Subsidizing risk prevention

Mario Menegatti¹

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Abstract

This work examines the effects of different kinds of subsidies on risk prevention from a theoretical standpoint. We show that both a subsidy on the cost of prevention activities and a subsidy on wealth have ambiguous effects on the level of present contemporaneous prevention. Similar kinds of subsidies have however increasing effects on the level of advance prevention and, under plausible assumptions, on future levels of contemporaneous prevention. We also show that social security subsidies may have decreasing effects on prevention activities while a kind of reverse social security has an increasing effects on them. This indicates that there is a trade-off between the social security aim of mitigating the negative consequences of bad events and the prevention aim of incentivizing choices which reduce the probability that these bad events occur.

Keywords Prevention · Risk · Subsidy · Social security

JEL Code: D81 · H24

1 Introduction

Prevention is an action or an activity requiring financial, physical or psychological effort, which generates a reduction in the probability that a possible future bad event will occur. Together with insurance, which mitigates the negative effects of bad events but leaves the probability of their occurrence unchanged, prevention is recognized as one of the most important instruments of individual risk management.

The individual benefits of prevention have been widely studied by decision theory, as described below. Beyond these individual benefits, however, there is a growing consensus on the idea that prevention is also beneficial at social level.

✉ Mario Menegatti
mario.menegatti@unipr.it

¹ Dipartimento di Scienze Economiche e Aziendali, Università di Parma, via Kennedy 6, 43123 Parma, Italy

Several examples can be provided. One is disease prevention. The recent COVID pandemic has shown clearly that individual behavior in terms of risk prevention is a crucial element in determining the spread of contagion in the population. Similarly, prevention of diseases related to obesity and smoking has positive effects on health systems. Positive social effects of prevention, however, are not limited to prevention of health risks. For instance, prevention of car accidents has beneficial effects at the individual level but it also helps to keep traffic flow efficient. Similarly, prevention of financial risks has a social impact in lowering the probability of impoverishment and thus the potential need for social security interventions. Lastly, preventing the risk of homelessness has positive effects on crime rates and on the livability of urban areas.

Recognising the social impact of prevention entails that, in many cases, policy interventions aimed at increasing it can be justified and promoted. Significant evidence of subsidies/taxes introduced for this purpose can be found in different fields. For instance, different mixes of subsidies and taxes have been introduced in order to prevent diseases by promoting a healthy lifestyle (e.g. Thow et al. 2018; Zorbas et al. 2020,). Different kinds of measures, involving penalties in case of violations, have recently been introduced in many countries to eliminate behaviors spreading infection in the COVID pandemic (e.g. Bruinen de Bruin et al. 2020). Subsidies are widely used in the prevention of homelessness and housing instability (Brisson and Covert 2015 and Szeintuch 2017). Lastly, specific kinds of subsidies are currently under design to incentivize the use of safety devices, for instance, in the automobile sector.¹

Moreover, the literature compares different types of subsidies/taxes both from an empirical and from a normative perspective, and finds that there are significant differences in the degree of effectiveness of different instruments (e.g. Ludbrook, 2019 and Bruinen de Bruin et al. 2020). Possible limitations on the effectiveness of public intervention aimed at affecting people's behavior were also recently identified in the case of COVID pandemic since the actions implemented by governments and regulators to make people adopt behaviours reducing the spread often had small effect (e.g. Jacobo 2020, Pennycook et al. 2020, Schnell 2020 and BBC 2020).

Despite its significant role, the study of the effects of subsidies or taxes on risk prevention, has, to my knowledge, been completely ignored by decision theory. As noted above, the literature usually defines prevention as a costly activity performed by a decision maker in order to reduce the probability of a future loss, which can be of different nature. A well known approach to studying prevention was proposed in the seminal paper by Ehrlich and Becker (1972), who study an action taken by a decision maker in the same period that he risks incurring the loss. This kind of contemporaneous prevention has been widely studied in works examining the role of different aspects of preference in determining the choice of its optimal level (Dionne and Eeckhoudt 1985; Eeckhoudt and Gollier 2005; Courbage et al. 2017;

¹ See, for instance, for the case of Japan: <https://asia.nikkei.com/Business/Automobiles/Japan-speeds-adoption-of-car-safety-devices-for-aging-drivers>.

Lee 2019) and the effects of changes in risk of different kinds on this level (e.g., Jindapoin and Neilson, 2007, Huang 2012; Crainich et al. 2016).

In a more recent paper, Menegatti (2009) argued that, in many cases, the effort in preventing a risk is made in a time interval which precedes the period where the decision maker faces the risk of incurring the loss.² Various aspects of this advance prevention have also been widely studied in recent years (e.g., Eeckhoudt et al. 2012; Courbage and Rey 2012; Menegatti 2014; Xue and Cheng 2013; Wang and Li 2015).

Lastly, a model where both contemporaneous and advance prevention are introduced together has been analyzed by Hofmann and Peter (2015) and by Menegatti (2018).

As emphasized above, this literature neglects the issue of how different subsidies may affect decision makers optimal choices on prevention activities. The aim of this paper is to fill this gap. We study the issue with reference to both advance and contemporaneous prevention. This will be done by examining contemporaneous prevention in Ehrlich and Becker's (1972) one-period model, advance prevention in Menegatti's (2009) two-period model and in a two-period model which includes both kinds of prevention together.

There are two reasons for studying these different models. The first is the aim to provide a complete analysis of the effects of subsidies, considering all the main frameworks in which prevention has been studied in the literature. The second reason is that we do not know *a priori* whether choices on advance and contemporaneous prevention are made jointly or separately. In fact, as emphasized by the literature on choice bracketing (e.g. Read et al. 1999) people make choices by grouping them in different ways, and it is very difficult to know a priori which choices are made together. In particular, in this respect, choices on advance and contemporaneous prevention may be made both jointly and separately: they may be made jointly as they relate to the same problem and they may be made separately as they are made in different periods. It is thus useful to study them both in separate specific models and together.

