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The value of disease prevention vs treatment

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ABSTRACT

We present an integrated valuation model for diseases that are life-threatening. The model extends the standard one-period value-per-statistical-life model to three health prospects: healthy, ill, and dead. We derive willingness-to-pay values for prevention efforts that reduce a disease's incidence rate as well as for treatments that lower the corresponding health deterioration and mortality rates. We find that the demand value of prevention always exceeds that of treatment. People often overweight small risks and underweight large ones. We use the rank dependent utility framework to explore how the demand for prevention and treatment alters when people evaluate probabilities in a non-linear manner. For incidence and mortality rates associated with common types of cancers, the inverse-S shaped probability weighting found in experimental studies leads to a significant increase in the demand values of both treatment and prevention.

1. Introduction

How should government expenditures on health be allocated to maximize social welfare? Answers to this question require understanding people's preferences for different health interventions (Fuchs and Zeckhauser, 1987). In this paper, we develop a stylized health valuation framework and apply it to the combat of chronic, severe diseases. Cancer is a prime example. Although significant progress has been made over the last 40 years in preventing, diagnosing, and treating cancers, they remain among the leading causes of death.[1] Some researchers have therefore argued that society spends too much on the development of new cancer drugs and other treatment methods, and too little on prevention and diagnosis (Chabner and Roberts, 2005; Faguet, 2005; Sporn, 1996). If that claim were true, then society would not operate at the production possibility frontier (where the good to be produced is additional health and longevity) and a Pareto improvement could be achieved by re-allocating resources from R&D on treatment to prevention and screening efforts.

While efficiency concerns have been raised against the supply side of fighting dreaded diseases such as cancer, similar arguments hold for the demand side as well (Bosworth et al., 2010). Consider empirical studies that suggest people value a reduction in the risk of dying from cancer more than they value a reduction in the risk of dying from other causes (Hammitt and Liu, 2004; Van Houtven et al., 2008; Viscusi et al., 2014), or those that suggest people value prevention of a life-threatening illness more than treatment even when the expected health benefits are the same (Corso et al., 2002). If well informed, such preferences should be reflected in the allocation of the health budget as they are essential to health policy assessments, e.g., in quantifying the social value of fighting cancer (Lakdawalla et al., 2010) or of using statins and other drugs to lower the burden of cardiovascular diseases (Grabowski et al., 2012).

We present willingness-to-pay (WTP) metrics for prevention-based and treatment-based health interventions and study value tradeoffs between the incidence rate, mortality rate, and the life quality associated with chronic disease. The proposed model extends the standard economic model of preferences for mortality risk reductions (Jones-Lee, 1974; Weinstein et al., 1980), which spurred the development of the value per statistical life (VSL) metric. In the spirit of Gerking et al. (2014), we presume that disease-induced mortality is conditional on suffering the disease. Therefore, our model includes three health states: healthy, ill, and dead.[2] The explicit

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[1] In 2012, cancer caused approximately 8.2 million deaths worldwide, making it the leading cause of death ahead of coronary heart disease (Ferlay et al., 2015).

[2] In an online Appendix, we extend the baseline model to accommodate a competing mortality risk and show that the conclusions derived by Eeckhoudt and Hammitt (2001) carry over to our three-state model.

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inclusion of the illness state allows us to identify the relative value of a gain in life quality when ill (Hammitt, 2002). In particular, we provide a formal intuition for why a more painful course of disease increases the WTP for prevention, but has an ambiguous effect on the WTP for treatment. The model also allows exploring diseases which involve only a small risk of dying. The main finding with regard to such diseases is that the value of prevention is discounted proportionally to the risk of dying, while the value of health-state improving measures is increased proportionally to the incidence rate.

Whereas our baseline model is consistent with the welfare economic approach of valuing health risks (i.e., expected utility), it does not capture the fact that most people have neither a clear understanding of the risk of developing a particular disease nor of the likelihoods of various outcomes of screening tests and treatment methods (Peters et al., 2006; Slovic et al., 2005). When presented with statistical information, they tend to overweight small probabilities and underweight large ones, implying an inverse-S shaped probability weighting function (Tversky and Wakker, 1995). As severe diseases involve relatively small incidence rates and relatively large mortality rates, probability weighting may significantly affect people's valuation of disease prevention and treatment allowing them to express pessimism or optimism with regard to specific health outcomes. In order to assess the bias introduced by non-linear weighting of probabilities, we extend Bleichrodt and Eeckhoudt's (2006) application of the rank dependent utility (RDU) framework to three health states.[3] Calibrations of the RDU version of our model to a number of dreaded diseases suggest that non-linear probability weighting may indeed result in demand values of reductions in both incidence and mortality rates that are several times larger than those derived under the expected utility framework.

