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What should (public) health insurance cover?☆

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Abstract

In any system of health insurance, a decision must be made about what treatments the insurance should cover. One way to make this decision is to rank treatments by their ratios of health benefits to treatment costs. If treatments that are not offered by the health insurance can be purchased out of pocket, the socially optimal ranking of treatments to be included in the health insurance is different from this standard cost-effectiveness rule. It is no longer necessarily true that treatments should be ranked higher the lower are treatment costs (for given health benefits). Moreover, the larger are the costs per treatment for a given benefit–cost ratio, the higher priority should the treatment be given. If the health budget in a public health system does not exceed the socially optimal size, treatments with sufficiently low costs should not be performed by the public health system if treatment may be purchased privately out of pocket.

JEL classification: H42; H51; I10; I18

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1. Introduction

In any health insurance system, public or private, one must make a decision about what treatments the health insurance should cover. Health economists have often argued that cost-effectiveness analysis should play an important role in choosing what should be offered by health

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insurance. Cost-effectiveness is in this context usually defined as the minimum cost for a given health benefit, or equivalently, maximal health benefits for given expenditures on health care.[1] There is a large literature that is critical to this type of analysis. One line of criticism is that cost-effectiveness analysis requires an aggregate measure of health benefits. Whether this measure is "quality adjusted life years" (QALYs) or some other measure, one needs severe restrictions on a general preference ordering over life years and health quality of each life year to be able to represent preferences by any simple aggregate measure.[2] A second line of criticism has been that whatever aggregate health benefit measure one uses to represent preferences at the individual level, one might question the ethical or welfare theoretical basis for aggregating health benefits across individuals.[3]

The present paper ignores the above-mentioned problems with cost-effectiveness analyses of prioritization issues. The focus is instead on a different important issue: at least for public health insurance, most of the literature that discusses how a health budget should be allocated across potential medical interventions explicitly or implicitly assumes that the health interventions that are not funded by the public budget are not carried out. However, both under public and private health insurance it is often possible to purchase treatment out of pocket if treatment is not covered by the health insurance. Examples of treatments that typically may be purchased out of pocket are surgical sterilization, assisted fertilization, cataract surgery, dental care, prescription medicine. Comparing different insurance arrangements one will find that they differ with respect to what is covered and what is not. When treatments of the type above are not covered by the health insurance, they are nevertheless available for those who want to finance the treatment out of pocket.

The paper discusses the use of cost-effectiveness analyses for prioritizing a health budget for a public health system or a private insurance company when an out of pocket option exists. It is shown that when there is an out of pocket option, a simple cost-effectiveness criterion of maximizing the sum of some aggregate measure of health benefits for a given budget is not necessarily the best way to allocate the health budget. In particular, such standard cost-effectiveness analysis does not maximize the sum of utility levels of the members of the health insurance. The reason for this is that the benefit of including a particular treatment in the insurance program can no longer be measured simply by the gross health improvement this treatment gives: some of the health care would otherwise have been performed in any case, so the net health increase is lower than the gross increase. On the other hand, by including a treatment in the health insurance, there are reduced personal costs of treatment financed out of pocket. This cost saving should be included in the benefit side of including the treatment in the health insurance. In order to add the benefits of improved health with the personal cost saving one is thus forced to make a monetary valuation of the net increase in health benefits. The paper shows that maximizing the sum of utility levels of the members of the health insurance (given the budget) gives a different outcome than simply maximizing gross or net health benefits for the given health budget. A comparison is also

[1] For a further discussion of analyses based on the cost-effectiveness see e.g. Weinstein and Stason (1977), Johannesson and Weinstein (1993), Garber and Phelps (1997) and Garber (2000).

[2] See e.g. Broome (1993), Mehrez and Gafni (1989), Culyer and Wagstaff (1993), Bleichrodt and Quiggin (1999) and Gafni et al. (1993).

[3] Criticism of this type of aggregation has been given by e.g. Harris (1987), Wagstaff (1991), Nord (1994), Olsen (1997) and Dolan (1998), while e.g. Bleichrodt (1997), Bleichrodt et al. (2004) and Østerdal (2005) have provided axiomatic analyses showing how one can aggregate individual QALYs to reach a social objective function with a sound welfare theoretical basis.

given between the ranking that maximizes the sum of utility levels and the standard cost-effective ranking of different treatments.

