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Average willingness to pay for disease prevention with personalized health information

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Abstract

Personal health related information modifies individuals' willingness to pay for disease prevention programs inasmuch as it allows health status assessment based on intrinsic (instead of average) characteristics. In this paper, we examine the effect that personalized information about the baseline probability of disease has on the average willingness to pay for programs reducing either the probability of disease (self-protection) or the severity of disease (self-insurance). We show that such an information rises the average willingness to pay for self-protection while it increases the average willingness to pay for self-insurance if health and wealth are complements (*i.e.* the marginal utility of wealth rises with health).

JEL Classification: D81; I18

Keywords: Personalized health information; disease prevention; willingness to pay

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Introduction

Willingness to pay is usually seen by economists as the most appropriate way to convert into monetary units the benefits resulting from investments reducing the probability of death or disease (see for instance the influential contributions of Drèze (1962), Schelling (1968) and Mishan (1971)). The measure has been exploited in several studies evaluating the effects of public policies increasing safety. For instance, the willingness to pay for improvements in road safety (Jones-Lee et al., 1985), for pesticide free food (Misra et al., 1991), for poison control centers (Philips et al., 1997), for improved air quality (Carlsson and Johansson-Stenman, 2000), for electronic waste recovering and recycling programs (Nixon and Saphores, 2007) and for moving to a neighborhood with less violent crimes (Bishop and Murphy, 2011) have been assessed.

The theoretical foundations of the willingness to pay for reductions in the probability of death or disease have been introduced by Drèze (1962). Since then, a deeper understanding of the properties of this measure has been provided in the literature. For instance, Jones-Lee (1974) describes the form of the functional relationship between the willingness to pay for reductions in the probability of death and the size of these reductions. Jones-Lee (1974) also shows that the willingness to pay should rise with the baseline probability of death, a phenomenon termed "dead anyway effect" by Pratt and Zeckhauser (1996). These last authors also address the concentration of the risk in the population. Specifically, keeping the aggregate risk constant, Pratt and Zeckhauser (1996) determine if the willingness to pay for larger reductions in the probability of death concentrated on a small number of individuals is higher than the willingness to pay for smaller reductions in probability spread within a larger population. Hammitt (2000) examines the effects of the health status and of wealth on the willingness to pay for reductions in the probability of death (expressed as the value of statistical life). He indicates that the first effect depends on the way the marginal utility of wealth changes with health status. Assuming that additional wealth is more valuable in life than as a bequest, Hammitt (2000) also indicates that the value of statistical life increases as wealth rises if individuals are risk averse or risk neutral. Dachraoui et al. (2004) examine the effect of risk aversion on the willingness to pay for self-protection. They show that risk aversion increases (resp. decreases) this willingness to pay[1] only when the baseline probability of loss is above (resp. below) $\frac{1}{2}$. Crainich et al. (2015) specify this relationship by showing that the willingness to pay to reduce the probability of disease is the product of the willingness to pay under risk neutrality and an adjustment factor that depends on both risk aversion and downside risk aversion. The impact of background risks on the willingness to pay for self-protection has been analyzed by Eeckhoudt and Hammitt (2001)

[1] Outside the willingness to pay literature, the absence of unambiguous relationship between risk aversion and self-protection had already been pointed out by Dionne and Eeckhoudt (1985) and by Bryis and Schlesinger (1990) in the context of self-protection decisions.

and by Bleichrodt et al. (2003). Eeckhoudt and Hammitt (2001) examine how various sources of mortality affect the willingness to pay for reducing the probability of death while Bleichrodt et al. (2003) highlights the conditions under which the willingness to pay to reduce the probability of a given disease increases as the probability and severity of comorbidities rise. The impact of information about individuals' heterogeneity on the willingness to pay for projects reducing the probability of death has been examined by Hammitt and Treich (2007) who show that when the reduction in the probability of death differs across individuals, the average willingness to pay decreases with information about individual risk change.