In these different frameworks, we consider four different kinds of subsidies potentially affecting prevention: a subsidy reducing the cost of contemporaneous prevention, a subsidy reducing the cost of advance prevention, a subsidy increasing first-period wealth and a subsidy increasing second-period wealth. Moreover, we also analyze the effects of social security subsidies on prevention, and examine a particular variation of these policies. Lastly we briefly discuss the role of the choice on saving, which can be made either together with or separately from the choice on prevention.

The paper proceeds as follows. Sect. 2 studies the effects of subsidies in the one-period model with contemporaneous prevention. Section 3 analyzes the same effects in a two-period model with advance prevention. Section 4 considers both advance and contemporaneous prevention together. Section 5 studies social security subsidies. Section 6 concludes.

² Menegatti (2009) provides examples which illustrate the difference between advance and contemporaneous prevention.

2 Contemporaneous prevention

In this section we examine the effect of subsidies on contemporaneous prevention, which is introduced as the sole instrument of risk management used by a Decision Maker (henceforth DM). For this purpose we consider a standard one-period framework á la Ehrlich and Becker (1972).

Consider, in particular, a DM whose preferences are represented by the utility function $U(x)$, which exhibits non-satiation ($\frac{\partial U}{\partial x} = U'(x) > 0$) and risk aversion ($\frac{\partial^2 U}{\partial x^2} = U''(x) < 0$). The DM has an initial wealth equal to W and faces the risk of incurring a loss L with probability p (i.e. his wealth remains W with probability $1 - p$ and becomes $W - L$ with probability p). We also assume that the DM can exert a costly effort to reduce the probability of incurring the loss. This implies that p is a function of the effort e as $p = p(e)$ and $\frac{dp}{de} = p'(e) < 0$. Effort e has a unit cost c and is exerted in the same period where the loss may occur. Many papers in the prevention literature assume that this function is convex, but it is worth noting that many other papers in the same field assume linearity (e.g. Eeckhoudt and Gollier 2005; Menegatti 2009; Eeckhoudt et al. 2012; Hofmann and Peter 2015; Wang and Li 2015; Crainich et al. 2016; Courbage et al. 2017). Moreover, the assumption that cost is linear is specifically relevant for this paper since it makes possible to clearly study the effects of a subsidy on the cost of prevention, which can simply be examined by analyzing a reduction in parameter c .³ Lastly, in this model everything takes place in one period and prevention is contemporaneous to the potential loss.

In this context, the DM chooses effort e in order to solve the following maximization problem:

$$\max_e V(e) = p(e)U(W - L - ce) + [1 - p(e)]U(W - ce) \quad (1)$$

The first-order condition (FOC) of this problem is:

$$\begin{aligned} p'(e)[U(W - L - ce) - U(W - ce)] - c[p(e)U'(W - L - ce) \\ + [1 - p(e)]U'(W - ce)] = 0 \end{aligned} \quad (2)$$

The second-order condition (SOC) of the problem is:

$$\begin{aligned} p''(e)[U(W - L - ce) - U(W - ce)] - 2cp'(e)[U'(W - L - ce) - U'(W - ce)] \\ + c^2[p(e)U''(W - L - ce) + [1 - p(e)]U''(W - ce)] < 0 \end{aligned} \quad (3)$$

We assume that the SOC is satisfied.⁴

Given (2) we can study the effect of different kinds of subsidies on prevention. We consider two instruments: a subsidy on effort cost (i.e. a subsidy reducing c) and

³ On the contrary, in case of a convex cost function, it would be more complex (and maybe partially arbitrary) to choose how the subsidy would act on prevention cost.

⁴ It is easy to see that the usual assumption of risk aversion is not sufficient to ensure that the SOC is satisfied. For this reason, in models of prevention, it is usual to directly assume that the SOC holds. Notice that a similar reasoning can be made for models in Sects. 3 and 4.

a subsidy on wealth (i.e. a subsidy increasing W). In order to implement this analysis we totally differentiate (2). We have that:

$$V_{ee}de + V_{ec}dc = 0 \quad (4)$$

where $V_{ij} = \frac{\partial^2 V}{\partial i \partial j}$, which implies

$$\frac{de}{dc} = -\frac{V_{ec}}{V_{ee}} \quad (5)$$

Similarly we have:

$$V_{ee}de + V_{eW}dW = 0 \quad (6)$$

which implies

$$\frac{de}{dW} = -\frac{V_{eW}}{V_{ee}} \quad (7)$$

Since $V_{ee} < 0$ by the second-order condition we have that the sign of $\frac{de}{dc}$ is the same as the sign of V_{ec} and the sign of $\frac{de}{dW}$ is the same as the sign of V_{eW} . Given this, we have:

$$\begin{aligned} V_{ec} = & -ep'(e)[U'(W - L - ce) - U'(W - ce)] - p(e)U'(W - l - ce) \\ & - [1 - p(e)]U'(W - ce) \\ & + ce[p(e)U''(W - L - ce) + [1 - p(e)]U''(W - ce)] \end{aligned} \quad (8)$$

and

$$\begin{aligned} V_{eW} = & p'(e)[U'(W - L - ce) - U'(W - ce)] - c[p(e)U''(W - L - ce) \\ & + [1 - p(e)]U''(W - ce)] \end{aligned} \quad (9)$$

The sign in both Eqs. (8) and (9) is ambiguous. This implies that:

Proposition 1 *Both a subsidy reducing the cost of prevention and a subsidy increasing wealth have ambiguous effects on contemporaneous prevention.*

The explanation for both results reflects that both kinds of subsidies generate conflicting effects on DM's incentive to exert effort in prevention. To examine these effects we start from the analysis of the subsidy increasing wealth. The first effect of greater wealth is that the DM has more resources to spend on prevention. In this direction, thus, greater wealth pushes the DM to increase prevention since the marginal cost of effort is lower. But on the other hand, greater wealth also implies a mitigation of the negative consequences of the occurrence of loss L , since the reduction in utility due to the loss is lower when the DM is wealthier. This second effect pushes the DM to reduce effort in prevention. It is not possible to determine *a priori* which of the two effects prevails, so the overall effect of the subsidy is ambiguous.