The paper proceeds as follows. In section 2, we introduce the baseline expected utility model and derive the WTP metrics for reductions in incidence rate, conditional mortality, and health deterioration rate and compare their relative sizes. In section 3, we replace the linear probability measures of the expected utility model by non-linear probability weighting and compare the rank dependent WTP metrics to those derived for the baseline model. We calibrate our model to some types of cancer and cardiovascular disease to illustrate the possible size of the resulting welfare distortions. Section 4 concludes.

2. Baseline model

In this section, we introduce the baseline model of disease valuation and derive WTP values for a reduction in incidence rate, mortality rate and deterioration of life quality. In doing so, we loosely follow the notation of Bleichrodt et al. (2003).

2.1. Set up

Let an individual derive utility $U(W, H)$ from wealth W and health H. We denote first (second) derivatives with respect to wealth by the subscript 1 (11) and those with respect to health by the subscript 2 (22). We make the following conventional assumptions about $U(W, H)$:

- Non-satiation with respect to money: $U_1(W,H)>0$;
- Non-satiation with respect to health: $U_2(W,H)>0$;
- Weak financial risk aversion: $U_{11}(W,H)\leq 0$;
- Weak health risk aversion: $U_{22}(W,H)\leq 0$; and
- Correlation affinity: $U_{12}(W,H)\geq 0$.

The first two assumptions are the usual non-satiation assumptions. The next two assumptions state that less risk over either health or wealth is preferable to more risk. The last assumption implies that the marginal utility of wealth does not decrease with better health. In other words, a person enjoys the benefits of an extra dollar at least as much when healthy as when ill.[4] Viscusi and Evans (1990), Sloan et al. (1998), and more recently Finkelstein et al. (2013) provide empirical support for this assumption.

Now, consider a target disease that threatens health with probability $q=\mathrm{pr}(\text{sick})$. The population average value of q is equal to the population incidence rate of the target disease. Conditional on falling ill, the individual faces a probability $p=\mathrm{pr}(\text{death}|\text{sick})$ to die from the disease. Thus, there are three possible states of the world in our model:

1. Remaining at the current (good) health level H_G with probability $(1-q)$;
2. Developing the disease and surviving in the reduced (bad) health state H_B with probability $q(1-p)$; and
3. Dying from the target disease, which implies health H_D with probability qp.

Note that our model applies to chronic (or incurable) diseases, from which one cannot return to good health H_G.

Without loss of generality, we measure health quality on a unit scale so that $H_G=1$, $H_D=0$, and $H_B=1-h$, where $h<1$ is the health deterioration associated with the non-fatal outcome of the disease. This normalization is convenient as it puts all three dimensions on a common scale with a range from best (0) to worst values (1). The value of h can be measured using a standard gamble question in which the respondent reveals the probability that makes him or her indifferent between a binary lottery between death (H_D) and living with health endowment H_G, or living with health H_B for certain (holding wealth constant in all states).

Each of the above health conditions is associated with a state-dependent utility function $U(W,H_G)>U(W,H_B)>U(W,H_D)$ satisfying the preferential order $H_G \succ H_B \succ H_D$, where $\succ$ indicates strict preference. More precisely, we will use the utility function for health, longevity, and wealth that is admissible under the assumption that preferences for health and longevity are consistent with any life-year measure including QALYs, DALYs, and life years lost to disease (Hammitt, 2013).[5] For any given wealth endowment W, let the state-dependent utility be given by $U(W,H_G)=u(W)+v(W)$, $U(W,H_B)=(1-h)u(W)+v(W)$, and $U(W,H_D)=v(W)$, where $v(.)$ is the utility of wealth conditional on death (i.e., the utility of a bequest) and $u(.)$ is the incremental utility of living with health H_G. We adopt the standard assumptions that $u>0$, $u'>0$, $v'\geq 0$ and $u'', v''\leq 0$.

Under the assumptions made so far, the individual's expected utility takes the form:

$$E[U(W,H)]=(1-q)U(W,H_G)+q[(1-p)U(W,H_B)+pU(W,H_D)]. \quad (1)$$

Substituting the expressions for the state-dependent utility functions and simplifying yields:

$$E[U(W,H)]=[(1-q(p+h-ph)]u(W)+v(W). \quad (2)$$

We are interested in how much a representative individual is willing to pay for a reduction in the incidence rate q ("prevention"), the conditional mortality rate p ("treatment"), and the health

[3] This is not a trivial extension of the two-state model, however, since probability weighting with more than one source of risk raises several additional questions that we address in Section 3 and Appendix B.

[4] We note that Eeckhoudt et al. (2007) propose a straightforward way to empirically test the sign of $U_{12}(W,H)$.

[5] In Appendix A, we derive the analytical results presented in this section for the general case.

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