Endogenous private health investment and the willingness to pay for public health projects: The effects of income

Liqun Liu\textsuperscript{a}, William S. Neilson\textsuperscript{b,}\textsuperscript{*}

\textsuperscript{a}Private Enterprise Research Center, Texas A&M University, USA
\textsuperscript{b}Department of Economics, Texas A&M University, 4228 TAMU, College Station, TX 77843-4228, USA

Received 20 May 2004; accepted 20 December 2004
Available online 2 April 2005

Abstract

A distinction is made between the WTP for health improvement and the WTP for health-improving projects through endogenizing private health investment. While the former always increases in income, income’s effect on the latter depends on whether private and public health inputs are substitutes or complements.

© 2005 Elsevier B.V. All rights reserved.

Keywords: Willingness to pay; Health-improving projects; Income effect

JEL classification: I1; H4; D6

1. Introduction

Willingness to pay (WTP) is widely used to measure the benefits of publicly provided projects that are aimed at improving health, safety, recreation and other amenities that have different monetary values to different consumers. To ensure equitable public financing, it is often of considerable interest to see how the WTP for these types of projects changes with income. The conventional wisdom on this issue is that the WTP for a “personal good” such as health rises as income increases because, for two otherwise
identical individuals, the one with higher income has a larger marginal utility of health and a smaller marginal utility of consumption.\(^1\)

However, the reasoning behind this conventional wisdom has ignored two factors that seem to be relevant to the issue. First, the wealthier (i.e. higher income) of two individuals may spend more to improve her health, ending up having a better health condition than her poorer counterpart. As a result, it is not quite appropriate to hold the health status constant in comparing the WTPs for health improvement of two individuals with different income levels. Importantly, accounting for the larger private health investment and the better health status of the wealthier individual increases the marginal utility of consumption but decreases the marginal utility of health, both putting a downward pressure on the WTP for health improvement. Second, in cost–benefit analysis of publicly financed health projects, the more relevant benefit-side measure is the WTP for a health-improving project rather than the WTP for health improvement itself, which is particularly important because a single health-improving project may produce different magnitudes of health improvement in different individuals. In the case of two individuals with different income, for example, the same health-improving project would probably produce a smaller health improvement in the wealthier individual due to the heavier private health investment. As a result of the differential health effects of a project between the wealthy and the poor, the WTP for the health-improving project does not necessarily positively correlate to income, even when the WTP for health improvement does.

In this paper, we endogenize private health investment and make a distinction between the WTP for health improvement and the WTP for health-improving projects. In particular, we study how an increase in income affects private health investment and both WTP measures.

2. Endogenous private health investment

Suppose that an individual derives satisfaction from consumption \(C\) and health \(H\), with the utility function being \(U(C, H)\). Throughout the paper, we maintain that \(U_1, U_2 > 0, U_{11}, U_{22} < 0, \text{ and } U_{12} \geq 0\). The first two inequalities are uncontroversial because they simply say that the individual is non-satiated and risk-averse with respect to both consumption and health. The third inequality says that consumption and health are complements in generating utility, namely, the marginal utility of consumption does not decrease as health improves. Although the theoretical foundation of this third inequality is not as unambiguous as the other two, there exists empirical evidence that it is true. As a result, it is imposed as a standard assumption in the literature.\(^2\)

The individual faces a trade-off between consumption and health, which can be explored through a private health investment \(I\) that reduces the individual’s net consumption but improves health status. In the meantime, the individual’s health can be enhanced by publicly-financed health-improving projects, which cumulatively incur a total cost/expenditure of \(E\) and generate output of \(G\) for every individual. As a result of the private health investment and the public health-improving projects, the realized health

---

\(^1\) See Jones-Lee (1974) for an excellent example of such reasoning. In making this argument, standard assumptions, that health and consumption are complementary in generating utility and that the marginal utility of consumption diminishes with the level of consumption, are imposed.

\(^2\) For example, the assumption \(U_{12} \geq 0\) is made by Bleichrodt et al. (2003), Eeckhoudt and Hammit (2001), Jones-Lee (1974), and Pratt and Zeckhauser (1996). Empirical evidence supporting this assumption can be found in Sloan et al. (1998) and Viscusi and Evans (1990).
status of the individual is $H=f(I,G;H_0)$, where $H_0$ represents initial health. In this paper, we focus on income differences across individuals and assume that initial health is the same for everyone. Therefore, the health production function can be simply written as $H=f(I,G)$. We maintain that $f_1, f_2>0$ as both private and public efforts improve health and $f_{11}, f_{22}<0$ because of diminishing marginal productivities. The sign of $f_{12}$ depends on the substitutability/complementarity between $I$ and $G$, with $f_{12}<0$ if the two health inputs are substitutes and $f_{12}>0$ if they are complements. After making the health investment, the individual’s net consumption is $C=Y-I$, where $Y$ is the (net-of-tax) income. Whether $I$ and $G$ are substitutes or complements depends on the nature of the expenditure. If the publicly-provided service is free prenatal care, then any pregnant woman who took advantage of the free prenatal care would spend less of her own money on prenatal care, and the private and public expenditures would be substitutes. There is also evidence that publicly-provided vaccinations can lead to reduced incentives for someone to get a vaccination himself, because the publicly-provided vaccinations make the disease less prevalent, which in turn reduces the benefit from vaccinating one’s self. In contrast, clinical trials for preventive medicine, such as studies of the safety and efficacy of vitamin E supplements to prevent heart disease, may be complementary to individual activities to prevent heart disease. These studies guide individuals regarding the most effective ways to prevent disease, and so they can increase the marginal benefit of individual health expenditures. Also, if the private investment prevents one disease and the public investment prevents another, the two types of investment are complementary because as one disease becomes less likely, the benefit from avoiding the other one increases.

For any given $Y$ and $G$, the optimal private health investment satisfies the first order condition

$$-U_1(Y-I,f(I,G)) + U_2(Y-I,f(I,G)) \cdot f_1(I,G) = 0. \quad (1)$$

Through standard comparative statics analysis, the effects of increases in $Y$ and $G$ on private health investment are given, respectively, by

$$\frac{dI}{dY} = \frac{U_{11} - U_{12}f_1}{\Delta} \quad (2)$$

and

$$\frac{dI}{dG} = \frac{(U_{12} - U_{22}f_1)f_2 - U_2f_{12}}{\Delta}, \quad (3)$$

where

$$\Delta = U_{11} - 2U_{12}f_1 + U_{22}(f_1)^2 + U_2f_{11}. \quad (4)$$

Under the maintained assumptions on the first and second order partial derivatives of the utility function $U$ and the health production function $f$, we have $\Delta<0$ (hence, the second order sufficient condition for the

---

3 Thus, we do not consider the possible positive correlation between income and initial health, which is not essential to the purpose of this paper.

4 The tax level should be sufficient enough to cover the public health expenditure $E$ and possible other government expenditures. However, we do not need to explicitly consider government budget constraint since our focus here is individuals’ valuation of the outputs of public health projects rather than a complete cost–benefit analysis of these projects.


6 See Dow et al. (1999).
individual’s health investment problem is satisfied), $d/dY>0$, and, if $f_1<0$, $d/dG<0$. These results concerning the effects of changes in $Y$ and $G$ on $I$ are summarized in the following proposition.

**Proposition 1.** Individual health investment increases in income. It decreases in the public health input if the two health inputs are substitutes.

### 3. WTP for health improvement and WTP for health-improving projects

In this section we argue that endogenous private health investment gives rise to a substantial distinction between the WTP for health improvement and the WTP for health-improving projects. We further illustrate the distinction between the two WTPs by comparing the effects of income on both contingent valuation measures.

The marginal WTP for health improvement, denoted as MWTP$_H$, is the ratio of the marginal utility of health to the marginal utility of consumption. That is,

$$MWTP_H = \frac{U_2[Y - I, f(I,G)]}{U_1[Y - I, f(I,G)]}.$$  \hfill (5)

Fixing $I$, the previous studies reasoned that MWTP$_H$ must rise as income $Y$ goes up because the marginal utility of health (the numerator of the above MWTP$_H$ expression) is nondecreasing in $Y$ (since $U_{12} \geq 0$) and the marginal utility of consumption (the denominator) is decreasing in $Y$ (since $U_{11} < 0$). When the endogeneity of the private health investment $I$ is recognized, however, income’s effect on MWTP$_H$ is no longer as straightforward. As we have established, individuals invest more in health, and as a result, have better health, when income goes up. This places downward pressure on the marginal utility of health (since $U_{22} < 0$) and an upward pressure on the marginal utility of consumption (since $U_{12} \geq 0$), both working to reduce MWTP$_H$. To find the overall impact of higher income on MWTP$_H$, these negative effects through an endogenous change in $I$ must be compared with the previously identified positive effects. Nonetheless, the following proposition indicates that the positive effects outweigh the negative effects.

**Proposition 2.** The marginal WTP for health improvement, MWTP$_H$, increases in income $Y$.

**Proof.** From the first order condition (1), at the optimal private health investment $I$, $MWTP_H = 1/f_1(I,G)$. Therefore,

$$\frac{dMWTP_H}{dY} = \frac{-f_{11}}{f_1^2} \frac{dI}{dY} > 0.$$  \hfill (6)

Now we turn to the marginal WTP for health-improving public projects, which is denoted by MWTP$_G$. A one-unit increase in $G$ at the margin is welfare-equivalent to an $f_2$-unit increase in $H$. Therefore,

$$MWTP_G = MWTP_H \cdot f_2.$$  \hfill (7)

If $I$ is fixed, there is no substantial difference between MWTP$_H$ and MWTP$_G$, since they differ only by a common conversion factor, $f_2(I,G)$. As a result, if MWTP$_H$ increases in $Y$, so does MWTP$_G$. On the
other hand, if $I$ is endogenous and differs across individuals with different income, the positive correlation between $\text{MWTP}_H$ and $Y$ cannot be automatically translated into a positive correlation between $\text{MWTP}_G$ and $Y$. For example, suppose $G$ and $I$ are substitutes such that $f_{12} < 0$. Then, the conversion factor $f_2$ would be smaller for an individual with a higher income because, as Proposition 1 indicates, higher income implies a larger private health investment $I$. Being a substitute to the private health investment, the same increase in $G$ would cause a smaller health improvement if the private health investment is higher. The following proposition shows how the effect of income on the marginal WTP for health-improving public projects depends on the substitutability/complementarity between the two health inputs.

**Proposition 3.** The marginal WTP for health-improving public projects, $\text{MWTP}_G$, increases in income $Y$ if $f_{12} \geq 0$, but is invariant with $Y$ if $G$ and $I$ are perfect substitutes such that $f(I,G)$ can be written as $h(I + g(G))$, where $h', g' > 0$ and $h'' < 0$.

**Proof.** From the first order condition (1), $\text{MWTP}_G = f_2(I,G)/f_1(I,G)$. Therefore,

$$
\frac{d\text{MWTP}_G}{dY} = \frac{f_2 f_{12} - f_2 f_{11}}{f_2^2} \frac{dI}{dY} ,
$$

which is positive if $f_{12} \geq 0$ but is 0 if $f(I,G)$ can be written as $h(I + g(G))$, because in the latter case, $f_1 f_{12} - f_2 f_{11} = g' h' h'' - g' h' h'' = 0$.

A comparison of Propositions 2 and 3 delineates the differences between the MWTP for health and the MWTP for health-improving projects. Proposition 2 establishes that $\text{MWTP}_H$ always rises when income rises, but Proposition 3 only guarantees that $\text{MWTP}_G$ rises if income rises when the two health inputs are complements. Indeed, if the two are substitutes and if the returns to private health investment do not diminish too quickly, $d\text{MWTP}_G/dY$ could be negative, so that an increase in income reduces the amount individuals are willing to pay for public health projects.

Since much of publicly-financed health care can also be purchased by individuals in the health market, $G$ being a perfect substitute to $I$ serves as a benchmark case, in which the MWTP for public health expenditures is invariant with $Y$. On the other hand, $G$ being complementary to $I$ is probably relevant when the government finances such health programs as research and development, clinical trials of preventive medicine, and health education. In addition, as Dow et al. (1999) establish, if the public expenditure fights one disease and the private expenditure fights another, the two expenditures are complementary since an increase in one expenditure increases the benefit from the other.

### 4. Conclusion

In this paper we made a distinction, by allowing for endogenous private health investment, between the WTP for health improvement and the WTP for health-improving projects. While the former WTP is the focus of the literature, the latter is arguably a more relevant concept for cost–benefit analysis of public health care projects. We show that, as income increases, the WTP for health improvement rises, even after incorporating the effects through endogenous private health investment that work to reduce the WTP. On the other hand, the effect of income on the WTP for health-improving projects depends on the substitutability/complementarity between the private health investment and the output of public health projects in the production of health. Two health inputs being complementary in health production...
is sufficient for a positive correlation between income and the WTP for health-improving projects, but
the WTP is insensitive to income in the benchmark case where the two health inputs are perfect
substitutes.

While we used “health” as the “personal good” in question in our formal presentation, the endogeneity
of private effort and distinction between the two kinds of WTP also have implications for the evaluation
of benefit incidence of public projects/regulations that provide other personal goods such as highway or
working environment safety, recreation, environmental quality, or fire and police protection that have no
market price and whose monetary values differ from one person to another. A lesson from this paper is
that, on the “benefits principle” of taxation, the wealthier do not always have to pay more for these
projects. In particular, the complementarity/substitutability between private investment and public
projects is relevant for the equitable financing of public projects.

Acknowledgments

Neilson thanks the Private Enterprise Research Center for financial support, and we thank Harold
Winter for helpful comments.

References

Public Economics 87, 2399–2406.
Review 89, 1358–1371.
261–279.
104, 747–763.