Similar reasoning can be made in the case of a subsidy which reduces the cost of prevention. The reduction in this cost clearly determines an incentive to increase

effort since it is a direct reduction in its marginal cost. But, on the other hand, the reduction in this cost also generates an increase in DM's wealth, which causes the effects described above, and, in particular, the incentive to reduce effort in prevention due to the mitigation of the reduction in utility suffered in case of loss. This implies again an ambiguous total effect.

It is worth noting that the effects described are partially similar to those found, in a different context, by Jaspersen and Richter (2015). Jaspersen and Richter in fact show that insurance premium subsidies have ambiguous effects since they can generate an increase in moral hazard by reducing the sensitivity of the insured towards the monetary consequences of losses. Moreover, in a more general sense, the opposing effects described above are also related to two other well-known trade-offs. On one hand, insurance literature showed the trade-off between making optimal risk sharing and avoiding moral hazard, which is also at the basis of some much used contractual instruments, such as deductible and coinsurance (see, for instance, Winter 2013). On the other hand, the law and economics literature on liability for accidental harm (torts) recognizes a tension between providing optimal incentives for deterrence/prevention and optimal compensation (see, for instance Shavell, 1987 and Polinsky and Shavell 2007).

Lastly notice that one of the ambiguous effects highlighted in Proposition 1 can be unambiguously determined in one specific case. In fact, it is easy to see that the second addend of the right-hand side of (9) would be null if the DM were risk neutral (i.e. if the utility function were linear). This implies that, when function $U(\cdot)$ is close to a linear function (which generally implies that the DM is very weakly risk averse),⁵ $V_{eW} < 0$, implying, in turn, $\frac{de}{dW} < 0$ and that a subsidy on wealth reduces contemporaneous prevention. On the other hand, the ambiguous effect of a subsidy on prevention cost shown in Proposition 1 still holds even when function $U(\cdot)$ is close to linearity.

3 Advance prevention

We now examine the effect of subsidies on advance prevention, which is introduced as the sole instrument of risk management used by the DM, by considering the two-period framework first studied by Menegatti (2009).

For this purpose, we consider a model similar to that studied in Sect. 2. The only difference we introduce is that the effort in prevention is exerted in a period which precedes the period when the DM faces the risk of incurring the loss L . We thus have a two-period framework where effort is made in the first period and the risk is faced in the second period. We assume that the utility function is additively separable between the two periods. This assumption clearly implies possible limitations for the results but is usual in many two-period models studying optimal choice under risk (see, for instance, Gollier 2001) and is standard in two-period

⁵ A typical measure of the degree of risk aversion is the Arrow-Pratt index of absolute risk aversion $-\frac{U''(\cdot)}{U'(\cdot)}$. For many utility functions a very low value of the index implies the utility function to be close to a linear function.

models of prevention (e.g. Menegatti 2009; Eeckhoudt et al. 2012; Hofmann and Peter 2015; Wang and Li 2015 and Courbage et al. 2017).

In this context, the DM chooses effort e in order to solve the following maximization problem:

$$\max_e U(W_0 - ce) + p(e)U(W_1 - L) + [1 - p(e)]U(W_1) \quad (10)$$

where W_0 is first-period wealth, W_1 is second-period wealth and L is the potential loss. The FOC of this problem is

$$-cU'(W_0 - ce) + p'(e)[U(W_1 - L) - U(W_1)] = 0 \quad (11)$$

The SOC of the problem is:

$$c^2U''(W_0 - ce) + p''(e)[U(W_1 - L) - U(W_1)] < 0 \quad (12)$$

We again assume that the second-order condition is satisfied.

Given (11) we can study the effect of three kinds of subsidies on prevention: a subsidy on effort cost (i.e. a subsidy reducing c), a subsidy on first-period wealth (i.e. a subsidy increasing W_0), and a subsidy on second-period wealth (i.e. a subsidy increasing W_1). The same steps as described in Sect. 2 imply that the sign of $\frac{de}{dc}$ is the same as the sign of V_{ec} , the sign of $\frac{de}{dW_0}$ is the same as the sign of V_{eW_0} and the sign of $\frac{de}{dW_1}$ is the same as the sign of V_{eW_1} . Given this, we have:

$$V_{ec} = -U'(W_0 - ce) + ceU''(W_0 - ce) < 0 \quad (13)$$

$$V_{eW_0} = -cU''(W_0 - ce) > 0 \quad (14)$$

$$V_{eW_1} = p'(e)[U'(W - L) - U'(W)] < 0 \quad (15)$$

Eqs. (13), (14) and (15) imply that:

Proposition 2 *Advance prevention is increased by: a) a subsidy reducing the cost of prevention; b) a subsidy increasing first-period wealth; c) a tax on second-period wealth.*

This result also implies that:

Corollary 1 *A subsidy on first-period wealth financed by a tax on second-period wealth is a self-financing policy which increases prevention.*

The explanation for these results is that, in the case of advance prevention, only the first of the two effects described in the discussion of results in Sect. 2 is at work. In particular, when a subsidy reducing the cost of prevention is introduced into the two-period framework we have a reduction in marginal cost of effort which pushes the DM to increase prevention. As in the case of one-period framework studied in Sect. 2, this reduction in costs generates an increase in wealth. But, unlike in the one-period framework, the increase in wealth does not cause here a mitigation of the reduction in utility due to the potential loss L , since the increase in wealth occurs in the first period while the potential loss is in the second period. Thus, unlike in the

one-period framework, in the two-period framework there is a temporal separation between the increase in wealth and the potential occurrence of loss which removes the incentive to reduce prevention. This makes the effect of the subsidy clear and not ambiguous.