While most of the content of the present paper applies both to public and private health insurance, it is perhaps most relevant for public health insurance. For public health insurance, the members of the health insurance will typically be exogenous, and often equal to the total population. It then makes good sense to allocate an exogenously given health budget to maximize the sum of the members' utility levels (although this is not the only conceivable social objective). As a *normative* recommendation, this also makes sense if the health insurance is private. However, in the latter case health insurance will often be voluntary and there will typically be a choice between insurance companies. The present analysis has nothing to say about what is optimal from the point of view of an insurance company, or how the allocation of persons across insurance companies may depend on what treatments the insurance companies offer. Finally, we disregard the issue of a possible mix of private and public insurance, as discussed by e.g. Blomqvist and Johansson (1997), Allesandro (1999) and Hansen and Keiding (2002).

The rest of the paper is organized as follows. In Section 2 the basic model is introduced, and the socially optimal ranking of different treatments is defined as the ranking that maximizes the sum of utility levels of the members. The standard cost-effective ranking (i.e. ranking according to ratios between health benefits and costs) is compared with the socially optimal ranking. When there is no out of pocket option these ranking are identical. With an out of pocket alternative, however, the rankings differ. An important result in this section is that it is not obvious how the costs of treatments should affect the ranking. It is shown that for identical health benefits, a treatment with higher costs may be ranked higher than a treatment with lower costs. Moreover, the larger are treatment costs for a given benefit–cost ratio, the higher priority should the treatment be given. While the health budget is assumed exogenous in Section 2, the socially optimal budget is derived in Section 3 for the case of public health insurance. It is shown that if the budget is not higher the optimal level, treatments with sufficiently low costs should not be covered by the health insurance, no matter how large the health benefits are. Section 4 discusses some extensions, and Section 5 concludes.

2. Prioritizing for an exogenously given health budget

The utility level of a healthy person with net income y is given by an increasing and strictly concave utility function $u(y)$. If this person gets an illness j the person's utility is reduced from $u(y)$ to $v_j^U(y)$ if no treatment is given. However, if treatment is given for this illness (without any payment) the utility level will instead be $v_j^T(y)$, which by assumption is higher than $v_j^U(y)$. It is also reasonable to assume that $v_j^T(y) \leq u(y)$. Since the occurrence of an illness will be assumed exogenous, we can without loss of generality assume that treatment gives full recovery in the sense that $v_j^T(y) = u(y)$.[4] Finally, we assume that the utility loss in the absence of treatment $(= v_j^T(y) - v_j^U(y) = u(y) - v_j^U(y))$ is independent of income, and we denote this utility loss by h_j. Utility as healthy or treated after an illness is thus $u(y)$, while utility with an illness j that is untreated is $u(y) - h_j$. The assumption that the utility loss due to an illness is independent of income makes the analysis simpler, and also makes it possible to aggregate health benefits of

[4] If $v_j^T(y) < u(y)$ there would be an unavoidable utility loss of $u(y) - v_j^T(y)$ in the case of illness j, independent of whether or not treatment was given for this illness, and an additional utility loss of $v_j^T(y) - v_j^U(y)$ if treatment was not given.

treatments by aggregating the h_j-terms over persons without having to consider which persons one is aggregating over. Notice also that the assumption of utility losses being independent of income is consistent with the willingness to pay for a treatment being increasing in income.[5] However, the assumption of utility losses being independent of income is not consistent with the empirical finding of e.g. Viscusi and Evans (1990) that the marginal utility of income is higher the better health one has. If the marginal utility of income is rising with health, our variable h_j must be increasing in y instead of independent of y as we have assumed. We return to this issue in Section 4.

There are n mutually exclusive potential illnesses, and each person gets illness j with an exogenous probability π_j. The cost of treating illness j is c_j. As explained above, the health benefit of treating illness j is h_j. Standard cost-effectiveness analyses recommend that treatments are ranked according to the ratios h_i/c_i, and that the health insurance (public or private) should cover all treatments for which this ratio is above some threshold determined by the size of the health budget.