Our paper complements these theoretical developments by examining the effects that personalized health information should have on the *average* willingness to pay for disease prevention actions. The ever growing availability of personal health related information (due for instance to the development of genetic testing, to the multiplication of public health campaigns and to the increasing use of internet for medical purposes) changes the way diseases are perceived by individuals and thus modifies their propensity to prevent them[2]. In this paper, we examine prevention actions reducing either the probability of disease or its severity (self-protection and self-insurance, respectively, in Ehrlich and Becker's (1972) terminology) and focus on personal information about the baseline probability of disease (provided by genetic predisposition tests for instance). With such an information, individuals do not make medical decisions based on the prevalence of the disease (*i.e.* based on average information) but according to personal characteristics instead. Whether they learn that their intrinsic probability to develop a given disease is higher or lower than the prevalence of the disease, individuals' willingness to pay for prevention should, in theory, be modified. Consequently, an interesting question related to the development of personalized health information is whether the willingness to pay for prevention based on the average information (*i.e.* in the absence of personalized information) is higher than the average willingness to pay for prevention (*i.e.* with personalized information). In this paper, we address this question the answer to which determines how the relevance of prevention program is affected by the development of genetic testing. Note that in contrast to Hammitt and Treich (2007), the heterogeneity we deal with is about the baseline probability of disease (*i.e.* because this is an information that genetic tests bring) and not about the reduction in the probability of death resulting from a public project.

In the first model developed in the paper, we show that personalized information about the probability of disease raises the average willingness to pay for self-protection (section 2). We then show (Section 3) that the same information raises the average willingness to pay for self-insurance if the marginal utility of wealth rises with health. Section 4 concludes.

[2]Empirical studies support that providing the public with risk information changes individuals' attitude (see for example Hsieh et al. (1996) about the effects of anti-smoking campaigns on smoking behaviour or Barnett et al. (2007) about the public response to the UK government advices about mobile phone health risks).

2 Average willingness to pay for self-protection

Consider an expected utility maximizing individual who derives utility from wealth (w) and health (h), hence $u(w,h)$. The utility function is increasing and concave in both arguments[3] ($u_1(w,h) > 0$, $u_2(w,h) > 0$, $u_{11}(w,h) < 0$ and $u_{22}(w,h) < 0$). No *a priori* assumption is made about the sign of $u_{12}(w,h)$. A given disease occurs with a probability p and lowers the individual's health status from h to $h-m$ (where m denotes the severity of the disease).

As a result, an individual's expected utility is given by:

$$\overline{EU} = (1-p)u(w,h) + pu(w,h-m) \tag{1}$$

Suppose that public authorities are considering the implementation of a prevention program which reduces by Δ the probability of disease (an activity termed "self-protection" in the literature), so that the probability of disease is $p-\Delta$ instead of p. The individual's willingness to pay (denoted by v) for this programe is implicitly defined by equation (2):

$$(1-p)u(w,h) + pu(w,h-m) = (1-p+\Delta)u(w-v,h) + (p-\Delta)u(w-v,h-m) \tag{2}$$

In this expression, v corresponds to the wealth change which - when coupled with a reduction Δ in the probability of disease - keeps $\overline{EU}$ constant.

Because of different genetic predispositions, the baseline probability of disease (p) differs across individuals. In the absence of predisposition genetic tests, this information is not available to individuals[4]. We examine the effect of the dissemination of this information (through the development of genetic testing): individuals are thus supposed to switch from a situation where they are unaware of their intrinsic probability of disease (they just know the prevalence of the disease, *i.e.* the average probability in the population) to a situation where they know this probability. Note that we do not analyze here individuals' willingness to pay for the information or their propensity to take the information. We assume that the information is available, free and that individuals take it. The question we address is whether the genetic information modifies the average willingness to pay for a prevention program which reduces the probability of disease by Δ. We may expect individuals' willingness to pay for such a program to change once they learn that their probability to develop the disease is higher or lower that what they expected. We analyze the way the genetic information changes individuals' willingness to pay as well as the way it modifies the average willingness to pay for prevention. This last question is important since it determines the effect of personalized health related information on the total benefit (and hence on the relevance) of disease prevention programs.