Similar reasoning can be made for the subsidy increasing first-period wealth. In fact, this subsidy increases wealth in the period where the DM exerts the effort, and pushes the DM to increase prevention, without affecting his wealth in the period where he faces the potential loss.

In the case of a tax on second-period wealth, the effect is exactly the opposite. The tax reduces wealth in the period where the DM potentially faces the loss. This implies that the loss can incur in the presence of less wealth and thus exacerbates the effect of the potential loss on utility. This pushes the DM to invest more first-period wealth in advance prevention, increasing effort in the first period.

Lastly, as stated in Corollary 1, the fact that the effects of a subsidy on first-period wealth and a tax on second-period wealth are in the same direction implies that a policy using both instruments together can generate a self-financing scheme, which is able to increase advance prevention.

4 Advance and contemporaneous prevention together

We now consider a model where advance prevention and contemporaneous prevention studied in previous sections are introduced together. For this purpose we retain all the common assumptions common to Sects. 2 and 3 and we assume that the probability of incurring the loss is a function of two variables: advance prevention e_0 and contemporaneous prevention e_1 . We thus have $p = p(e_0, e_1)$ where $\frac{\partial p}{\partial e_0} = p_{e_0}(e_0, e_1) < 0$ and $\frac{\partial p}{\partial e_1} = p_{e_1}(e_0, e_1) < 0$.

In this context, the DM chooses e_0 and e_1 in order to solve the following maximization problem:

$$\max_{e_0, e_1} V(e_0, e_1) = \max_{e_0, e_1} U(W_0 - c_0 e_0) + p(e_0, e_1)U(W_1 - L - c_1 e_1) + [1 - p(e_0, e_1)]U(W_1 - c_1 e_1) \quad (16)$$

where W_0 is first-period wealth, W_1 is second-period wealth, L is the potential loss, c_0 is the cost of advance prevention and c_1 is the cost of contemporaneous prevention.

The FOCs of this problem are:

$$-c_0 U'(W_0 - c_0 e_0) + p_{e_0}(e_0, e_1)[U(W_1 - L - c_1 e_1) - U(W_1 - c_1 e_1)] = 0 \quad (17)$$

$$p_{e_1}(e_0, e_1)[U(W_1 - L - c_1 e_1) - U(W_1 - c_1 e_1)] - c_1[p(e_0, e_1)U'(W_1 - L - c_1 e_1) + [1 - p(e_0, e_1)]U'(W_1 - c_1 e_1)] = 0 \quad (18)$$

The SOC's are:

$$c_0^2 U''(W_0 - c_0 e_0) + p_{e_0 e_0}(e_0, e_1)[U(W_1 - L - c_1 e_1) - U(W_1 - c_1 e_1)] < 0 \quad (19)$$

$$\begin{aligned} & p_{e_1 e_1}(e_0, e_1)[U(W_1 - L - c_1 e_1) - U(W_1 - c_1 e_1)] \\ & - 2c_1 p_{e_1}(e_0, e_1)[U'(W_1 - L - c_1 e_1) - U'(W_1 - c_1 e_1)] \\ & + c_1^2 [p(e_0, e_1)U''(W_1 - L - c_1 e_1) + [1 - p(e_0, e_1)]U''(W_1 - c_1 e_1)] > 0 \end{aligned} \quad (20)$$

and

$$D = V_{e_0 e_0} V_{e_1 e_1} - V_{e_0 e_1}^2 > 0 \quad (21)$$

We assume that all these conditions are satisfied.

By totally differentiating (17) and (18) with respect to the choice variables e_0 and e_1 and to the parameter c_0 we obtain:

$$V_{e_0 e_0} de_0 + V_{e_0 e_1} de_1 + V_{e_0 c_0} dc_0 = 0 \quad (22)$$

and

$$V_{e_1 e_0} de_0 + V_{e_1 e_1} de_1 + V_{e_1 c_0} dc_0 = 0 \quad (23)$$

We know by second-order conditions that $V_{e_0 e_0} < 0$ and $V_{e_1 e_1} < 0$. We also have

$$\begin{aligned} V_{e_0 e_1} &= p_{e_0 e_1}(e_0, e_1)[U(W_1 - c_1 e_1 - L) - U(W_1 - c_1 e_1)] \\ &\quad - c_1 p_{e_0}(e_0, e_1)[U'(W_1 - c_1 e_1 - L) - U'(W_1 - c_1 e_1)] \end{aligned} \quad (24)$$

where $p_{e_0 e_1}(e_0, e_1) = \frac{\partial^2 p}{\partial e_0 \partial e_1}$. This implies that if $p_{e_0 e_1}(e_0, e_1) \leq 0$ then $V_{e_0 e_1} > 0$. Otherwise the sign is ambiguous.

It is worth noting that the case $p_{e_0 e_1}(e_0, e_1) \leq 0$ has a clear interpretation. When $p_{e_0 e_1}(e_0, e_1) < 0$ the reduction in the probability of loss occurrence due to an increase in advance (contemporaneous) prevention is a decreasing function of contemporaneous (advance) prevention. Since both $p_{e_0}(e_0, e_1)$ and $p_{e_1}(e_0, e_1)$ only exhibit negative values, this means that the absolute value of $p_{e_0}(e_0, e_1)$ is an increasing function of contemporaneous prevention and the absolute value of $p_{e_1}(e_0, e_1)$ is an increasing function of advance prevention. This implies that the effect on probability of one type of prevention is higher when the level of the other type of prevention is high, meaning that the two kinds of prevention reinforce each other. This generates, in turn, a kind of complementarity between the two types of prevention, determining a positive interaction between them. Also note, however, that the assumption $p_{e_0 e_1}(e_0, e_1) \leq 0$ is a kind of weak complementarity since it includes the case $p_{e_0 e_1}(e_0, e_1) = 0$ which is the case where the level of effort in one type of prevention does not affect the size of the effects of the other type. A simple case where $p_{e_0 e_1}(e_0, e_1) = 0$ is obtained by assuming that the probability p is a function of the sum of advance and contemporaneous prevention, i.e. that $p(e_0, e_1) = p(e_0 + e_1)$. Clearly weak complementarity between different actions of prevention holds in some cases but not in others, and it is worth emphasizing that

the results provided below depend on this assumption.⁶ Notice, however, that this assumption is not new since both Hofmann and Peter (2015) and Menegatti (2018), who both study advance and contemporaneous prevention together, obtain their results under conditions which are sub-cases of weak complementarity.