In the absence of the possibility of financing treatment out of pocket, such a decision rule will also maximize the sum of all persons' utility levels. To see this, let $F(y)$ be the income distribution function, i.e. $F(y)$ tells us what share of the population has net income below or equal to y. Without loss of generality we assume that the lowest and highest income is 0 and 1, respectively, implying $F(1) = 1$. To simplify the analysis we also assume $F(0) = 0$, but none of the results depend on this assumption. The density function corresponding to F is $f(y) = F'(y)$. At the level of the society, the probabilities π_i are shares of persons with each of the n illnesses. We define a vector of policy variables $\delta_1, \ldots, \delta_n$, where $\delta_j = 1$ if treatment for illness j is covered by the health insurance and $\delta_j = 0$ otherwise.[6] In the absence of the possibility of financing treatment out of pocket, illnesses that are not covered by the health insurance are not treated. In this case the sum of utilities of all persons, henceforth called social welfare, is therefore given by[7]:

$$W = \sum_i \delta_i \pi_i \int_0^1 u(y)\, f(y)\, \mathrm{d}y + \sum_i (1-\delta_i)\pi_i \int_0^1 [u(y) - h_i] f(y)\, \mathrm{d}y \tag{1}$$

In Appendix A it is shown that maximization of W subject to an exogenous budget constraint implies that all treatments satisfying

$$\frac{h_j}{c_j} > \lambda \tag{2}$$

should be covered by the health insurance, where λ is the shadow price of the budget constraint, and thus is lower the higher is the budget.[8]

[5] The willingness to pay for treatment of illness j, denoted WTP_j is defined by $u(y - \mathrm{WTP}_j) = u(y) - h_j$, and is increasing in y due to the concavity of u.

[6] It is assumed throughout that there are no co-payments for treatments covered by the health insurance. Introducing co-payments would not change our results as long as the co-payments are so small that they do not deter anyone from choosing treatments that are offered by the health insurance.

[7] With this setup we have implicitly assumed that $\Sigma_i \pi_i = 1$. If there is a state of no illness, this state is included in the list of n "illnesses" with $h_i = 0$ for this state.

[8] Due to the integer problem, there will typically be one marginal treatment, given by equality instead of the inequality in (2). This treatment should be partially included, i.e. some but not all persons should be offered treatment. The proportion of persons treated is determined so that the budget is exactly used up. This integer problem is from now on ignored.

We now introduce the possibility of financing treatment out of pocket. Assume that if a particular treatment j is not covered by the health insurance, each person has the option to buy treatment out of pocket at the same price as the cost would have been for the public health system or the private insurance company. If treatment for illness j is not covered by the health insurance a person thus has the choice between buying treatment, giving him/her the utility level $u(y-c_j)$, or going untreated, giving him/her the utility level $u(y)-h_j$. The person will choose the alternative that gives the highest utility level: if $u(y-c_j)<u(y)-h_j$ for a person who gets illness j, this person will prefer to be untreated than to pay for treatment out of pocket. If $u(y-c_j)>u(y)-h_j$ for a person who gets illness j, this person will prefer to pay for treatment out of pocket rather than go untreated. If $u(y-c_j)<u(y)-h_j$ for all y, then no one will buy treatment that is not offered by the health insurance. If $u(y-c_j)>u(y)-h_j$ for all y, everyone will buy treatment if this treatment is not covered by the health insurance. The most interesting case is the case where there exists a critical value $\xi(h_j, c_j)\in(0, 1)$ defined by

$$u(\xi(h,c)-c)=u(\xi(h,c))-h \tag{3}$$

In this case the persons who have incomes below $\xi(h_j, c_j)$ will choose to go untreated if treatment is not covered by the health insurance, while persons with incomes above $\xi(h_j, c_j)$ will buy treatment out of pocket.[9]

When there is an out of pocket alternative social welfare W is no longer given by (1), but instead by the following expression:

$$\begin{aligned}W={}&\sum_i \delta_i\pi_i\int_0^1 u(y)\,f(y)\,\mathrm{d}y+\sum_i(1-\delta_i)\pi_i\int_0^{\xi(h_i,c_i)}[u(y)-h_i]\,f(y)\,\mathrm{d}y\\&+\sum_i(1-\delta_i)\pi_i\int_{\xi(h_i,c_i)}^1 u(y-c_i)\,f(y)\,\mathrm{d}y\end{aligned} \tag{4}$$