[3] First and second derivatives of the utility function with respect to the first argument (wealth) are respectively denoted by $u_1(w,h)$ and $u_{11}(w,h)$. First and second derivatives of the utility function with respect to the second argument (health) are respectively denoted by $u_2(w,h)$ and $u_{22}(w,h)$. The cross derivative is denoted by $u_{12}(w,h)$.

[4] They do not consider their family history for instance as an indicator of their probability of disease.

To achieve this objective, we first determine the way v changes with p by using equation (2) and the implicit function theorem. We obtain:

$$\frac{dv}{dp} = \frac{[u(w,h) - u(w-v,h)] - [u(w,h-m) - u(w-v,h-m)]}{(1-p+\Delta)u_1(w-v,h) + (p-\Delta)u_1(w-v,h-m)} = \frac{G}{EU_1} \tag{3}$$

The denominator of (3) is positive since it corresponds to the expected marginal utility of wealth (denoted by EU_1 henceforth). The sign of the numerator of (3) depends on the comparison between the utility loss resulting from a wealth decrease (from w to $w - v$) in two health states: the perfect health state (h) and the disease state ($h - m$). When the reduction in wealth is more painful in the perfect health state (*i.e.* when[5] $u_{12}(.,.) > 0$), the numerator of (3) is positive and the willingness to pay for the prevention program rises with the baseline probability of disease. The reverse holds when $u_{12}(.,.) < 0$. In short:

$$\frac{dv}{dp} \gtreqless 0 \Longleftrightarrow u_{12}(.,.) \gtreqless 0$$

We now determine whether $\frac{dv}{dp}$ changes at an increasing, constant, or decreasing rate with p. Using (3), we obtain:

$$\frac{\partial\left(\frac{dv}{dp}\right)}{\partial p} = \frac{u_{12}(.,.)^2}{(EU_1)^2} \geq 0 \tag{4}$$

Note that our objective is to define the values taken by v for different levels of p. Since these levels of p do not result from changes in self-protection actions but are instead exogeneous (they result from the genetic information), we do not have to consider the way p modifies w. From (4), we conclude that no matter the sign of $u_{12}(.,.)$, $\frac{dv}{dp}$ changes at an increasing rate with p. While the sign of $u_{12}(.,.)$ determines whether v is decreasing or increasing in p, the relationship is convex in both cases (it is linear when $u_{12}(.,.) = 0$). The relationship between the willingness to pay for self protection (v) and the baseline probability of disease (p) is represented in figures 1a and 1b.

[5] At the numerator of (9), u_{12} is evaluated at a wealth level included between w and $w - z$ and at a health level included between h and $h - m$. Therefore, the notation $u_{12}(.,.)$ is used.