Given all the above, without assuming $p_{e_0e_1}(e_0, e_1) \leq 0$ and given $V_{e_0c_0}$ and $V_{e_1c_0}$ (reported in the Appendix), after simple manipulations of (22) and (23), we obtain

$$\frac{de_0}{dc_0} = \frac{1}{D}(V_{e_0e_1}V_{e_1c_0} - V_{e_0c_0}V_{e_1e_1}) < 0 \quad (25)$$

where D which is positive for SOC (21).

Under the assumption $p_{e_0e_1}(e_0, e_1) \leq 0$ we also obtain

$$\frac{de_1}{dc_0} = \frac{1}{D}(V_{e_0e_1}V_{e_0c_0} - V_{e_1c_0}V_{e_0e_0}) < 0 \quad (26)$$

Making similar steps and given the values of $V_{e_0W_0}$, $V_{e_1W_0}$, $V_{e_0c_1}$, $V_{e_1c_1}$, $V_{e_0W_1}$ and $V_{e_1W_1}$ (all reported in the Appendix) we also obtain the following results. First we have

$$\frac{de_0}{dW_0} = \frac{1}{D}(V_{e_0e_1}V_{e_1W_0} - V_{e_0W_0}V_{e_1e_1}) > 0 \quad (27)$$

Under the assumption $p_{e_0e_1}(e_0, e_1) \leq 0$ we also obtain

$$\frac{de_1}{dW_0} = \frac{1}{D}(V_{e_0e_1}V_{e_0W_0} - V_{e_1W_0}V_{e_0e_0}) > 0 \quad (28)$$

Lastly we have:

$$\frac{de_0}{dc_1} = \frac{1}{D}(V_{e_0e_1}V_{e_1c_1} - V_{e_0c_1}V_{e_1e_1}) \quad (29)$$

$$\frac{de_1}{dc_1} = \frac{1}{D}(V_{e_0e_1}V_{e_0c_1} - V_{e_1c_1}V_{e_0e_0}) \quad (30)$$

$$\frac{de_0}{dW_1} = \frac{1}{D}(V_{e_0e_1}V_{e_1W_1} - V_{e_0W_1}V_{e_1e_1}) \quad (31)$$

$$\frac{de_1}{dW_1} = \frac{1}{D}(V_{e_0e_1}V_{e_0W_1} - V_{e_1W_1}V_{e_0e_0}) \quad (32)$$

whose signs are ambiguous.

The implications of these results for the effects of different kinds of subsidy are summarized in the following proposition.

⁶ Different examples of simple cases where weak complementarity is very plausible can be provided. In the case of vaccination a booster dose often strengthens the first dose. Similarly, the two actions of changing parts of an old car and performing regular maintenance exhibit complementarity in their effects of reducing the probability of car accidents. Lastly, installing anti-virus software and regularly updating the operating system exhibit complementarity in reducing the probability of malware entering a computer.

Proposition 3 *Advance prevention is increased by: a) a subsidy reducing the cost of advance prevention; b) a subsidy increasing first-period wealth. Assuming weak complementarity between advance and contemporaneous prevention ($p_{e_0e_1}(e_0, e_1) \leq 0$), the same effects hold for contemporaneous prevention. The effects of subsidies reducing the cost of contemporaneous prevention or increasing second-period wealth are instead ambiguous on both advance and contemporaneous prevention.*

Results described in Proposition 3 share some elements with those obtained in previous sections, as well as showing several other significant aspects. First, the findings in Proposition 3 confirm what is stated in Proposition 2 on the positive effects on advance prevention of subsidies on the cost of advance prevention and on first-period wealth. The explanation for these results is the same as that provided in Sect. 3.

However, a new and very important conclusion can now also be drawn: if $p_{e_0e_1}(e_0, e_1) \leq 0$ the two subsidies have positive effects on contemporaneous prevention too. This new result is explained by the interaction between advance and contemporaneous prevention. In fact, as shown above, if $p_{e_0e_1}(e_0, e_1) \leq 0$ there is a weak complementarity between the two kinds of prevention. This implies that, when choosing the levels of the two kinds of effort, the DM is pushed to “move” these levels in the same direction (i.e. to either increase or reduce them together). This implies, in turn, that, once the DM is pushed to increase advance prevention, he is then pushed to increase contemporaneous prevention too. This determines the effects of the two subsidies on contemporaneous prevention.

Moreover, we obtain here that, as in Proposition 1, a subsidy on contemporaneous prevention and a subsidy on second-period wealth have ambiguous effects on contemporaneous prevention. The reasons for this are the same as those described in Sect. 2. Because the two kinds of prevention interact, this also implies that the two subsidies have ambiguous effects on advance prevention.

Lastly, in discussing these results, there is a further consideration about subsidies on wealth to make. As shown above, an increase in first-period wealth has a positive effect on both advance prevention and contemporaneous prevention. As stated in the introduction, contemporaneous prevention is prevention which occurs in the same period where the potential loss may occur. The contemporaneity is thus with the potential loss. But contemporaneity does not refer to the period where wealth increases, since the increment in wealth we are considering is in the first-period, while the contemporaneous prevention we are examining is made in the second period. An important clarification is to be made deriving from this observation: a subsidy increasing first-period wealth generates an *immediate* increase in advance prevention, and an increase in *future* contemporaneous prevention.