The first term in this expression gives the welfare level in the states of illness for which the health insurance covers treatment. The second and third term give the welfare level in the states for which treatment is not covered by the health insurance. The second term is the welfare of those who choose to be untreated, and the third term is the welfare of those who choose treatment and pay for this out of pocket. In Appendix A it is shown that maximization of this expression subject to the budget constraint implies that a treatment j should be covered by the health insurance if and only if

$$R(h_j,c_j)>\lambda \tag{5}$$

where λ as before is the shadow price of the budget constraint, and the "ranking function" $R(h, c)$ is defined by

$$R(h,c)=\frac{1}{c}\left\{hF(\xi(h,c))+\int_{\xi(h,c)}^1[u(y)-u(y-c)]f(y)\,\mathrm{d}y\right\} \tag{6}$$

The following lemma is proved in Appendix A (where subscripts denote partial derivatives):

[9] More precisely, $\xi(h, c)$ is defined as follows: (i) $\xi(h, c)=0$ for $h\geq u(0)-u(0-c)$ (and thus $u(y-c)\geq u(y)-h$ for all $y\in[0, 1]$ since $u(y)-u(y-c)$ is declining in y due to the concavity of u), (ii) $\xi(h, c)=1$ for $h\leq u(1)-u(1-c)$ (and thus $u(y-c)\leq u(y)-h$ for all $y\in[0, 1]$), and (iii) by (3) for $u(1)-u(1-c)<h<u(0)-u(0-c)$.

Lemma 1. *The function $R(h, c)$ defined by (6) and (3) has the following properties*:

i $R(h, c) < h/c$ *for* $h > u(1) - u(1-c)$ *and* $R(h, c) = h/c$ *for* $h \leq u(1) - u(1-c)$
ii $R_h(h, c) > 0$ *for* $h < u(0) - u(0-c)$ *and* $R_h(h, c) = 0$ *for* $h \geq u(0) - u(0-c)$
iii $R_c(h, c) > 0$ *for* $h > u(0) - u(0-c)$ *and* $R_c(h, c) < 0$ *for* $h < u(1) - u(1-c)$
iv $R(\alpha h, \alpha c) > R(h, c)$ *for* $\alpha > 1$ *and* $h > u(1) - u(1-c)$
v $\lim_{c \to 0} R(h, c) = \int_0^1 u'(y) f(y)\,\mathrm{d}y$

Several interesting results follow from this lemma. The first result concerns the importance of the availability of the out of pocket option: it has so far implicitly been assumed that all treatments can be financed out of pocket if not covered by the health insurance. In practice, there may for various reasons be some treatments that will not be offered at all if they are not covered by the health insurance. One reason for this could be fixed costs (not formally included in our model). If the number of persons wishing to purchase treatment out of pocket is too small, such treatment may not be offered. A second reason could be that in a country with compulsory public health insurance, the government could forbid various types of private treatment.[10] A third reason is related to the fact that for many illnesses there may be several alternative treatments. Consider an illness with two treatments A and B, with health benefits and costs higher for A than for B. If one of the treatments for sure is going to be offered by the health insurance, the relevant issue is which of the treatments the health insurance should offer. In our analysis, the relevant health benefit is the difference between A and B and the relevant cost is the cost difference between A and B. If B but not A is offered by the health insurance, several persons might wish to pay the cost difference between A and B and thus get treatment A instead of B. However, both in public and private health insurance this is often not permitted: if one wants to have A instead of B one has to pay the *whole* cost of A, and not only the cost difference between A and B. Given this, A will often not be a relevant alternative to purchase out of pocket.

