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# Fairness in cost-benefit analysis: an application to health technology assessment

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**ABSTRACT.** We evaluate the introduction of various forms of antihypertensive treatment in France with a distribution-sensitive cost-benefit analysis. Compared to traditional cost-benefit analysis, we implement distributional weighting based on equivalent incomes, a new concept of individual well-being that does respect individual preferences but is not subjectively welfarist. Individual preferences are estimated on the basis of a contingent valuation question, introduced into a representative survey of the French population. Compared to traditional cost-effectiveness analysis in health technology assessment, we show

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that it is practically feasible to go beyond a narrow evaluation of health outcomes while still fully exploiting the technical sophistication of medical information. Sensitivity analysis illustrates the relevancy of this richer welfare framework, the importance of the distinction between an ex ante and an ex post-approach, and the need to consider distributional effects in a broader institutional setting.

**KEYWORDS.** Cost-benefit analysis, distributional weights, equivalent income, antihypertensive treatment.

# 1 Introduction

In many countries with a publicly financed health care system, governments are becoming more and more concerned about the sharp and continuous increase in health care expenditures. There is a growing consensus that only effective interventions should be reimbursed. Although sometimes the evaluation of new treatments is restricted to clinical effectiveness (as in the "comparative effectiveness research", promoted by the Affordable Care Act in the US), many observers and politicians are convinced that costs should also enter the picture. This is most outspoken in the application of cost-effectiveness analysis by the National Institute for Health and Care Excellence (NICE) in the UK, but many other countries are moving in the same direction. As soon as these techniques are used to determine what should be included in the public health system coverage, distributional issues come to the fore. Many find it difficult to accept that richer citizens can pay out of pocket for therapies that are considered to be insufficiently cost-effective to be included in the public coverage and that are therefore denied to the poor.

For a welfare economist the most natural approach to evaluate these decisions is cost-benefit analysis (CBA). Yet, both the medical community and, partly as a consequence, most health economists show a deep reluctance against traditional CBA, i.e. the approach in which maximization of the unweighted sum of individual consumer surpluses (or related concepts such as compensating variations) is taken as the social objective. Using willingness-to-pay as a monetary valuation of health changes is considered morally objectionable. Moreover, the fact that the rich can have a higher willingness-to-pay for

a treatment just because they can afford it is seen as inequitable. As an alternative, it has become common practice to implement cost-effectiveness analysis (CEA), using as objective function the sum of health outcomes (e.g. as measured in QALY's). This is sometimes advocated as a non- or extra-welfarist approach. However, while CEA can be useful in guiding choices within a given health care budget, it has obvious weaknesses in light of the challenges described before.

First, the determination of the optimal size of the health care budget requires an analysis of the trade-off between health and other dimensions of life. Focusing exclusively on health outcomes is not sufficient, as one must introduce some measure of overall well-being. Second, although in theory it is possible to introduce distributional (e.g. severity) weighting in CEA, the usual practice is to take as social objective the unweighted sum of health outcomes. The argument is that it is ethically acceptable to give the same weight to an additional unit of health for all individuals, whereas it would be unacceptable to assume that an additional euro has the same value for the poor and the rich. This argument is not convincing. From an empirical perspective, taking the unweighted sum of health outcomes as the social objective is rejected by a majority of the population.[3] More fundamentally, equity requires comparing individuals in terms of all the relevant dimensions of life, and not just in terms of health. "A state of affairs in which those who are otherwise worse off are healthier than those who are otherwise more fortunate is more just rather than less just than a state of affairs which is exactly the same except that health is equally distributed" (Hausman, 2007).

In this paper we show that it is possible to formulate a version of CBA which answers the criticism raised by health economists and does not suffer from the limitations of CEA. More specifically we propose to perform economic evaluation in health care with a *distributionally sensitive* social welfare function of individual *well-being* levels in an *ex post*-perspective. First, we propose to implement as a measure of individual well-being the so-called equivalent income. As we will explain, this measure does respect individual preferences, but is not subjectively welfarist, because it does not coincide with subjective utility. Individual preferences are then used to operationalise the trade-offs between the different dimensions of life. In this approach, money is just a measuring rod. Second, we will introduce distributional weights through a social welfare function (SWF). Although

[3] An overview of relevant survey results can be found in Gaertner and Schokkaert (2012).

this is not common practice in CBA, it is not an innovative step in a welfare economic perspective. It is already known for a long time that the traditional approach without distributional weighting is logically flawed and ethically unattractive (see, e.g., Blackorby and Donaldson, 1990; Fleurbaey and Blanchet, 2013). Third, both CEA and traditional CBA handle cases of uncertainty from an *ex ante* perspective, i.e. by first calculating expected values of the outcomes (respectively health or utility) at the individual level and then defining the social welfare function over these expected values. We will advocate an *ex post* perspective, which takes into account the inequality in the final outcomes in each of the possible social states.

We cannot go into the broad intellectual debate on these three issues. In section 2 we will present our theoretical background in general terms. We will briefly argue why our proposal is worth considering, but we refer to other papers for a deeper discussion (see, e.g., Fleurbaey et al., 2013). The main contribution of our paper is to show that this approach can be applied in a real-world setting. Indeed, one criticism that is often put forward in favour of traditional CEA and against CBA with distributional weights is that the latter is unrealistically ambitious. We show that this judgement is too pessimistic. Our empirical application is the assessment of antihypertensive treatments for patients with essential hypertension in France. We describe the decision problem in section 3 and in our empirical work we use the empirical information that was already used by the Haute Autorité de la Santé (HAS, French National Authority for Health) to evaluate the various treatments in a traditional CEA. In section 4 we introduce new data, obtained from a survey with a representative sample of the French population, and we show how they can be used to estimate individual preferences. These results on preferences are generic, in the sense that they can be meaningfully transferred to other applications. In section 5 we then go through the different steps of our specific application: from the calculation of equivalent incomes to the calculation of the social welfare effect of the different treatments. In section 6 we show the results of the evaluation exercise and we present a series of sensitivity analyses to illustrate the characteristic features of our approach and to compare it with traditional CEA and with unweighted CBA. In the conclusion (section 7), we discuss some important remaining open questions.

Since we focus on health, the emphasis of our paper is on a comparison between distributionally weighted CBA and CEA. However, our theoretical approach is much broader

than only health. Our empirical illustration of how to implement distributionally-sensitive CBA with equivalent incomes is also informative for applications in other policy domains.

# 2 Theoretical background

As soon as one aims to go beyond health, it becomes essential to formulate assumptions about the desirable trade-offs between health and other dimensions of life. We will focus in this paper on only two dimensions, income $y$ and health $h$, and we describe the life situation of individual $i$ by the bundle $(y_i, h_i)$. Of course, people care about other life dimensions in addition to these two: about the quality of their job, about their social relations, about the social and economic environment in which they are living. Although the theoretical framework that we will propose can easily accommodate more dimensions, we restrict our analysis to income and health in order to keep the empirical analysis tractable.

In a welfarist approach the ultimate criterion to evaluate the individual's situation is her level of subjective satisfaction. The limitations of welfarism have been hotly debated in the literature. We propose an alternative welfare measure, the so-called equivalent income in section 2.1. We then argue that distributional considerations can be modelled in a natural way through a social welfare function (section 2.2). We finally point out that the distinction between an *ex ante* and an *ex post* approach does matter in this context (section 2.3) and we show how an ex post-approach can be implemented.

## 2.1 A welfare measure: equivalent income

We assume that individual $i$ has preferences defined over bundles $(y_i, h_i)$, capturing what he considers to be important in life, i.e. his own personal life project.[4] We write

[4] "Preferences" have been interpreted in many different ways in the economic literature. The most popular interpretation refers to "revealed preferences", i.e. the preferences that can be derived from individual rational choices. This is *not* our interpretation. We believe that choice behaviour does not always reveal the true underlying convictions of individuals, e.g. because of informational and decision-making limitations. The preferences, as we define them, are a mental construct, a representation of the (cognitive) life project of the individual.