5 Social security and prevention

An issue complementary to those studied in previous sections is the effect of social security on prevention. A typical kind of social security is a payment made by the government to ill or poor people. Thus, if we assume that the loss L is a worsening

in health status due to a disease or a financial loss which significantly reduces DM's wealth, the social security system may make a payment to the DM in the case where the loss occurs.⁷

In our framework, the social security intervention can be seen as a subsidy paid to the DM in the case of loss occurrence. From the analytical standpoint the DM's maximization problem in Sect. 4, becomes now:⁸

$$\max_{e_0, e_1} V(e_0, e_1) = \max_{e_0, e_1} U(W_0 - c_0 e_0) + p(e_0, e_1)U(W_1 - L - c_1 e_1 + k) + [1 - p(e_0, e_1)]U(W_1 - c_1 e_1) \quad (33)$$

where k is the social security subsidy and where $k \leq L$.

The FOCs of this problem are:

$$-c_0 U'(W_0 - c_0 e_0) + p_{e_0}(e_0, e_1)[U(W_1 - L - c_1 e_1 + k) - U(W_1 - c_1 e_1)] = 0 \quad (34)$$

$$p_{e_1}(e_0, e_1)[U(W_1 - L - c_1 e_1 + k) - U(W_1 - c_1 e_1)] - c_1[p(e_0, e_1)U'(W_1 - L - c_1 e_1 + k) + [1 - p(e_0, e_1)]U'(W_1 - c_1 e_1)] = 0 \quad (35)$$

Starting from these conditions we can obtain different results. First a trivial case is when $k = L$. In this case, simple computations show that e_0 and e_1 are both 0. This conclusion is intuitive since a subsidy which completely nullifies the loss is a kind of full insurance provided free to the DM. This result is the first evidence of the trade-off related to social security and prevention, which will be examined in more detail below. In fact, a subsidy acting as a full insurance may be optimal for the purpose of compensating people suffering a bad event, but it has the significant shortcoming of pushing people to eliminate costly activities undertaken in order to reduce the occurrence of this event.

We consider now the case where $k < L$.⁹ Here we can easily compute the effect of a variation in k on optimal choices of advanced and contemporaneous prevention. The steps taken in the previous section imply that:

⁷ This reasoning implicitly assumes that wealth and health status affect DM's utility in a similar way and that an increase in one of them reduces the marginal utility of the other. However, the health economics literature often studies more complex cases where wealth and health status are different arguments of the utility function and where their cross-effects can have different directions. A discussion of this can be found in Rey and Rochet (2004). See also Eeckhoudt et al. (2007) and Liu and Menegatti (2019a) on the higher-order cross-effects in the relationship between wealth and the health status in the utility function.

⁸ We directly examine this issue in the model of Sect. 4. The conclusion obtained can be translated to the two models in Sects. 2 and 3.

⁹ Note that, in this case, the subsidy can be seen as an instrument reducing the loss L . Ehrlich and Becker (1972) and Sweeney and Beard (1992) showed that, in the model of contemporaneous prevention, a reduction in the size of loss has, in general, ambiguous effects on prevention and has unambiguous effects only under specific assumptions on preferences. Generalizations of these conclusions are studied by Crainich et al. (2016) in the case where the DM makes prevention in the presence of random outcomes and by Courbage et al. (2017) in a two-period model with multiple risks. Lastly, Lee (1998) studies the case where the effort in prevention also generates a kind of self-insurance, causing a reduction in the loss size.

$$\frac{de_0}{dk} = \frac{1}{D} (V_{e_0e_1} V_{e_1k} - V_{e_0k} V_{e_1e_1}) \quad (36)$$

$$\frac{de_1}{dk} = \frac{1}{D} (V_{e_0e_1} V_{e_0k} - V_{e_1k} V_{e_0e_0}) \quad (37)$$

Simple computations show that

$$V_{e_0k} = p_{e_0}(e_0, e_1) U'(W_1 - L - c_1 e_1 + k) < 0 \quad (38)$$

and

$$V_{e_1k} = p_{e_1}(e_0, e_1) U'(W_1 - L - c_1 e_1 + k) - c_1 p(e_0, e_1) U''(W_1 - L - c_1 e_1 + k) \quad (39)$$

The sign of (39) is, in general, ambiguous. Simple computations, however, show that this sign is negative if

$$-\frac{e_1 p_{e_1}(e_0, e_1)}{p(e_0, e_1)} > -\frac{e_1 c_1 U''(W_1 - L - c_1 e_1 + k)}{U'(W_1 - L - c_1 e_1 + k)} \quad (40)$$

A closer inspection of condition (40) suggests that it requires that the elasticity of the probability of being in the bad state of nature with respect to effort in contemporaneous prevention must be higher than the elasticity of marginal utility with respect to the total cost of contemporaneous prevention.

Substituting the values of $V_{e_0e_1}$, $V_{e_1,k}$, $V_{e_0,k}$ and V_{e_1,e_1} in (36) and (37) we obtain that:

Proposition 4 *An increase in the social security subsidy has, in general, ambiguous effects both on advance prevention and on contemporaneous prevention. If the elasticity of the probability of being in the bad state of nature with respect to effort in contemporaneous prevention is higher than the elasticity of marginal utility with respect to the total cost of contemporaneous prevention then an increase in the social security subsidy reduces optimal effort in both advance and contemporaneous prevention.*

The explanation of Proposition 4 is based on reasoning partially similar to that made in previous sections. As above, in fact, overall effects are ambiguous because of the different effects of contemporaneous prevention. An increment in social security subsidy implies an increase in second-period expected wealth, due to the increase in wealth in the bad state of nature. This pushes the DM to increase contemporaneous prevention. On the other hand, however, the social security subsidy partially mitigates the negative effect of the potential loss. This pushes the DM to reduce contemporaneous prevention. In general, the overall effect is thus ambiguous.