For a treatment for which no out of pocket alternative exists, we can simply set $\xi = 1$ instead of being determined by (3). It is straightforward to verify that all of the analysis above remains valid, so that $R(h_j, c_j) = h_j/c_j$ instead of (6) for a treatment that is not available if not covered by the health insurance. From part i of Lemma 1 we know that for illnesses for which some persons would finance treatment out of pocket if not covered by the health insurance, the ranking function is lower when out of pocket financed treatment is available than when it is not. The following proposition therefore follows:

Proposition 1. *If there are treatments that are not available if not covered by the health insurance, such treatments should be given higher priority as a candidate for inclusion in the public health program than treatments that have the same ratio h_j/c_j of health benefits to costs but are available even if not covered by the health insurance, provided some persons would choose such treatment.*

Loosely speaking, this proposition says that treatments without an out of pocket option should be given higher priority than treatments for which an out of pocket option exists. The intuition is that when an out of pocket option exists, some persons will in any case get treatment. For these persons the benefit of offering treatment through the health insurance is "only" the personal cost

[10] In e.g. Norway there is a legal regulation prohibiting new inpatient facilities (some beds were accepted before the law came into practice in 1986). Treatments requiring inpatient facilities can thus only be purchased privately by going abroad, implying a cost considerably higher than the cost of the domestic public treatment.

savings by not having to pay for the treatment. These personal costs are lower than the utility loss of not having a treatment at all, so treatments with an out of pocket option should therefore be valued lower than treatments without.

Part ii of Lemma 1 says that the ranking function is increasing in health benefits for any illness for which some persons would choose to be untreated if the insurance program did not cover the treatment. We therefore have the following proposition:

Proposition 2. *Consider illnesses for which some persons would choose to be untreated if the insurance program did not cover the treatment. For such illnesses one should give higher priority to a treatment j the higher is the health benefit h_j of the treatment for a given cost c_j.*

This result is very similar to what follows from standard cost-effectiveness analysis. A more interesting result follows from part iii of Lemma 1. This part of Lemma 1 is illustrated in Fig. 1. The fully drawn curve is $R(h, c)$, and the dashed hyperbole is h/c. For sufficiently small treatment costs, i.e. values of c that are so low that $h > u(y) - u(y - c)$ holds for all incomes ($c < c^*$ in Fig. 1), everyone will choose treatment even if it is not covered by the health insurance. Including this treatment in the insurance program is thus simply an insurance against monetary costs as long everyone in any case chooses treatment. This insurance benefit is increasing more than proportionally with costs due to risk aversion, i.e. the concavity of the utility function u. If on the other hand treatment costs are sufficiently high, i.e. c is so high that that $h < u(y) - u(y - c)$ holds for all incomes ($c > c^{**}$ in Fig. 1), no one will choose treatment if it is not offered by the health insurance. In this case $R(h_j, c_j) = h_j/c_j$, i.e. the ranking function is lower the higher is the treatment cost. The exact properties of the function R between these two cost limits is ambiguous, and depends on both the utility function u and the distribution function F. Although it is assumed single-peaked in Fig. 1, this need not be the case.

From Fig. 1 we have the following proposition:

Proposition 3. *The ranking of treatments differing in costs but having the same health benefits is ambiguous. In particular, there may exist three treatments with identical health benefits but different costs $c_1 < c_2 < c_3$ where treatment 2 should be ranked higher than both 1 and 3.*

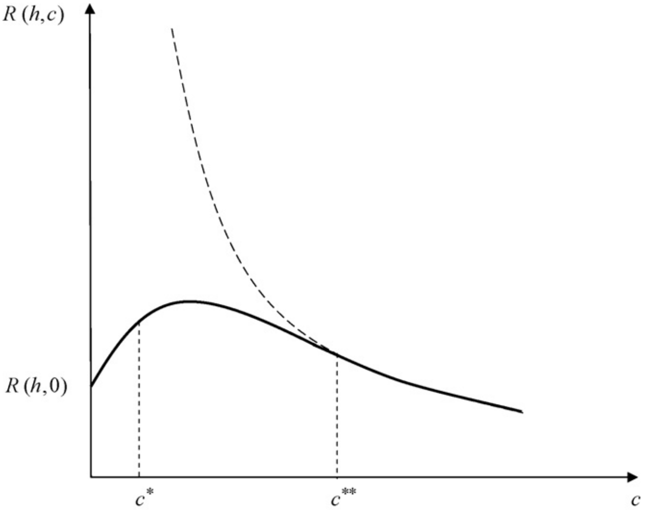

Fig. 1. $R(h, c)$ and h/c for a given value of h.