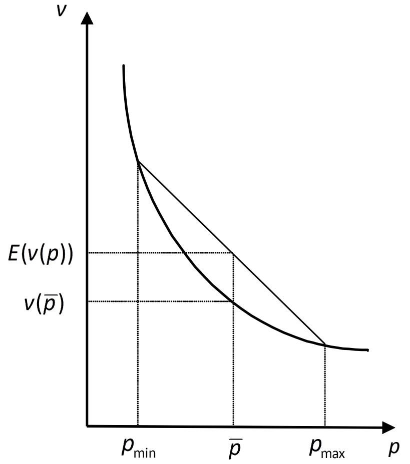

Figure 1a : $u_{12}(w,h) < 0$

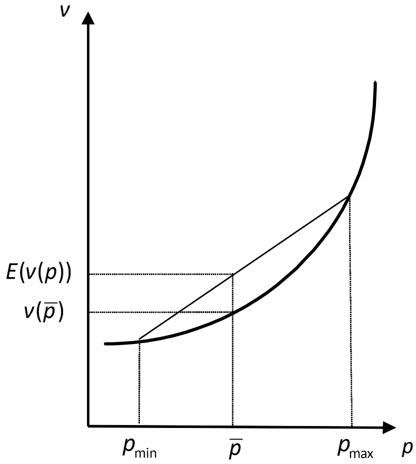

Figure 1b : $u_{12}(w,h) > 0$

From there, using Jensen's theorem, it is straighforward to show that whatever the distribution of p around its mean value $\overline{p}$, $E(v(p)) \geq v(\overline{p})$. That is, the willingness to pay for self-protection based on the average information is lower than the average willingness to pay for prevention. As a consequence, the development of genetic predisposition tests should raise the relevance of self-protection actions.

2.1 An extension: the efficiency of self-protection actions

The literaure on disease prevention usually assumes that the efficiency of self-protection actions increases with the baseline probability of disease. This characteristics has not been taken into account in section 2 where it was assumed that the reduction in the probability of disease resulting from the self-protection action was constant (and equal to Δ) whatever the baseline probability of disease. In this section, we address this property of self-protection actions by assuming instead that $\Delta(p)$ (the reduction in the probability of disease due to prevention depends on the initial probability of disease) with $0 < \Delta'(p) < 1$.

However, we must specify the probability function $\Delta(p)$ in such a way that the average reductions in the probability of disease before and after the genetic information are equal. We make this assumption in order to only capture the effect of the genetic information on the willingness to pay for self-protection. In other words, given this assumption, changes in the average willingness to pay for self-protection solely result from the information about the probability distribution and not from larger or lower average reduction in the probability of disease. In order to isolate a pure information effect, we thus assume $\Delta''(p) = 0$. Using Jensen inequality, this assumption ensures that whatever the distribution of the probability of disease around its mean, self-protection has the same effect on the average reduction in the probability of disease.

As in section 2, the initial expected utility is given by (1). The willingness to pay (denoted by y) for a reduction $\Delta(p)$ in the probability of disease is defined by:

$$(1-p)u(w,h) + pu(w,h-m) = (1-p+\Delta(p))u(w-y,h) + (p-\Delta(p))u(w-y,h-m) \quad (5)$$

Expressing y as a function of p by using (5) and the implicit function theorem, we obtain:

$$\frac{dy}{dp} = \frac{[u(w,h) - u(w-y,h)] - (1-\Delta'(p))\,[u(w,h-m) - u(w-y,h-m)]}{(1-p+\Delta(p))u_1(w-y,h) + (p-\Delta(p))u_1(w-y,h-m)} = \frac{K}{EU_2} \quad (6)$$

The denominator of (6) - denoted by EU_2 henceforth - corresponds to the expected marginal utility of wealth and is therefore positive. From equation (3), we know that $u_{12} \gtreqless 0 \iff [u(w,h) - u(w-y,h)] \gtreqless [u(w,h-m) - u(w-y,h-m)]$ (see section 2). Since $\Delta'(p) > 0$, we thus conclude that complementarity between wealth and health (*i.e.* a positive sign of the cross derivative u_{12}) implies that the willingness to pay for self-protection rises with the baseline probability of disease ($u_{12} \geq 0 \Rightarrow \frac{dy}{dp} > 0$). When Δ was constant with p (section 2), $u_{12} > 0$ was necessary and sufficient to reach this result. Since we assume $\Delta'(p) > 0$ in this section, an extra incentive to implement self-protection actions is provided to individuals whose baseline probability of disease is higher. Therefore, $u_{12} \geq 0$ is now only sufficient for the willingness to pay for self-protection to rise with the baseline probability of disease.