The two effects on marginal utility, however, are mediated by the elasticity of probability with respect to effort and by the elasticity of marginal utility with respect to the cost of prevention. Condition (40) is the condition ensuring that the incentive to reduce contemporaneous prevention is stronger. Since, as shown by

(38), there is an incentive for the DM to reduce advance prevention, all incentives work, in this case, in the same direction and both kinds of prevention are reduced.

It is worth noting that, when Condition (40) holds, a higher social security subsidy determines less prevention. In this case, there is again a trade off between two possible goals of public policy. On one hand, a higher subsidy generates greater protection for people in the case where a bad event occurs. On the other hand, it causes people to reduce their effort in avoiding the occurrence of the bad event.

Note that, in a completely different framework, Fleurbaey and Ponthiere (2013) show the existence of a dilemma between prevention of early death and compensation for it, since no social ordering on allocations can satisfy both aims. The present paper shows a dilemma between prevention of bad events and compensation for loss. It is worth emphasizing that both sets of results, although derived in different contexts and reflecting different reasons, are in the same direction.

There are two possible ways to mitigate the trade off described in Proposition 4. The first way is to design the subsidy so that it is conditional on making a minimum level of effort in prevention. This implies that, in many cases, the DM will set his effort at this minimum level. This in turn implies that an increase in the subsidy may still reduce prevention but this reduction would have now a lower bound.

A second solution is to design the subsidy as an increasing function of the effort in prevention. In general, this solution implies that an increase in the subsidy will have an ambiguous effect on effort even in the case where Condition (40) is satisfied, and partially mitigates the trade off described above. Note that a simple example of this design could be to make $k = k_1 e_1$. Introducing the plausible assumption that $k_1 < c_1$, the social security subsidy would become in this case simply a subsidy which reduces the cost of contemporaneous prevention, but only in the bad state of nature. It would thus be a variant of one of the subsidies studied in Sects. 2 and 3.

Lastly, the reasoning above on the mechanism generating ambiguous effects of social security on prevention suggests a possible particular type of subsidy which could have a positive influence on prevention. We noted above that social security has ambiguous consequences on prevention, since the positive effect of the increase in expected wealth that it generates can be outweighed by the negative effect of the mitigation in the loss that it produces. Starting from this premise, there is a way to retain the first effect and replace the second one with a further incentive to take prevention measures. Consider a subsidy which is not paid to the DM in the case where he incurs a loss, but instead is paid in the case where the bad event does not occur. DM's maximization problem becomes in this case:

$$\begin{aligned} \max_{e_0, e_1} V(e_0, e_1) = & \max_{e_0, e_1} U(W_0 - c_0 e_0) + p(e_0, e_1) U(W_1 - L - c_1 e_1) \\ & + [1 - p(e_0, e_1)] U(W_1 - c_1 e_1 + k) \end{aligned} \quad (41)$$

To save space we omit the FOCs (which are similar to (34) and (35)) and we directly compute:

$$V_{e_0k} = -p_{e_0}(e_0, e_1)U'(W_1 - c_1e_1 + k) > 0 \quad (42)$$

and

$$V_{e_1k} = -p_{e_1}(e_0, e_1)U'(W_1 - c_1e_1 + k) - c_1[1 + p(e_0, e_1)]U''(W_1 - c_1e_1 + k) > 0 \quad (43)$$

Since $V_{e_0e_1} > 0$ and since $V_{e_0e_0} < 0$, by substituting (42) and (43) in (36) and (37) we obtain that, in this case, $\frac{de_0}{dk} > 0$ and $\frac{de_1}{dk} > 0$. This means that:

Proposition 5 *A subsidy paid in the case where the loss does not occur increases both advance and contemporaneous prevention*

The subsidy just analyzed would be a kind of “reverse social security” where payment is made to the DM when he *does not* have losses. The mechanism by which this subsidy increases prevention is simple: it gives more resources to the DM and it increases the gap between his utility in the good and in the bad states of nature. Clearly, however, although the mechanism is effective in increasing prevention, it exacerbates rather than mitigates the negative effects of the potential occurrence of the loss for the DM. We thus again have a trade-off between the goal of enhancing prevention of bad events and the goal of mitigating their consequences.

6 Conclusions

The examination of the effects of subsidies on optimal choices shows that incentivizing prevention is a complex task.

In particular, the analysis clearly indicates that subsidies are, in general not necessarily effective in generating an immediate increase in prevention activities undertaken in the period where the risk occurs (contemporaneous prevention). In fact, neither a subsidy on the cost of contemporaneous prevention nor a subsidy on wealth can unambiguously cause an immediate increase in contemporaneous preventive actions. This is because both these incentives produce two different counteracting effects: they make prevention relatively less costly for the decision maker but they also make the potential loss associated with the risk relatively less disadvantageous.

Social security policies are also shown to generate a change in optimal decisions on prevention whose direction cannot, in general, be determined *a priori*. Moreover, social security policies often produce a disincentive to risk prevention activities, potentially causing a trade-off between the aim of protecting people from the negative effect of bad events and the aim of encouraging people to try to reduce the probability that these events will occur. Unexpectedly, the analysis of social security also shows that one kind of subsidy which could potentially generate an immediate increase in contemporaneous prevention is a kind of “reverse social security” where a subsidy is paid to the decision maker in the case where he does not incur a loss. This kind of subsidy, however, is effective in enhancing prevention but it is clearly debatable in terms of social equity.

More satisfying results are obtained with reference to actions made in order to increase advance prevention. In this regard, in particular, both subsidies on the cost of prevention and on wealth are effective in increasing the prevention activities made in the period which precedes the moment where the decision maker faces the risk. This occurs since, in this case, the effect of reduction in the cost of prevention is not accompanied by a mitigation in the negative consequences of the loss because the loss potentially occurs in a different period.