Part iv of Lemma 1 gives us the following proposition:

Proposition 4. *Consider illnesses for which some persons would choose to be untreated if the insurance program did not cover the treatment. For such illnesses one should give higher priority to a treatment j the higher is the cost c_j of the treatment for a given ratio h_j/c_j of benefits to costs.*

Proposition 4 points at an important difference between the present case and the case with no out of pocket alternative. One can no longer simply rank treatments by their benefit–cost ratios, the cost per treatment is also an important factor to take into consideration. The reason for this result is the concavity of the utility function: the higher is the cost of a treatment, the fewer will choose to finance treatment out of pocket, even if health benefits increase proportionally with treatment costs. This means that the term h/c in (6), which is larger than the second term, gets increased weight (higher F) as c and h are increased proportionally.

3. The optimal size of the health budget

So far it has been assumed that the budget is exogenously given. For the case of public health insurance financed through taxes, it is of interest to ask what size of the budget maximizes the social welfare level W given by (4). To answer this question, one must make an assumption about how taxes are distributed among different persons. We shall assume that an increase in the health budget reduces all net incomes by the same amount. This can be justified by assuming that the initial tax system is optimally designed, where this optimization has taken into consideration possible distributional preferences. Starting at such an optimum, it makes no difference which element of the tax system one changes in order to finance a small increase in the required tax revenue.

Since B is the budget per capita, we thus assume that an increase in B reduces all net incomes by the same amount, i.e. $\mathrm{d}u/\mathrm{d}B = u'(y)(-1)$. Using this and maximizing social welfare W with respect to B gives (see Appendix A for details)

$$\lambda = \int_0^1 u'(y)f(y)\,\mathrm{d}y + \sum_i (1-\delta_i)\pi_i \int_{\xi(h_i,c_i)}^1 [u'(y-c_i) - u'(y)]f(y)\,\mathrm{d}y \tag{7}$$

The second term in this expression would vanish if it was not possible to purchase treatment that was not covered by the health insurance (i.e. if $\xi = 1$). In this case (7) in combination with (2) would have a straightforward interpretation: treatments for the different illnesses should be included in the public health system if and only if the health gain (in utility units) per Euro exceeds the population average of the marginal utility of income (i.e. the inverse of the marginal willingness to pay for a health improvement).

When treatments that are not covered by the health insurance can be financed out of pocket, the second term in (7) is positive due to the concavity of u. The shadow price of the budget is thus higher for this case than for the case where there is no out of pocket alternative. Moreover, we know from part i of Lemma 1 that the ranking function R is not higher with than without an out of pocket option. It therefore follows that fewer treatments pass the criterion for inclusion in the public health program in the present case than in the case when there is no out of pocket option. In other words:

Proposition 5. *The optimal budget of a public health system is smaller when treatment also is available financed privately out of pocket than it is when there is no such option.*

From part v of Lemma 1 we know that the first term in (7) is equal to $\lim_{c\to 0} R(h, c)$, implying that $\lim_{c\to 0} R(h, c) < \lambda$. Since the shadow price λ of the budget constraint is larger the smaller is the budget, the following proposition follows from Fig. 1:

Proposition 6. *If the health budget is equal to or smaller than the socially optimal size, treatments that may be financed out of pocket should not be included in the public health program if the costs of these treatments are sufficiently low, no matter how high the ratio of health benefits to treatment costs are.*

4. Some generalizations

In the formal analysis above we have used several simplifying assumptions. However, several of the results are likely to hold also under more general assumptions. In this section we shall consider three possible generalizations.

In the analysis, it was assumed that the utility loss from an untreated illness is the same for everyone. However, as argued in Section 2, it might be more realistic to assume that the utility loss of an untreated illness h_j is increasing with income, and is thus different for different persons. Even among persons with the same income, the utility loss of an untreated illness will typically vary among persons. The way the model is set up, it seems natural to think of h_j as a measure of the severity of illness j (if untreated). An example of such an interpretation is physical illnesses that may be associated with different levels of pain for different persons. In other cases it may be just as natural to think of h_j as a parameter describing a person's preferences. An example could be a couple who can only have children through assisted fertilization. The term h_j is in this case a variable reflecting how much worse of the couple feels without children than with, i.e. a variable measuring the strength of the preferences for having children.