$(y_i, h_i)R_i(y_i', h_i')$ if individual $i$ weakly prefers $(y_i, h_i)$ to $(y_i', h_i')$ and we use the notation $I_i$ to indicate indifference. Different individuals have different ideas about what is important in life. It seems natural that a democratic society should respect this diversity of life projects. As we believe that each individual is best placed to decide about the trade-offs between the various dimensions of his/her own life, we look for an individual welfare measure $v_i(y_i, h_i)$ that does respect these individual ideas about the good life, i.e. such that

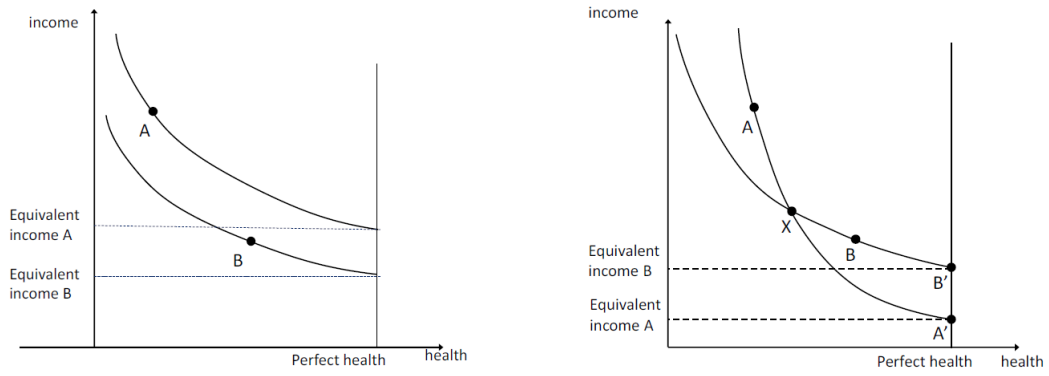
$$v_i(y_i', h_i') \geq v_i(y_i, h_i) \Leftrightarrow (y_i', h_i')R_i(y_i, h_i). \tag{1}$$

If an individual is in a situation that she herself finds better (in the light of her own convictions), this should be reflected in the measure of well-being.

Eq. (1) shows that $v_i(y_i, h_i)$ can be interpreted as an individual utility function. This might create the impression that imposing (1) boils down to subjective welfarism. However, this is a mistake. Indeed, there are many different functions that respect ordinal preferences, all positive monotonic transformations of each other. Taking subjective well-being or happiness is just one possible choice out of all these possible cardinalisations. The problem with this specific happiness-scale becomes obvious when one extends the idea of respecting individual preferences to interpersonal comparisons. Take two individuals $i$ and $j$ with identical preferences, say $R_i = R_j = \overline{R}$. Respecting these common preferences then imposes

$$v_i(y_i', h_i') \geq v_j(y_j, h_j) \Leftrightarrow (y_i', h_i')\overline{R}(y_j, h_j). \tag{2}$$

Figure 1a illustrates. Ann (in A) and Bob (in B) have identical preferences. Eq. (2) then implies that Ann is better off than B, since A is on a higher indifference curve. Yet this does *not* imply that the subjective satisfaction of Ann is larger than that of Bob, even if the measurement of subjective satisfaction respects ordinal preferences at the level of each individual. Measuring subjective satisfaction refers to a specific cardinalisation of the indifference curves. Introducing the notation $S_A(X)$ for the subjective satisfaction of A in X, respecting ordinal preferences implies in our example that $S_A(A) > S_A(B)$ and that $S_B(A) > S_B(B)$. Yet this does not at all preclude that $S_B(B) > S_A(A)$, which would go against condition (2). It is possible that both individuals prefer A to B, while at the same time the individual in B reaches a higher satisfaction level than the individual in A. The most common situation in which this can occur in the real world is one in which




a. Identical preferences b. Different preferences

Figure 1: Equivalent income

individuals adapt their aspirations to what is feasible for them in their actual situation.[5]

The challenge is then to formulate a concept of individual well-being that does respect condition (2) and can also be applied in comparisons between two individuals with different preferences. Here is one possibility. A more elaborate justification of the concept of equivalent income and a comparison with alternative ways of measuring well-being can be found in Fleurbaey and Blanchet (2013) and in Decancq et al. (2015a). Take "perfect health" $h^*$ as a reference level for health and define the equivalent income $y_i^*$ of individual $i$ implicitly by

$$(y_i, h_i) I_i(y_i^*, h^*), \tag{3}$$

i.e. the hypothetical income that together with perfect health would put the individual in a situation that is for her as good as her actual situation $(y_i, h_i)$. The proposal is to take this equivalent income as the definition of individual well-being, i.e.

$$v_i(y_i, h_i) \equiv y_i^*(y_i, h_i). \tag{4}$$

Let us give some more interpretation to explain the intuition behind the approach. We

[5]This was called "physical-condition neglect" in Sen (1985). The empirical happiness literature has collected a lot of information showing that this phenomenon also occurs in the case of health (see, e.g., Loewenstein and Ubel, 2008). A deeper discussion on the pros and cons of the use of different well-being measures for welfare analysis can be found in Decancq et al. (2015a, 2015b) and in Fleurbaey and Blanchet (2013).

want to compare the well-being level of Ann in situation A and Bob in situation B, with their respective indifference curves as shown in Figure 1b. For Ann, her actual situation A is equivalent to the hypothetical situation A'. For Bob, his actual situation B is equally good as the hypothetical situation B'. The hypothetical situations A' and B' are both situations of perfect health, and the basic underlying assumption is that we can compare the well-being levels of Ann and Bob in A' and B' on the basis of the incomes in these situations only, i.e. on the basis of the equivalent incomes indicated in the figure. To see why this is meaningful, consider another hypothetical situation X. If both Ann and Bob were in X, they would have the same health and the same income. Yet, their equivalent incomes would be different. The reason is that preferences are taken into account and the shape of the indifference curves indicates that Ann cares more about being ill than Bob: in X, her marginal rate of substitution between income and health is larger than that of Bob. Yet, it seems reasonable to assume that preferences should not count if the individuals are in the best possible health situation, i.e. if Ann were in situation A' and Bob were in situation B'. If we accept that preferences should not play a role in well-being comparisons between A' and B', and since the health situation is the same in A' and B', the comparison can be fully based on the incomes in these situations. We can then use "equivalent incomes" as a measure of well-being to compare A' and B', and hence also to compare A (equivalent to A') and B (equivalent to B').

Two important points. First, the equivalent income approach is definitely *not* subjectively welfarist. This is well illustrated in Figure 1a, which immediately shows that equivalent incomes satisfy our condition (2). If two individuals share the same preferences, the one that reaches a higher indifference curve will always have a larger equivalent income. Second, the equivalent income approach does not fall into the opposite trap of money fetishism either. Despite the fact that it is expressed in monetary terms (with all the ensuing practical advantages), it is an encompassing measure of well-being, taking into account the welfare loss as a consequence of being ill. Eq. (3) can indeed be written as

$$y_i^*(y_i, h_i) = y_i - WTP_i(h_i \to h^*), \tag{5}$$

where $WTP_i(h_i \to h^*)$ denotes the willingness-to-pay of individual $i$ to go from his actual

health situation $h_i$ to the reference "perfect" health level $h^*$.[6] This willingness-to-pay $WTP_i(h_i \rightarrow h^*)$ can be large, and the ranking of individuals on the basis of equivalent incomes can then be very different from their ranking in terms of income. In Figure 1b, Ann's income in A is larger than Bob's income in B, but nevertheless her equivalent income is lower (because her health situation is worse, and she cares greatly about health).

As mentioned before, a common criticism on the use of willingness-to-pay measures is that the rich normally will have a larger willingness-to-pay than the poor, just because they can afford it, and that this does not mean that they care more about their health. The resulting equity issues can be solved, however, if one introduces a distribution-sensitive social welfare function.

## 2.2 Distribution: the social welfare function

Suppose there are $N$ individuals. Since in our approach the ultimate criterion to evaluate social states and policies is the well-being of the individuals, all the information that is needed for such an evaluation is given by the vector $(y_1^*, \ldots, y_N^*)$. For the moment we keep $N$ fixed, and we will explain later how we handle mortality in our empirical work. Let us also assume that there is no uncertainty, i.e. that there is only one possible state of the world after a policy (in our case the reimbursement of a specific health treatment) has been introduced. We will introduce uncertainty in the next section.