Let us now determine the rate at which y changes with p. To do so, we must compute:

$$\frac{\partial\left(\frac{dy}{dp}\right)}{\partial p} = \frac{\frac{dK}{dp}EU_2 - K\frac{dEU_2}{dp}}{[EU_2]^2} \quad (7)$$

where:

$$K > 0 \text{ if } u_{12} \geq 0$$

$$\frac{dK}{dp} = \Delta''(p)\,[u(w,h-m) - u(w-y,h-m)] = 0 \text{ since } \Delta''(p) = 0$$

$$EU_2 > 0$$

$$\frac{dEU_2}{dp} = (1-\Delta'(p))\,[u_1(w-k,h-m) - u_1(w-k,h)] \lesseqgtr 0 \text{ if } u_{12} \gtreqless 0$$

The easiest case to consider is $u_{12} \geq 0$ which leads to $\frac{\partial\left(\frac{dy}{dp}\right)}{\partial p} > 0$ via $K > 0$ and $\frac{dEU_2}{dp} < 0$. Complementarity between wealth and health ($u_{12} \geq 0$) thus implies that the willingness to pay for self-protection rises at an increasing rate with the baseline probability of disease. Using the Jensen inequality, we thus have that the average willingness to pay rises with personalized information in that case.

The same conclusion holds when u_{12} is sufficiently negative so that $K < 0$. Combined with $\frac{dEU_2}{dp} > 0$ (which follows from $u_{12} < 0$), this leads to $\frac{\partial\left(\frac{dy}{dp}\right)}{\partial p} > 0$ and the personalized information about the baseline probability of disease increases the average willingness to pay for self-protection. Note that this conclusion is reinforced in these two situations when $\Delta''(p) > 0$.

Finally, when u_{12} is not too negative so that $K > 0$, we obtain that personalized information about the baseline probability of disease lowers the average willingness to pay for self-protection. This conclusion is reinforced when $\Delta''(p) < 0$.

3 Average willingness to pay for self-insurance

We suppose in this section that the severity of disease can be reduced (its probability remaining constant) through another disease prevention activity (termed "self-insurance"). We use again the methodology exploited in the previous section to determine whether the average willingness to pay for this type of disease prevention action rises or falls as individuals become informed about their baseline probability of disease.

The individual expected utility is again given by Eq. (1). The willingness to pay (denoted by z) for a given reduction Ψ in the severity of the disease is implicitly obtained from (8):

$$(1-p)u(w,h) + pu(w,h-m) = (1-p)u(w-z,h) + pu(w-z,h-m+\Psi) \tag{8}$$

In equation (8), z corresponds to the wealth variation which - when coupled with the reduction Ψ (such that $\Psi > 0$) in the severity of the disease - leaves individuals at the constant expected utility $\overline{EU}$.

Using equation (8) and the implicit function theorem, the way z changes with p is defined as follows:

$$\frac{dz}{dp} = \frac{[u(w,h) - u(w,h-m)] - [u(w-z,h) - u(w-z,h-m+\Psi)]}{(1-p)u_1(w-z,h) + pu_1(w-z,h-m+\Psi)} = \frac{F}{EU_3} \tag{9}$$

The denominator of (9) corresponds to the expected marginal utility of wealth and is therefore positive. The sign of the numerator of (9) depends on the sign of u_{12}. It compares two health deteriorations at two wealth levels. Specifically, the first term of F $(u(w,h) - u(w,h-m))$ measures the effect of reducing the health status by m when the individual's wealth is equal to w. The second term of F $(u(w-z,h) - u(w-z,h-m+\Psi))$ measures the effect of a smaller reduction in health $(m-\Psi)$ which occurs at a lower wealth level $(w-z)$. When the effect of health losses decreases as wealth falls (*i.e.* if $u_{12} > 0$), the second term of F is lower than the first since the health reduction considered is lower and since it occurs at lower wealth levels and is therefore less painful. Formally, we have:

$$F = [u(w,h) - u(w,h-m)] - [u(w-z,h) - u(w-z,h-m)] + \Psi u_2(w-z,\alpha)$$

with $h - m < \alpha < h - m + \Psi$.