Whatever the background for the differences in the h_j variables among persons, this distribution will affect who will choose out of pocket treatment and who will not. This choice will thus no longer only depend on income as assumed in the previous analysis. However, there is good reason to believe that the results above will hold also when there is heterogeneity in the population in the h_j variables in addition to income. An important factor behind several of the results was that the benefits of including a treatment in the health insurance to those who would get this treatment in any case is lower than the benefits as measured by the utility gains h_j. Also for this case we therefore get a ranking function resembling (6), with the terms in the integral being lower than the term h_j. In an earlier version of the present paper it is demonstrated that all of our results are valid with heterogeneity of preferences/illness severity for the special case of incomes being the same for all. See also Hoel (2006), where some of the results are derived for the case of heterogeneity both in income and preferences.

In the formal analysis it has been assumed that the illnesses are mutually exclusive. In reality, there is also the possibility of co-morbidities, i.e. two illnesses occurring simultaneously. Such co-morbidities may cause problems even for standard cost-effectiveness analyses, as the utility loss from two illnesses 1 and 2 need not be equal to $h_1 + h_2$. If e.g. $h_{1+2} > h_1 + h_2$ (in obvious notation) it may be the case that illnesses 1 and 2 are rejected based on the ranking criterion (2), while nevertheless $h_{1+2}/(c_1 + c_2) > \lambda$. For the case with an out of pocket alternative, co-morbidities may create problems for the ranking even if $h_{1+2} = h_1 + h_2$: from Proposition 4 it follows that we cannot rule out the possibility of $R(h_1 + h_2, c_1 + c_2) > \lambda$ even if $R(h_1, c_1) < \lambda$ and $R(h_2, c_2) < \lambda$. In practise, it may be difficult to include treatment of 1 and 2 when they occur simultaneously, but not include them when they occur independently. One possible practical solution could then be to let the decision of whether or not to include treatments in the insurance program be affected by how frequently the illnesses occur jointly as opposed to individually.

In the formal analysis, it was assumed that the cost per treatment was independent of whether it was financed by the health insurance or out of pocket. This need not be the case. If there is a public health system and treatments out of pocket are supplied by private supplementary health providers, the reason for cost differences could be differences in efficiency between the public and the private sector. Profit margins could also differ depending on whether a treatment was purchased by an insurance company or privately out of pocket. If cost differences between treatments covered by the insurance and purchased out of pocket vary across treatments, this may obviously affect the optimal ranking of treatments. However, if there are differences in costs but the proportion between out of pocket costs and insurance covered costs are identical across treatments, our analysis is easy to generalize. In this case we let the cost of the insurance company for treatment j be c_j (as before) and the out of pocket treatment cost be kc_j, where k is some positive number (smaller or larger than 1). In our analysis the terms $\xi - c$ and $y - c_i$ in (3) and (4) would be replaced by $\xi - kc$ and $y - kc_i$. Going through the proofs in Appendix A with this modification it can be shown that all of our results remain valid (with $y - c$ in the ranking function replaced by $y - kc$).

5. Concluding remarks

The preceding analysis has shown that the existence of an out of pocket option has important consequences for the ranking of treatments in a cost-effectiveness analysis of what health insurance should cover. The conclusions are summarized in Propositions 1–6. To be able to make an exact ranking over alternatives, one would in addition to the health benefits that enter a standard cost-effectiveness analysis also have to compute the second term of the ranking function given by (6). However, even without such an exact calculation of this term, our qualitative results may be of some use in how to rank different treatments. In particular, for treatments with roughly the same benefit–cost ratios (h/c) that are all close to the threshold level λ, our analysis suggests that the health insurance should cover the treatments with large costs per treatment but not those with relatively small costs per treatment. An example of treatment with low costs could be surgical sterilization (at least for men). This is a once in a lifetime treatment and the cost is only a small fraction of 1% of the life time income of most people. The present analysis therefore gives a good justification for not including this treatment among the treatments covered by the health insurance. Prescription medicines for chronic diseases are on the other hand often quite costly (over a life time), and there are thus good reasons for covering such expenses by the health insurance, even in cases where the health benefit to cost ratio is lower than for some treatments that are not covered by the insurance.

Appendix A. Derivation of results

A.1. The optimal ranking

With the notation introduced in Section 2, the budget constraint (per capita) is

$$\sum_i \delta_i \pi_i c_i \leq B \tag{8}$$

where B is exogenous. The Lagrangian corresponding to maximizing (4) subject to (8) is

$$L = \sum_i \delta_i \pi_i \int_0^1 u(y)\, f(y)\,\mathrm{d}y + \sum_i (1-\delta_i)\pi_i \int_0^{\xi(h_i,c_i)} [u(y)-h_i] f(y)\,\mathrm{d}y$$
$$+ \sum_i (1-\delta_i)\pi_i \int_{\xi(h_i,c_i)}^1 u(y-c_i) f(y)\mathrm{d}y + \lambda \left(B - \sum_i \delta_i \pi_i c_i \right) \tag{9}$$

A treatment j should be included in the public program if L is increasing in δ_j but not included if L is declining in δ_j. It follows from (9) that

$$\frac{\partial L}{\partial \delta_j} = \pi_j \left\{ h_j F(\xi(h_j,c_j)) + \int_{\xi(h_j,c_j)}^1 [u(y)-u(y-c_j)] f(y)\,\mathrm{d}y - \lambda c_j \right\}$$
$$= \pi_j c_j [R(h_j,c_j) - \lambda] \tag{10}$$

where R is defined by (6). This expression is positive if and only if (5) holds. For the case with no out of pocket option, we have $\xi = 1$, and the derivative in (10) is positive if and only if (2) holds.

A.2. *The optimal budget*

The optimal budget is found by maximizing W with respect to B given that the increase in B reduces all net incomes by the same amount, i.e. $\mathrm{d}u/\mathrm{d}B = u'(y)(-1)$. Using this and setting the derivative of (9) with respect to B equal to zero gives Eq. (7).

Proof of Lemma 1.

1.i $h > u(1) - u(1-c)$ implies that $\xi < 1$ (cf. (3) and footnote 9), and thus $F(\xi) < 1$. Since $u(y) - u(y-c) < h$ for those who choose to pay for treatment out of pocket, the first part of Lemma 1.i follows. $h \le u(1) - u(1-c)$ implies that $\xi = 1$, cf. footnote 9. This proves the second part of Lemma 1.i.

1.ii $h < u(0) - u(0-c)$ implies that $\xi > 0$ and thus $F(\xi) > 0$. From (6) it follows that

$$R_h = \frac{F}{c} + \{h - [u(\xi) - u(\xi - c)]\} f(\xi)\xi_h(h,c) \tag{11}$$

where the term in curly brackets is zero from the definition of ξ. We therefore have $R_h > 0$ for $F > 0$. If $h > u(0) - u(0-c)$ we have $\xi = 1$ and thus $F(\xi) = 0$, and R is independent of h.

1.iii $h > u(0) - u(0-c)$ implies that $\xi = 0$ and thus $F(\xi) = 0$. From (6) it follows that

$$R(h,c) = \int_0^1 \frac{u(y) - u(y-c)}{c} f(y)\,\mathrm{d}y \tag{12}$$

The fraction in the integral is increasing in c due to the concavity of u, implying $R_c > 0$. $h < u(1) - u(1-c)$ implies that $\xi = 1$ (cf. footnote 9), and thus $F(\xi) = 1$. In this case it follows from (6) that $R(h, c) = h/c$, implying $R_c < 0$.

1.iv Let $h = \beta c$. Keeping β constant and increasing c gives

$$\frac{\mathrm{d}R(\beta c, c)}{\mathrm{d}c} = \left\{ \frac{h}{c} - \frac{u(\xi) - u(\xi - c)}{c} \right\} f(\xi) \frac{\mathrm{d}\xi(\beta c, c)}{\mathrm{d}c} + \int_{\xi}^{1} \frac{\mathrm{d}}{\mathrm{d}c} \frac{u(y) - u(y - c)}{c} f(y)\,\mathrm{d}y \tag{13}$$

The term in curly brackets is zero. Moreover, when the initial values of h and c are such that $h > u(1) - u(1 - c)$, we have $\xi < 1$, and the derivative in the integral is positive due to the concavity of u. A proportional increase of h and c thus increases R.

1.v When c is sufficiently small, everyone will choose treatment even if it is not covered by the health insurance, implying that $\xi = 0$ for c sufficiently small. 1.v then immediately follows from L'Hopital's Rule. □

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