Denoting the equivalent income of individual $i$ after policy A by $y_i^{*A}$, we will then say that policy A is better than policy B if $(y_1^{*A}, \ldots, y_N^{*A})$ is socially preferred to $(y_1^{*B}, \ldots, y_N^{*B})$. Different rankings of well-being vectors will reflect different ideas regarding distributive justice. We can represent this ranking by a social welfare function $W(y_1^*, \ldots, y_N^*)$, with the functional form of $W(.)$ capturing the specific stance on (re)distribution. For an inequality-averse social welfare function it will be the case that $\partial W/\partial y_i^* > \partial W/\partial y_j^*$ if $y_i^* < y_j^*$. This takes care of the equity problem related to the use of willingness-to-pay. As an illustration, take two individuals with $y_i < y_j$ but with the same monetary value of the welfare loss due to illness, i.e. $WTP_i(h_i \rightarrow h^*) = WTP_j(h_j \rightarrow h^*)$. Since individual $j$

[6] Since this willingness-to-pay is conditional on $y_i$, it would be more correct to write it as $WTP_i(h_i \rightarrow h^*; y_i)$.

can better afford to pay for a better health, it may be misleading to infer from the equality of the willingnesses-to-pay that they both care equally about being ill. This is taken into account in the inequality-averse SWF, however. Given definition (5), we know that in this example $y_i^* < y_j^*$ and therefore the same individual loss will have a smaller negative effect on social welfare for the rich individual $j$ than for the poor individual $i$.[7]

In our empirical work, we will use the popular iso-elastic Atkinson SWF, defined as

$$SW = \frac{1}{1-\rho} \sum_i (y_i^*)^{1-\rho}, \tag{6}$$

with $\rho$ the parameter of inequality aversion. If one is not averse towards inequality, $\rho = 0$, and eq. (6) becomes the simple sum of equivalent incomes. If $\rho$ increases, a relatively larger and larger weight is given to the worse-off individuals. In the extreme case where $\rho \to \infty$, eq. (6) boils down to the maximin social welfare function, which gives a positive weight to only the worst-off individuals.[8] The choice of $\rho$ is a value judgement. In our empirical work we will show the results for different values of $\rho$. In the conclusion we come back to the place of CBA in democratic procedures of decision-making.

## 2.3 Uncertainty: ex ante versus ex post

Most health care interventions have uncertain outcomes. We will therefore now extend the approach in the previous section and assume that there are $S$ different possible states of the world, occurring with probabilities $(\Pi_1, \ldots, \Pi_S)$ with $\sum_s \Pi_s = 1$. Let us denote the vector of equivalent incomes in state $s$ by $(y_{1s}^*, \ldots, y_{Ns}^*)$.

[7] It is well-known that choosing either money or health as the numeraire does matter in an approach without distributional weights. The choice becomes irrelevant, however, as soon as one works within a coherent SWF-framework - see, e.g., the exchange of ideas between Brekke (1997), Drèze (1998) and Johansson (1998).

[8] If one considers marginal changes, eq. (6) implies that the "distributional weight" of individual $i$ is given by $(y_i^*)^{-\rho}$. An overview of such marginal weights with equivalent incomes calculated from a survey in Marseilles is given in Fleurbaey et al. (2013). However, in the empirical application of this paper we will consider discrete changes and therefore directly compare different values of $SW$.

The *ex ante*-approach first computes expected outcomes at the individual level

$$EY_i^* = \sum_s \Pi_s u_i\left(y_{is}^*\right), \tag{7}$$

where $u_i(y_{is}^*)$ is a von Neumann-Morgenstern utility function, and then introduces these individual expected outcomes into the social welfare function. This means that the inequality aversion pertains to individual expected outcomes. In the Atkinson-specification, this results in

$$SW^{exante} = \frac{1}{1-\rho}\sum_i (EY_i^*)^{1-\rho} = \frac{1}{1-\rho}\sum_i \left[\sum_s \Pi_s u_i\left(y_{is}^*\right)\right]^{1-\rho}. \tag{8}$$

Under the assumption of constant relative risk aversion $\varepsilon$, we can write $u_i(y_{is}^*)$ as

$$u_i\left(y_{is}^*\right) = \frac{1}{1-\varepsilon}(y_{is}^*)^{1-\varepsilon}. \tag{9}$$

We will use this specification in our empirical work.

In the *ex post*-approach we introduce inequality aversion with respect to the actual outcomes in each potential state of the world, and then compute the expected value of the social welfare function. This yields

$$SW^{ex\,post} = \sum_s \Pi_s \left[\frac{1}{1-\rho}\sum_i (y_{is}^*)^{1-\rho}\right] \tag{10}$$

In the case considered in this paper, however, there is an important simplification. The risks we consider are health risks at the individual level. Since each individual's risk is independent of other individuals' risks, there is no macrorisk. In that case, by the law of large numbers, the final distribution of individual situations is almost certain; i.e. the term in brackets is almost always the same independently of $s$.[9] Therefore we can simply compute final social welfare in terms of the known proportions of different individual

[9] In the case of macrorisk (e.g., a pandemic), formula (10) can also have a social von Neumann-Morgenstern function representing risk attitude at the social level: $\sum_s \pi_s V\left[EDE(y_{1s}^*,...,y_{Ns}^*)\right]$, where $V$ embodies the social attitude to risk and $EDE_s$ is the equally distributed equivalent in state $s$, i.e. $\sum_i (y_{is}^*)^{1-\rho} = N.(EDE_s)^{1-\rho}$ (see, e.g., Fleurbaey and Zuber, 2015).

health trajectories in the population. Equation (6) then remains the relevant definition of social welfare at the social level.

| individual state | S1 | S2 |
|---|---|---|
| individual outcome | 5 | 10 |

Policy A

| individual state | S1 | S2 |
|---|---|---|
| individual outcome | 7.5 | 7.5 |

Policy B

Table 1: Ex ante versus ex post

It is clear that the two objective functions (8) and (10) coincide if individuals have no risk aversion and if we do not care about inequality, i.e., if $\varepsilon = \rho = 0$.[10] In general, however, the functions will be different. We will follow the ex post-approach. One reason for this is the following. Compare in Table 1 the outcomes of two policies A and B with a large number of individuals and two possible states for each individual, each occurring independently for every individual and with a probability of 0.5.[11] In an ex ante-perspective, policies A and B are equivalent, as they yield the same vector of (equal) expected outcomes. From an ex post-perspective it matters that outcomes are equally distributed in all states with policy B, while with policy A there are unequal outcomes, because, almost surely, half of the individuals will have outcome 5 and half will have outcome 10. Another way of stating the same insight is by observing that with policy A an individual $i$ is unlucky if state S1 materialises for him, while an individual $j$ is lucky if state S2 occurs for him. Individuals cannot be held responsible for their good or bad luck.[12] Should we then not give a greater weight to those that are "unlucky" in the different social states? This advocates in favour of an ex post-approach.[13] However, we will also show the results of the ex ante-approach in our sensitivity analysis in section 6.2.1.

Let us summarise. In evaluating different treatments, in the ex post approach we first define the distribution of final situations for all the individuals in the population. We

[10] A special case is that of traditional cost-effectiveness analysis with the unweighted sum of QALYs as the objective function. In that setting there is no difference between ex ante and ex post evaluation.

[11] We therefore have $2^n$ social states $s$.

[12] We side-step here the huge debate on responsibility for lifestyles (and hence for the occurrence of diseases that may/are caused by lifestyle differences) - see, e.g., the survey in Fleurbaey and Schokkaert (2012). In our interpretation "luck" cannot be influenced by individual behaviour.

[13] In the traditional economic approach, the ex ante objective is in terms of expected utilities. The main argument in favour of ex ante is then that one should respect individual risk preferences. See, e.g., Fleurbaey (2008) for a more general discussion of the pros and cons of ex ante versus ex post social evaluation in a context of risk.

calculate for all individuals the well-being level they reach in each of these possible situations. Policy A is then better than policy B if the resulting level of social welfare is larger, where social welfare is calculated with eq. (6).