Since $u_2 > 0$ and $u_{12} \gtreqless 0 \iff [u(w,h) - u(w,h-m)] \gtreqless [u(w-z,h) - u(w-z,h-m)]$, we thus obtain:

$$u_{12} \geq 0 \Rightarrow \frac{dz}{dp} > 0$$

To determine the effect of personalized information about the average probability of disease, we must determine how $\frac{dz}{dp}$ changes with p. To do so, we compute:

$$\frac{\partial\left(\frac{dz}{dp}\right)}{\partial p} = \frac{\frac{dF}{dp} EU_3 - F\frac{dEU_3}{dp}}{[EU_3]^2} \tag{10}$$

where:

$$F > 0 \text{ if } u_{12} \geq 0$$
$$\frac{dG}{dp} = 0$$
$$EU_3 > 0$$
$$\frac{dEU_3}{dp} = u_1(w-z, h-m+\Psi) - u_1(w-z,h) < 0 \text{ if } u_{12} \geq 0$$

From (10), we obtain that $u_{12} \geq 0$ is a sufficient condition to have $\frac{\partial\left(\frac{dz}{dp}\right)}{\partial p} > 0$ via $F > 0$ and $\frac{dEU_1}{dp} < 0$. Under this condition, the willingness to pay for self-insurance increases at an increasing rate with the baseline probability of disease (z is convex in p). Using Jensen's inequality, this implies that the willingness to pay for self-insurance based on the average information is lower than the average willingness to pay for self-insurance. Under $u_{12} \geq 0$, we can thus conclude that genetic predisposition tests, by providing a personal information about the baseline probability of disease, rises the benefits of self-insurance programs.

In section 2.1, we provided an extension to the basic model developed in section 2 by assuming that the efficiency of self-protection actions increases with the baseline probability of disease. The same kind of extension could be provided here by assuming that the efficiency of self-insurance actions increases as the severity of the disease rises (*i.e.* $\Psi(m)$ with $\Psi'(m) > 0$). However, this would not change the result obtained. Therefore, with no loss of generality, we only suppose that the efficiency of the self-insurance action does not change with the severity of the disease.

4 Conclusion

The paper evaluates the way personalized information about the baseline probability of disease - the only source of heterogeneity in our model - modifies the average willingness to pay for disease prevention actions. This issue is of particular interest as the development of predisposition genetic tests will soon generalize this kind of information. The question we deal with in the paper is thus related to the way this information should modify the relevance of disease prevention programs.

Prevention action that either reduce the probability of disease (self-protection) or reduce the severity of the disease (self-insurance) are analyzed. We show that personalized health information about the probability of disease raises the average willingness to pay for self-protection when the efficiency of self-protection is constant with the baseline probability of disease. When the efficiency of self-protection actions rises with the baseline probability of disease, the same conclusion is obtained about the effect of personalized information on the average willingness to pay for self-protection as long as the marginal utility of wealth does not fall with individuals' health status (*i.e.* if $u_{12} \geq 0$), a preference that has been empirically supported by Viscusi and Evans (1990), Sloan et al. (1998) and Finkelstein et al. (2009)[6] among others. Under the same assumption about the cross derivative of the utility function, we also show that personalized information about the baseline probability of disease increases the average willingness to pay for self-insurance.

The effect of information on the relevance of disease prevention programs has been addressed by Snow (2011)[7] who indicates that the intensity of prevention efforts (both self-protection and self-insurance) made by (ambiguity averse) individuals is higher in the presence of ambiguity than in its absence. By removing the ambiguity surrounding the probability of diseases, predisposition tests should thus make individuals less prone to make prevention efforts. However, while Snow (2011) focuses on a pure ambiguity effect by analyzing changes in the prevention effort made by similar individuals once the the uncertainty about their probability of disease is removed, we evaluate the effect of the same information on the average willingness to pay of (ambiguity neutral) individuals differing in their baseline probability of disease. Our paper thus shows that the adoption of this different (and complementary) perspective leads to a qualification of the result obtained by Snow (2011).

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[6] Note that the opposite conclusion is reached when minor injuries are considered (see Evans et Viscusi (1991)).
[7] Even though it is not presented in terms of the development of genetic testing.

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Figure 1: