = 0 \qquad - c'(a) - p_a - p_A = 0. \tag{4}$$

It is useful to compare these conditions to those derived precedently when the social planner can only control a. The extra negative term $(-p_X)$ in the first condition in (4) compared to (2) emphasizes that the first-best policy accounts for the negative externality induced by going outside, thus putting a downward pressure on x. Moreover, observe that the second condition in (4) does not contain the negative term $(-p_X x'(a))$ exhibited in the second-best policy (see (3)). This is because there is no collective offsetting effect in the first-best policy, which puts an upward pressure on a compared to the second-best policy. Overall, one expects a higher value for a and a lower value for x in the first-best, compared to the case we have studied so far in

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

which the social planner could not control x,[7] and thus a reduction in the infection probability.

4 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 in Propositions 1 and 2 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 their home 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. As discussed in subsection 3.3, this is sub-optimal, and one can interpret our results as showing that a simultaneous regulation of both social distancing (lower x) and mask-wearing (higher a) has clear advantages when individual behavior responds to incentives (high elasticities).

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), or for information campaigns that may be effective when citizens hold incorrect beliefs. Our model suggests in particular a novel misperception channel: an individual might misestimate the key ratio q_A/q_a, for instance by believing that wearing a mask protects him while it mostly protects others.

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

[7]Note that the observation of these effects from a one-to-one comparison of each first-order condition is not enough to compare the optimal *levels* of a and x under the first- and second-best policies. This comparison is complex and left for future research.

or infected) of agents. An extension to heterogeneity in a static context, along the lines of Hoffmann and Rothschild (2019), is an interesting topic that we leave for future research. Furthermore, embedding the analysis in a fully dynamic epidemiological model would be interesting but also much more complex.[8]

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.

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[8]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

$$u'(x(a)) = (\beta + 1)x(a)^{\beta+\gamma}q(a, a),$$

so that, using obvious simplifying notations, the derivative $x'(a)$ is given by:

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

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

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

so that

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

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

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

and has the same sign as

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

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

$$-p_A - p_X x'(a) = x(a)^{\beta+\gamma}[-x(a)q_A - \gamma q x'(a)]$$

which has the same sign as

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

from which we get the inequality in the Proposition.