Moreover, under the assumption that advance and contemporaneous prevention have a complementary impact on the probability of loss occurrence, these kinds of incentives also generate a positive influence on future contemporaneous prevention, thus having a kind of “double effect” on prevention activities. This finding complements the above ones showing that subsidies have an ambiguous impact on immediate contemporaneous prevention but have a positive influence on future contemporaneous prevention.

It is worth noting that, as emphasized in Sect. 1, the analysis in the present work considers the choice on prevention as separate from that of other choice variables. This approach implies neglecting saving decisions in the two-period models of Sects. 3–5.¹⁰ This clearly opens space for future research. Given this premise, however, even without analytically introducing saving into the set of choice variables, it is possible to briefly discuss its possible implications for the effects of the subsidy on the cost of advance prevention and the subsidy on first-period wealth, shown in Sect. 4. In both cases the subsidy is paid in the first period. This implies that it can potentially push the DM to transfer wealth from the first to the second period by means of saving. This effect could reduce, or completely nullify, the positive impact of the subsidy on prevention.¹¹ This possible reduction is probably stronger in the case of a subsidy on wealth than in the case of a subsidy on the cost of effort. This reflects the fact that a subsidy on wealth is simply a direct increase in wealth while a subsidy on the cost of prevention is related to the level of prevention, which implies that, if the agent reduces prevention, the increase in wealth is also reduced. Moreover, we showed in Sect. 5 that an increase in both advance and contemporaneous prevention can be generated by means of a subsidy on wealth paid in the second period only in the state of nature where the DM does not incur a loss. The subsidy generates, in this case, an increase in second-period wealth. In the presence of saving, the DM can choose to transfer a part of the extra-wealth obtained from the second to the first period and this would affect the impact of the subsidy on prevention. This transfer, however, would imply negative saving, i.e. borrowing. But, in the case of frictions in financial markets or in the presence of asymmetric information, borrowing may be impossible for the DM. This would

¹⁰ Note that this approach is very common in the literature studying two-period models of prevention (e.g. Menegatti 2009; Courbage and Rey 2012; Eeckhoudt et al. 2012; Hofmann and Peter 2015; Wang and Li 2015; Courbage et al. 2017).

¹¹ Note that this ambiguous result is usual in a framework of this kind since ambiguous findings are, in general, typical when many choice variables are considered together, as the relationships become too numerous to draw general conclusions without introducing additional assumptions (see, for instance, Menegatti and Rebessi 2011; Hofmann and Peter 2015; Menegatti and Rebessi 2011 and Liu and Menegatti, 2019a; b).

imply that, in these circumstances, the effect of the subsidy would remain unchanged when the saving choice is taken into account.

Lastly, considering together all the conclusions in the present work, it is possible to derive significant policy implications from both a descriptive and a normative perspective.

On one hand, from a descriptive perspective, our results provide new insights into the reasons why different kinds of subsidies have different degrees of effectiveness, as is shown in the literature ((e.g. Ludbrook, 2019 and Bruinen de Bruin et al. 2020). Moreover, our findings also show why some interventions made by regulators may have less influence on people's behavior than expected, as was, for instance, found in the case of measures taken during the COVID pandemic.

On the other hand, from a normative perspective, our results clearly suggest that public policy should focus on incentivizing advance rather than contemporaneous prevention. This suggests, for instance, that subsidizing vaccination against a disease before a possible epidemic is more effective in changing people's choices than incentivizing behavior during the epidemic. Similarly, in preventing elderly diseases, incentives to lifestyle change should be more effective on young than on old people. Moreover, in preventing car accidents, subsidizing the installation of car safety devices should be more effective than penalties in the case of bad driving behavior. Lastly in preventing the risk of losses due to unwise financial decisions, subsidizing people to follow courses in financial literacy before the period where the financial decision is taken should be more effective in changing behavior than subsidizing professional consultancy in the period where the choice is made.

In conclusion, it is also important to note that, as emphasized above, the analysis in the present paper suggests that, in many cases, the effect of subsidies on prevention activities cannot be unambiguously predicted *ex ante*. For future research, this opens up space for a significant *ex post* analysis in specific cases. In this direction both empirical investigations and field experiments are promising research lines.

Appendix

We provide here values of different second-order derivatives of function V

$$V_{e_0c_0} = -U'(W_0 - c_0e_0) + c_0e_0U''(W_0 - c_0e_0) < 0 \quad (44)$$

$$V_{e_0W_0} = -c_0U''(W_0 - c_0e_0) > 0 \quad (45)$$

$$V_{e_0c_1} = -e_1p_{e0}(e_0, e_1)[U'(W_1 - L - c_1e_1) - U'(W_1 - c_1e_1)] > 0 \quad (46)$$

$$V_{e_0W_1} = p_{e0}(e_0, e_1)[U'(W_1 - L - c_1e_1) - U'(W_1 - c_1e_1)] < 0 \quad (47)$$

$$V_{e_1c_0} = 0 \quad (48)$$

$$V_{e_1 w_0} = 0 \quad (49)$$

$$\begin{aligned} V_{e_1 c_1} = & -e_1 p_{e_1}(e_0, e_1)[U'(W_1 - L - c_1 e_1) \\ & - U'(W_1 - c_1 e_1)] - p(e_0, e_1)U'(W_1 - L - c_1 e_1) \\ & - [1 - p(e_0, e_1)]U'(W_1 - c_1 e_1) \\ & + c_1 e_1[p(e_0, e_1)U''(W_1 - L - c_1 e_1) + [1 - p(e_0, e_1)]U''(W_1 - c_1 e_1)] \end{aligned} \quad (50)$$

$$\begin{aligned} V_{e_1 w_1} = & p_{e_1}(e_0, e_1)[U'(W_1 - L - c_1 e_1) - U'(W_1 - c_1 e_1)] \\ & - c_1[p(e_0, e_1)U''(W_1 - L - c_1 e_1) + [1 - p(e_0, e_1)]U''(W_1 - c_1 e_1)] \end{aligned} \quad (51)$$

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