# 3 The problem: evaluating antihypertensive treatments

Our empirical application is the assessment of three different treatments for patients with essential hypertension in France. Patients with essential hypertension are patients with high blood pressure (over 150 mmHg)[14] but without a history of cardiovascular events (i.e. stroke, myocardial infarction, angina or heart failure). Prescribing antihypertensive treatment to these patients aims at controlling arterial blood pressure and therefore at decreasing the probability of occurrence of further events (angina, myocardial infarction, stroke, heart failure), renal failure and end-stage renal failure. There are nine antihypertensive drug classes currently available on the French market. However, the effectiveness in terms of morbi-mortality reduction has been demonstrated for only five of them (HAS, 2013): diuretics, beta-blockers, calcium antagonists, angiotensin converting enzymes and angiotensin II receptor antagonists. Before 2013, French scientific guidelines did not distinguish between these five classes of drugs for use in primary prevention for patients with no specific comorbidity. Physicians were free to prescribe one of them or even bitherapy or tritherapy (i.e. a combination of two or three classes of drugs). There was just one recommendation: to prescribe a monotherapy as first-line treatment. If blood pressure still exceeds 140 mmHg after three months of treatment, other drug classes or a combination of drug classes are prescribed until blood pressure is under control.

It is of course not feasible to assess every combination of drugs in first, second and third line treatment. In this paper we therefore focus on the comparison of three strategies:

- Strategy A is the placebo comparator.[15] Patients are not treated with any antihypertensive treatment in primary prevention. Physicians only start prescribing an active

[14] According to French scientific guidelines, a blood pressure under 140 mmHg is considered under control.

[15] The term "placebo comparator" is in a certain sense a misnomer, since patients do not receive a "fake drug" in our strategy A, and there is hence no placebo effect. We could also have called it a "do nothing"-strategy.

antihypertensive treatment after patients have experienced an event.

- With Strategy B, every patient with essential high blood pressure is treated with ACE inhibitors in first-line treatment, with a bitherapy combining ACE inhibitors-diuretics in second-line treatment and finally with a tritherapy in third-line treatment. According to the available data, this strategy is the cheapest when both the cost of the treatment and the cost of avoided medical care are taken into account (HAS, 2012).
- With Strategy C, every patient with essential high blood pressure is treated with calcium antagonists in first-line treatment, with a bitherapy combining calcium antagonists-ACE inhibitors in second-line treatment and with tritherapy in third-line treatment. This is, according to the available data, the most effective strategy in terms of life years gained (HAS, 2012).

We use the model that is produced for HAS by IMS Health to calculate the costs of these three strategies and the resulting expectations surrounding the risk of cardiovascular events and renal failure disease. This model is based on a systematic literature review as well as the consultation of both a working group and a review group organised by HAS. It is validated by the HAS committees and used for a cost-effectiveness analysis in terms of costs per life year gained. We will use this information in the more complete evaluation strategy that has been described in section 2.

# 4 Data and the estimation of preferences

To calculate social welfare with eq. (6), it is not sufficient to collect information on a sample of patients that suffer from hypertension. Different reimbursement strategies have different financial consequences for the whole population. When one works with distributional weights, not only the total cost of the treatment, but also the distribution of that cost over the population has to be taken into account. We have therefore collected the necessary data from a representative sample of the French population. A total of 3,331 individuals were interviewed in the course of November and December 2009 using

computer-assisted face-to-face interviews. The parts of the survey that are relevant for this paper are described in section 4.1.[16] To simulate the effects of the policies on the equivalent incomes of the individuals, we need information on their preferences. Section 4.2 explains how these can be estimated starting from a contingent valuation question that measures the respondents' willingness-to-pay for perfect health. As mentioned before, these estimated preferences are not specific to our application on hypertension, but could also be used for any other evaluation exercise.

## 4.1 Description of the survey

The survey contained the usual questions on demographic and socio-economic characteristics of the individual and his/her household (gender, age, marital status, level of education, profession, level of monthly household income before taxes). We measure equivalised income $y_i$ as the reported household income divided by the modified OECD-scale (with a weight for a single person, 0.5 for each additional adult in the household and 0.3 for each child below the age of 14). It is crucial to avoid confusion between this "OECD-equivalised income" and the "equivalent income" that was introduced in section 2.1.

The questionnaire continued with detailed questions on specific diseases and health problems that the respondent might have experienced in the previous twelve months. Each respondent was presented a detailed list of 45 diseases grouped in 15 categories (e.g., respiratory diseases, cardio-vascular diseases, .....) and was asked whether he had been affected by any of these diseases during the last 12 months and whether he had been prescribed a treatment or not.[17] Open-ended questions were added for each of the 15 groups of diseases, in order to identify whether the respondent had suffered from another disease not specifically mentioned in the list. At the end of that section came a question on overall self-assessed health (SAH), where use was made of a visual 0-100 scale:

[16] More information on the survey (including the original formulation of the questions in French) can be found in Fleurbaey et al. (2012). In addition to the information that is used in this paper, the survey also contained a number of questions on subjective expectations for future health and future income. We report on these results in Dormont et al. (2014) and Luchini et al. (2015).

[17] The list of diseases was taken from the Enquête Santé et Protection Sociale (Health, Health Care and Insurance Survey) of IRDES (Institute for Research and Information in Health Economics).

"In the previous questions, you have indicated the health problems you have suffered from during the last twelve months. Taking this into account, can you now evaluate your health during the last twelve months on a scale from 0 to 100 (where 100 is the best possible health state and 0 is death)."

The SAH question was followed by a series of questions on health care use in the past twelve months, including non-reimbursed out-of-pocket payments. We also asked whether respondents have the "ALD" (chronic disease) status and for which disease,[18] as well as whether they benefit from complementary insurance coverage (through employers or as an individual voluntarily purchased insurance) or from the "universal medical coverage" (Couverture Maladie Universelle Complémentaire CMU-C, which provides a free complementary coverage for individuals with low income). Finally, individuals were asked about their lifestyles (smoking habits, alcohol consumption, weight and height, ...).

After respondents had considered their own economic and health situation in this fashion, they were confronted with a retrospective willingness-to-pay question (meant to measure $WTP_i(h_i \rightarrow h^*)$). Interviewers first introduced a hypothetical scenario:

"Imagine now that you would not have had any health problems during the last twelve months. In that case you would have been in perfect health and your quality of life would have improved. (We talk here only about the last twelve months and not about the potential improvement of your future health). Compared to your actual life experience during the last twelve months, would you have preferred not to have had the health problems that you had but with a reduction of your income (on top of the €$x$ that you now have already paid as non-reimbursed care expenditures)."

Respondents could answer "yes", "no" or "do not know". Those who answered "no" were asked for further information about their reasons. Some of them were ready to

[18] In the French system, patients who suffer from a disease which is classified as "chronic" are fully covered by the national health insurance for all the health care related to this disease. Examples are diabetes, heart failure, stroke or Alzheimer.

answer "yes" after some additional explanation. All those who answered "yes" were then asked:[19]

> "What is the maximal amount of monthly income you would have accepted to give up under these conditions (i.e. in exchange for being in a state of perfect health during the last twelve months)?"

As an aid the respondents were shown payment cards (ranging from "less than €15" to "more than €1500"). After having been shown the cards, they were asked an open question about the exact amount of income they were willing to give up.

We analysed the reasons given by respondents for answering "no" to the willingness-to-pay question. Respondents who answered that they did not want to give up any income because "my living standard is already so low that I cannot imagine having less, even with perfect health" or that answered "other aspects of my life are more important for me than my health" are included in our analysis as having a true willingness-to-pay equal to zero. Protest voters are those who answered that the question was too difficult or who, even after further explanation, retained the stance that "it is not my duty to pay for better health". They were removed from the analysis. Because the protest voters differed from the rest of the sample in terms of observable variables (e.g., there is a higher proportion of females), we introduced a selection equation in the estimation of preferences (see the following subsection). The selection bias, however, remains small for the most crucial variables. There are no significant differences concerning the prevalence of hypertension. After the removal of the incomplete and protest answers, the sample used in our analysis consists of 2413 individuals.[20]

Table 2 shows some descriptive information for the final sample of 2413 individuals and for the two subsamples that are especially relevant for our assessment exercise: (1) individuals with no hypertension and (2) individuals with hypertension and no cardiovascular

[19] It was made clear in the questionnaire that the relevant income concept was the equivalised income, i.e. the monetary income adjusted for household size.

[20] We removed 13 individuals that were either 18 years or more than 96 years old, because for these age groups the HAS-model does not contain probabilities for contracting hypertension or incurring a cardiovascular event.

| | All individuals | Individuals without hypertension | Individuals with hypertension |
|---|---|---|---|
| Share of women | 51.3 | 46.7 | 61.3 |
| Age | 48.5 (18.4) | 44.1 (17.6) | 58.1 (16.3) |
| SAH | 72.3 (18.5) | 74.9 (18.6) | 66.6 (17.1) |
| Personal Income | 1,247.2 €(690.7 €) | 1,256.2 €(720.3 €) | 1,227.2 €(620.9 €) |
| Equivalized Income | 1,341.7 €(894.6 €) | 1,348.6 €(968.9 €) | 1,326.5 €(704.5 €) |
| WTP | 69.9 €(169 €) | 62.2 €(158 €) | 86.9 €(190.2 €) |
| Nb of obs. | 2,413 | 2,035 | 378 |

Table 2: Descriptive information

event. This latter (crucial) group represents only 15.6% of our original sample.[21] This figure is much lower than the prevalence in the French population, which is likely to be larger than 30%.[22] This underestimation of hypertension is a common phenomenon in surveys, as many individuals are simply not aware that they suffer from hypertension. To be able to compare with the French population, all numbers in Table 2 are weighted with sample weights based on age, gender and the prevalence of hypertension. The same weighting will be used to derive all results in section 6. Table 2 shows that individuals with hypertension are older and declare a lower self-assessed health and a higher willingness-to-pay for being in perfect health. Note that SAH is quite high in the sample of individuals without hypertension: only 10% of individuals declare a self-assessed-health lower than 50, while another 10% declare a self-assessed-health higher than 95. The average level of willingness-to-pay for being in perfect health is low. For individuals who declare no hypertension, their average willingness-to-pay is 62.2€. The median is zero: 47% of these individuals have a willingness-to-pay for being in perfect health equal to 0. Reassuringly, in the subsample of individuals with hypertension, this willingness-to-pay is larger (86.9€).[23] The low average willingness-to-pay can be explained by the relatively

[21] Among the individuals reporting hypertension, 5% declare not being treated. We chose to interpret these answers as misreporting and exclude these individuals from the group of individuals with hypertension. Indeed, given the actual guidelines, every individual whose blood pressure is over 140 mmHg is prescribed a treatment. We therefore suppose that individuals who declare hypertension without being under treatment have a blood pressure under 140 mmHg.

[22] According to the "Étude Nationale Nutrition Santé", 31% of the French population was diagnosed with hypertension in 2006 and 2007 (Godet-Thobie H. et al., 2008). Data provided by the MONA LISA cohort study show that 47% of men and 35% of women in the French population aged between 35-74 years old were diagnosed with hypertension (Wagner et al., 2011).

[23] As a matter of fact, it is still larger in the subsample of individuals with more health problems, i.e. for those with hypertension who experienced a cardiovascular disease within the last 12 months. For them the

low incomes and high values of SAH in our sample. It can also be due to the fact that the WTP question referred to the health situation in the *previous* twelve months. Mortality issues were excluded and so was the anxiety related to uncertainty about future health.

## 4.2 Estimating preferences[24]

With the information that is available in the survey, we can now directly implement eq. (5) to compute equivalent incomes for all individuals in the sample. The mean and median equivalent incomes are €1271.8 and €1150.0 respectively. To simulate the effect of different policies on equivalent incomes, we need in addition information on preferences. Estimating preferences at the individual level is impossible with our data, however, since the only information available for each individual is that his/her actual situation $(y_i, h_i)$ and the hypothetical situation $(y_i - WTP_i, h^*)$ are on the same indifference curve. To make progress we must combine information obtained from different individuals and make the assumption that preferences are homogeneous at the group level. In order to not push the data into a straitjacket, we opted for a flexible functional form, allowing for coefficients that differ according to age and gender. We measure income as the OECD-equivalised income and health as self-assessed health (SAH).

More specifically, we specify the willingness-to-pay of individual *i* to be in perfect health as

$$WTP_i = \alpha_i(1-h_i) + \beta_i(1-h_i)^2 + \gamma_i y_i(1-h_i) + \delta_i y_i^2(1-h_i) + \mu_i y_i(1-h_i)^2 + \varepsilon_i \quad (11)$$

where $\varepsilon_i$ is an idiosyncratic disturbance term with mean zero. Interindividual differences in the marginal rate of substitution between income and health are modelled by varying the coefficients in eq. (11):

$$\begin{aligned} \alpha_i &= \alpha_0 + \alpha_A age_i + \alpha_M male_i \\ \beta_i &= \beta_0 + \beta_A age_i + \beta_M male_i \end{aligned}$$

average willingness-to-pay is 142.7€.

[24] More information on the estimation procedure, including more detailed estimation results, can be found in Schokkaert et al. (2013).

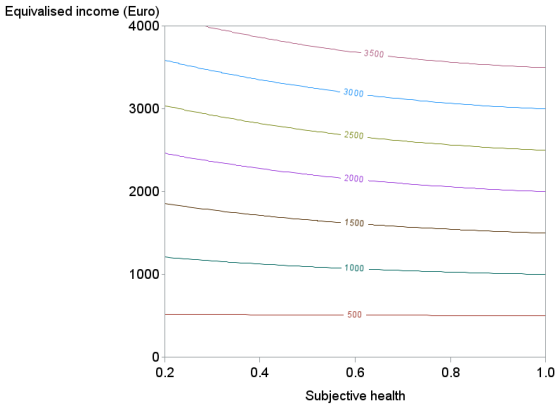
$$\begin{aligned} \gamma_i &= \gamma_0 + \gamma_A age_i + \gamma_M male_i \\ \delta_i &= \delta_0 + \delta_A age_i + \delta_M male_i \\ \mu_i &= \mu_0 + \mu_A age_i + \mu_M male_i \end{aligned} \tag{12}$$

where $age_i$ refers to the age of individual $i$ and $male_i$ is a dummy, taking the value 1 for males. The functional form (11) imposes neither monotonicity nor quasi-concavity of the utility function. However, it does impose that the expected willingness-to-pay for an individual in perfect health (i.e. with $h_i = h^* = 1$) is equal to zero. This theoretical constraint makes our specification consistent with the theoretical framework sketched in section 2.1.

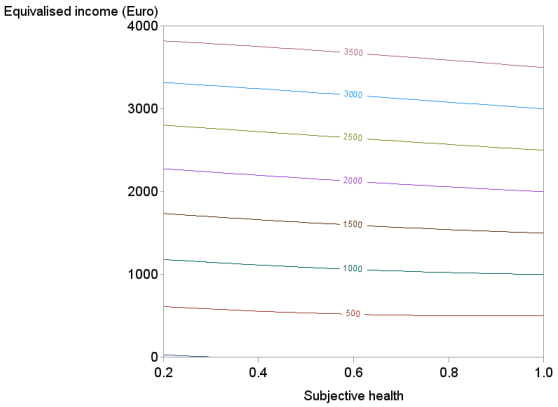
As announced in the previous subsection, we estimated the parameters of eqs. (11)-(12) with a two-step procedure in order to take into account that the protest voters are a selected sample.[25] The first step is a probit selection equation for refusing to give a WTP answer as a function of health, income, age and gender. In the second step we estimated eqs. (11)-(12) with OLS, including the inverse Mill's ratio derived from the probit equation as an additional regressor. Of course, this whole procedure is just a curve-fitting exercise and should not be seen as the testing of any theory. While an F-test shows that the overall fit of equation (11) is satisfactory ($p < 0.0001$), it is impossible to interpret the individual coefficients in a meaningful way given the highly nonlinear specification of eq. (11) and the large degree of multicollinearity between the right-hand side variables. It is more informative to look at the indifference curves that can be computed on the basis of the estimated parameters, taking into account that utility is given by $y_i^*(y_i, h_i) = y_i - WTP_i(y_i, h_i \rightarrow h^*)$.[26] These indifference curves are shown in Figure 2 for the three age quartiles. Overall, they look reasonably good, especially for income levels above €1000 (the median income in the full sample is €1200). For very low incomes, however, they are rather flat; this simply reflects the finding that WTP-answers are rather low in the survey.

[25] For this estimation, we removed 98 observations with SAH < 20 or with an income > €4000. Not surprisingly, our flexible functional form gives strange results for this range of variables, where we have very few observations.

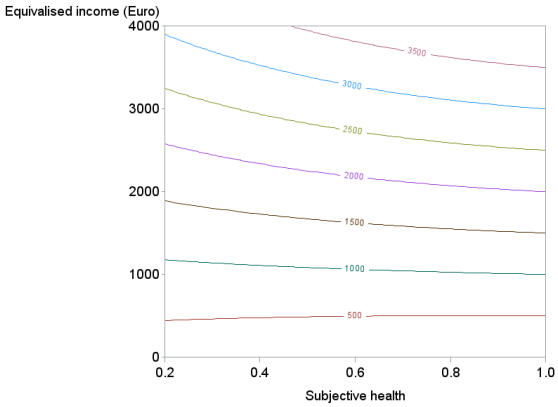
[26] The estimates of the individual coefficients are reported in Schokkaert et al. (2013).



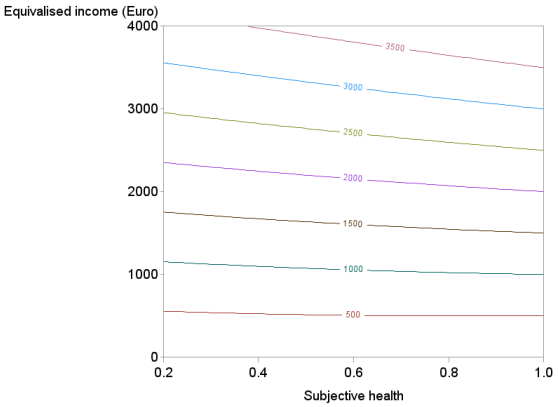

Males, age 39



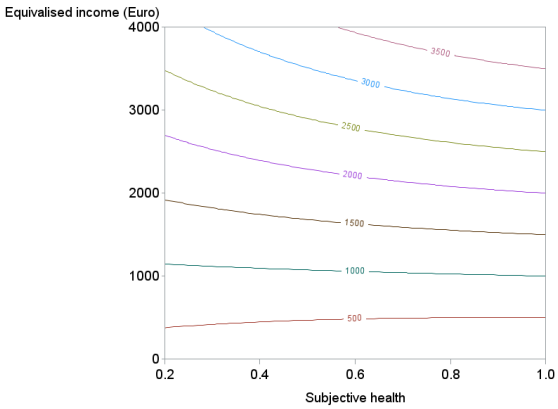

Females, age 39



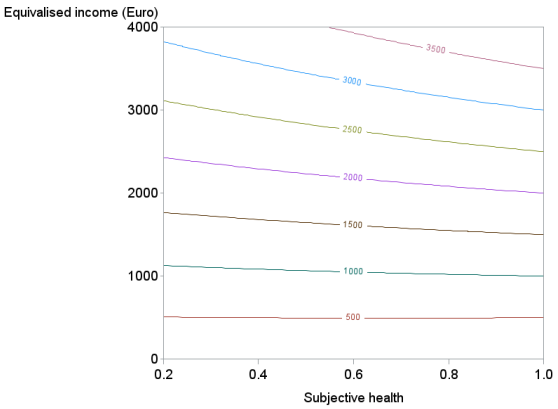

Males, age 54




Females, age 54




Males, age 66




Females, age 66

Figure 2: Estimated indifference curves

# 5 Empirical procedure

We now describe the additional empirical steps that are needed to assess the three strategies that were described in section 3. We choose to evaluate the strategies on a horizon of ten years. From now on, we will therefore introduce in our notation a subscript $\tau$ to indicate the period considered, where $\tau = 0$ represents the situation at the moment of our survey. In section 5.1 we show how we used the HAS prediction model to first define the possible health trajectories that the individual can experience during the period of ten years and to then associate with each of these trajectories individual-specific probabilities of occurrence. We then explain how we calculate equivalent incomes. Each individual starts out at period 0 with his observed income and SAH. Depending on which trajectories are followed we dynamically adjust his health (section 5.2) and income levels (5.3) over time. This enables us to compute, for each individual and period, the equivalent income for every possible trajectory. We can then compute the ex post social welfare for each period for the three strategies A, B and C. In section 5.4 we discuss how we introduced the time dimension into the calculation of social welfare.

## 5.1 The distribution of events resulting from the different strategies

Individuals with hypertension can, over the considered period of ten years, experience different cardiovascular events (stroke, angina, myocardial infarctus, heart failure) as well as renal failure and end-stage renal failure. They can die as a consequence of the event they experience, or they can survive. To keep the problem tractable we introduced some simplifying assumptions.[27] First, only one event can occur in each year. Second, individuals may experience only two events during the 10-year period. Third, each event happens in the beginning of the year. Even with these simplifying assumptions, each individual can follow very many different trajectories, as illustrated for the first two periods in the decision tree of Figure 3.[28] Over the whole time span an individual can experience 3376

[27] It should be obvious that the need to introduce simplifying assumptions has nothing to do with our choice of evaluative framework.

[28] The decision tree is simplified, because we do not show the arms "death from other causes" and "alive with no event".

different trajectories.[29]

We calculated the probabilities of all these trajectories using the information present in the HAS model. These probabilities obviously depend on the chosen treatment strategy. The HAS model works with two kinds of probabilities. First, there is the probability of experiencing a first cardiovascular or renal failure event. The probability of experiencing this first event increases with time (whatever the event). With the placebo strategy the risks depend on the individual's characteristics: gender, age, diabetes and smoking habits. In the case of antihypertensive treatment, these risks no longer depend on individual characteristics, but on the prescribed line of treatment (the probability of controlling blood pressure with tritherapy being fixed at 1). Second, there are the probabilities of experiencing a second event in period $\tau$, given that a first event occurred in period $\tau - h$, with $h \geq 1$. The probability of occurrence of a second event depends on the occurrence of a first event in a previous year and on the nature of this first event (stroke, angina, myocardial infarctus, etc.).[30]

Aside from these probabilities of events, all individuals in the sample, with or without hypertension, may die from other causes. We implement an "all causes mortality rate" dependent upon age and gender.[31]

This gives us all the information needed to calculate for each individual the probability of following any of the possible trajectories on the 10-year horizon. Denote the probability that individual $i$ follows the specific trajectory (path) $p$ by $\pi_{ip}$, with $\sum_p \pi_{ip} = 1$ for all $i$. In the ex post-approach these ex ante-probabilities are interpreted as ex post-shares of the population, i.e. we will assume that a fraction $\pi_{ip}/N$ of the population follows path $p$.[32]

[29] We cannot generate in our ex post approach a matrix that considers all possible trajectories and then give a probability of zero to those that are not relevant. Given the large number of possible trajectories, this would not be tractable. To tackle this problem, we worked with recursive functions and imposed restrictions for some trajectories that were not possible.

[30] We simplify the HAS assumptions with respect to mortality following heart failure. Contrary to stroke and myocardial infarcts, which are acute events, heart failure is a chronic disease. In the HAS model individuals may therefore die from heart failure each year following the event. We use cumulative probabilities of dying for heart failure and apply them at the time of occurrence. This simplifying assumption does not change the total number of people who die, but means that as a consequence people die earlier.

[31] We used the mortality rates that were produced for 2009 by the French Institute for Demographic Studies (INED).

[32] This means that the term in square brackets in eq. (10) or, since we assume that this term is the same for all $s$, equivalently eq. (6) is estimated as $\frac{1}{1-\rho}\sum_i \sum_p \pi_{ip}(y^*_{ip})^{1-\rho}$.

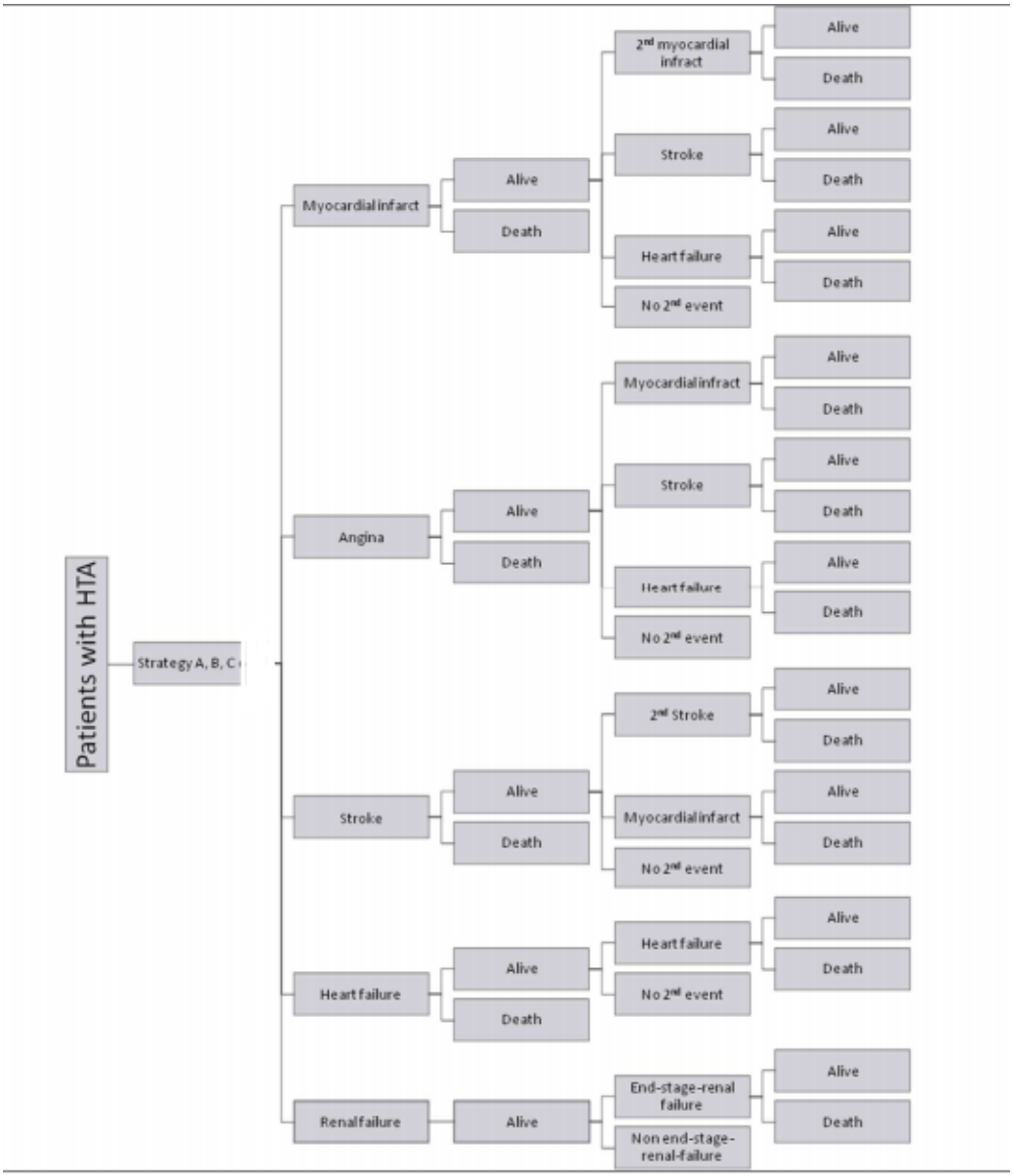



Figure 3: Decision tree

Each of the possible situations on a path will result in specific health and income levels that do not only depend on the event experienced in the last period but also on the history, i.e., on the specific trajectory that brought the individual into that state, and finally on his starting position in period 0.

## 5.2 Simulating the effects on health

Since we have estimated individual preferences with self-assessed health (SAH) as the health variable, the first step is to estimate the effect of the different events on SAH. For that purpose we estimate on our sample a simple linear regression

$$SAH_{i,0} = c + \sum_j s_j ev_{ij,0} + a_1 age_{i,0} + a_2 age_{i,0}^2 + \sum_k b_k x_{ik,0} + u_{i,0}, \tag{13}$$

where the subscript 0 is introduced to indicate that the regression is run on our sample data (i.e. each individual is in period 0 of his 10-year trajectory), $ev_{ij,0} = 1$ if individual $i$ experienced event $j$ in the 12 months before the interview, $age_{i,0}$ is the age of individual $i$ at the time of the interview, $x_{ik,0}$ indicates a list of control variables and $u_{i,0}$ is a disturbance term. The estimation results are shown in Table 3.[33] The coefficients of the control variables are in line with theoretical expectations, and SAH decreases with age except for the very old (where we have only a limited number of observations and where there is also a selection effect at work). Myocardial infarctus, stroke and angina have a strong negative effect on SAH. In line with the literature, the effect of infarctus is larger than that for angina. Note that the other three events (renal failure, end-stage renal failure and heart failure) were not included in the list of 45 diseases in the questionnaire and could therefore not be included in eq. (13). On the basis of the information on the utility levels associated with all cardiovascular events, as reviewed in the technology assessment reports produced by NICE, we use the coefficient obtained for myocardial infarctus as a proxy for the impact of heart failure and renal disease, and the coefficient obtained for stroke as a proxy for the impact of end-stage renal failure.[34]

[33] For this estimation, we did not exclude the protest voters from the sample.

[34] These are probably underestimates of the true effect. According to the National Clinical Guideline Centre (2011, p. 520), the utility level associated with heart failure (0.71) is lower than the utility level

| | | Coeff. | (Std Error) |
|---|---|---|---|
| Events | Angina | -10.469*** | (2.068) |
| | Myocardial infarctus | -14.857*** | (1.957) |
| | Stroke | -7.795*** | (2.494) |
| Socio-demographic | Age | -0.643*** | (0.102) |
| | Age Squared | 0.0044*** | (0.001) |
| | Male | 4.523*** | (0.679) |
| Education | No Diploma | -5.272*** | (1.279) |
| | Primary School Certificate | -3.862*** | (1.351) |
| | GCSE | -2.466** | (0.981) |
| | Baccalauréat | Ref. | Ref. |
| | University ($\leq$ 2 years) | 1.370 | (1.244) |
| | University ($\geq$ 3 years) | -1.098 | (1.227) |
| | Other Diploma | -17.151*** | 5.496 |
| Health Insurance | National Health Ins. only | -2.415* | (1.363) |
| | CMUC only | -2.366* | (1.400) |
| | Complementary Insurance | Ref. | Ref. |
| Family Situation | Marital Life | 3.033*** | (0.709) |
| | Single | Ref. | Ref. |
| | At least one child | 1.001 | (0.843) |
| | No child | Ref. | Ref. |
| Lifestyles | Smoker | -5.538*** | (0.726) |
| | Underweight | -1.013 | (2.118) |
| | Normal weight | Ref. | Ref. |
| | Overweight | -2.523*** | (0.786) |
| | Obese | -8.514*** | (0.939) |
| | Severely Obese | -14.454*** | (1.676) |
| | No alcohol | Ref. | Ref. |
| | Alcohol - no risk | 3.105*** | (0.732) |
| | Alcohol - risky behaviour | -0.543 | (1.610) |
| | Constant | 92.968*** | (2.439) |
| | R-squared | 0.193 | |
| | Nb of Obs. | 3,304 | |

Table 3: Estimation results for SAH

Using these estimates we simulate the dynamic development of SAH over time (for $\tau = 1,\ldots,10$) for an individual that is still alive in period $\tau$:

$$SAH_{i,\tau} = SAH_{i,\tau-1} + \sum_j \hat{s}_j ev_{ij,\tau} + \left[\hat{a}_1 + \hat{a}_2(age^2_{i,\tau} - age^2_{i,\tau-1})\right], \tag{14}$$

where the hats are used to indicate estimated coefficients. Eq. (14) implements a series of assumptions. First, all individuals undergo a natural depreciation of health as a function of age, whether they suffer from hypertension or not. This is captured by the terms in square brackets in eq. (14). Second, when individual $i$ experiences a cardiovascular event at the beginning of period $\tau$ (i.e. if $ev_{ij,\tau} = 1$), this has a negative effect on her self-assessed health as measured by $\hat{s}_j$.[35] Of course, given the structure of the trajectories described in the previous section, this can only occur for individuals with hypertension and it can only occur twice. Third, all the socio-demographic control variables (including lifestyle) are kept constant throughout the whole period of 10 years. Fourth, when the individual dies in period $\tau$, be it as the consequence of a cardiovascular event or from other causes, we assume $SAH_{it} = 0$ for the periods $t = \tau,\ldots,10$.

The resulting development of *SAH* will of course depend on the trajectory that is followed by the individual. We will further denote by $SAH_{ip\tau}$ the self-assessed health reached in period $\tau$ by individual $i$ when she follows trajectory $p$.

## 5.3 Simulating the effects on income

As far as income is concerned, we must distinguish two types of effects. First, income changes over time may be affected by the occurrence of cardiovascular events. Second, the costs of medical care must be allocated to the different individuals in the sample.

associated with myocardial infarctus (0.76 for the first six months), and the utility level associated with end-stage renal failure (0.60) is lower than the utility level associated with stroke (0.63).

[35] This means that we assume that the impact of an event on SAH is permanent, and that the impacts of different events are additive. These assumptions looked acceptable to us, and even more so since most of our other assumptions are rather conservative (e.g. the restriction to two health events).

### 5.3.1 The change of income over time

We assume that health events do not influence the transfer payments (and hence the equivalised income) of non-working individuals. For the subsample of working individuals we estimate the following regression

$$y_{i,0} = d + hSAH_{i,0} + l.age_{i,0} + \sum_k m_k z_{ik,0} + v_{i,0}, \tag{15}$$

with $y_{i,0}$ indicating the level of monthly personal income, $z_{ik,0}$ the control variables and $v_{i,0}$ a disturbance term. The estimation results are shown in Table 4. An increase of 10 points for self-assessed health is associated with an increase in income of €28 (recall that average personal income in the sample is 1247€).[36]

Different categories of individuals were now treated as follows:

1. For working individuals that are less than 65 years old, i.e. before the age of retirement, the income in period $\tau$ is calculated as

$$y_{i,\tau} = y_{i,\tau-1} + \hat{h}(SAH_{i,\tau} - SAH_{i,\tau-1}) + \hat{l}. \tag{16}$$

   The coefficient $\hat{l}$ captures the appreciation of income with age. The value of $SAH_{i,\tau}$ is first simulated using eq. (14) and then introduced into eq. (16).

2. Individuals that receive a transfer income in period 0 (pensioners, unemployed, housewives) keep the same level of transfer income during their whole trajectory. Individuals that are unemployed in the sample are assumed to remain unemployed during the whole period of 10 years. Conversely, individuals that are employed in period 0 do not become unemployed.

[36] We experimented with other functional forms, taking a logarithmic transformation of income as the dependent variable and/or introducing age squared as an explanatory variable, but these alternative specifications did not give a better fit than the simple linear form (15). Of course, this estimation on cross sectional data does not at all allow for a causal interpretation. There is a huge body of literature showing convincingly that a simple estimation of (15) will suffer from simultaneity bias. Our results should only be seen as a first and primitive illustration of how the association between health and income can be taken into account in a richer approach to policy evaluation.

| | | Coeff. | (Std Error) |
|---|---|---|---|
| Health | SAH | 2.844*** | (1.059) |
| Socio-demographic | Age | 17.350*** | (1.814) |
| | Male | 426.911*** | (39.180) |
| Education | No Diploma | -278.334*** | (82.025) |
| | Primary School Certificate | -219.759* | (113.863) |
| | GCSE | -91.558* | (53.219) |
| | Baccalauréat | Ref. | Ref. |
| | University ($\leq$ 2 years) | -36.669 | (63.391) |
| | University ($\geq$ 3 years) | 216.039*** | (70.340) |
| | Other Diploma | -304.834 | 496.085 |
| Profession | Farmer | -626.104*** | (165.735) |
| | Artisans / self-employed | 386.424*** | (77.739) |
| | Employee | Ref. | Ref. |
| | Top executive | 683.138*** | 81.865 |
| | Middle class profession | 285.259*** | (58.441) |
| | Workmen | -155.497*** | (49.136) |
| Family Situation | Marital Life | 66.508 | (41.082) |
| | Single | Ref. | Ref. |
| | At least one child | 31.063 | (40.647) |
| | No child | Ref. | Ref. |
| | Live in Paris area | 174.169*** | (54.037) |
| | Constant | 253.046** | (128.207) |
| | R-squared | 0.361 | |
| | Nb of Obs. | 1,252 | |

Table 4: Estimation results for equivalised income

3. Individuals that are employed in the sample but reach the age of 66 in period $\tau$, get for that period a retirement pension equal to the average pension of all the individuals in the sample with the same profession and the same sex. For the periods $t = \tau + 1, \ldots, 10$, they are treated in the same way as the other pensioners.

4. Individuals who are defined as "students" in the sample are assumed to enter the labour market at an age corresponding to their type of studies. In that period they receive an income equal to the average income of the working individuals in the sample who are between 30 and 40 years old and have the same level of education and the same sex. Afterwards their income is adjusted with eq. (16).

5. For individuals that die in period $\tau$, we assume that $y_{it} = 0$ for $t = \tau, \ldots, 10$.

6. To calculate equivalised incomes we assume in addition that the family composition and the income of the partner (if there is one) do not change over the 10-year period.

Similarly to self-assessed health, we will denote by $y_{ip\tau}$ the income obtained in period $\tau$ by individual $i$ when he follows trajectory $p$.

### 5.3.2 Allocating the costs of medical treatment

The costs of antihypertensive treatment (based on the costs of the drugs prescribed in the different strategies), the costs of the follow-up of the treatment (including physician consultations, measurement of blood pressure, laboratory testing, etc.) and the medical costs induced by the occurrence of a cardiovascular event (including the costs of hospitalisation and of follow-up treatment) are all taken from the HAS model. They are classified into two categories.

First, the out-of-pocket payments (OOP) are subtracted from the income of the concerned individuals. To calculate OOP payments we implement the French health insurance regulation. Individuals in primary prevention and not under ALD-status have to pay 35% of the cost of antihypertensive treatment themselves. As soon as an event occurs, indi-

viduals obtain ALD-status and the total cost of the treatment is covered by national health insurance. The same holds for individuals that have the CMU-C status.[37]

Second, the costs that are borne by the national health insurance are calculated for each period $\tau$ as

$$TC_\tau = \sum_i \sum_p \pi_{ip} C_{ip\tau}, \tag{17}$$

where $\pi_{ip}$ is the probability that individual $i$ follows trajectory $p$ and $C_{ip\tau}$ is the corresponding cost (after subtracting OOP-payments) in period $\tau$. Remember that in the ex post-approach the probabilities $\pi_{ip}$ must be interpreted as population shares. This total cost $TC_\tau$ is divided over all the individuals in the sample, i.e. over all tax payers, proportionally to their actual contribution to the system, which in turn is determined by the (simulated) equivalised income $y_{ip\tau}$.[38] The distribution of total health expenditures over the population taking into account the level of household income is taken from Caussat et al. (2005).

## 5.4 Estimating the total welfare change for society

We can now calculate for all individuals the income and health levels that correspond to each possible state in their potential trajectories, differentiated for the three strategies considered. We then simulate their equivalent incomes $y^*_{ip\tau}$ using eq. (11). The final step is to insert these values into eq. (6) to calculate social welfare. In our baseline simulation we do this period by period. Adapting eq. (6) to that situation gives

$$SW_\tau^{ex\,post} = \frac{1}{1-\rho} \sum_p \sum_i \pi_{ip} (y^*_{ip\tau})^{1-\rho} \tag{18}$$

[37] As mentioned before, all this information is collected in the survey. In our calculations we neglect the effect of private complementary insurance. The exact nature of the reimbursements by private insurance depends on the specific policy, which is unknown to us. Moreover, the amounts involved are rather small.

[38] In dividing the total costs over all the individuals in the sample, the deceased are not excluded from the individuals that have to pay. If $x\%$ is the share of surviving individuals, we only allocate $x\%$ of the total costs to them. We make this assumption to correct for the fact that there are no young newcomers in our sample. If we did exclude the dead, this would have resulted in the unrealistic situation where increasing costs must be paid by a continuously decreasing number of payers. Our approach boils down to the assumption that the share of the costs that we allocate to the dead ($(1-x)\%$) would in reality have been paid by the young adults (and, hence, that the number of young adults is approximately equal to the number of dead, so the total population remains constant).

with $\sum_p \pi_{ip} = 1$ for all $i$.

However, in principle we are interested in the well-being of individuals over the whole of their lives. The baseline approach in eq. (18) disregards the fact that equivalent incomes are correlated over time. Individuals that start at a lower health and income level in period 0 are likely to remain at a relatively lower health and income level during the whole period of 10 years. Since we have no information about intertemporal preferences, we cannot aggregate over time at the individual level in a sophisticated way. A simple sensitivity analysis is possible, however, in which we assume that there is no time preference and calculate life-cycle well-being simply as the sum of the equivalent incomes obtained by the individual during the ten years. This yields

$$SW^{ex\,post} = \frac{1}{1-\rho} \sum_p \sum_i \pi_{ip} (\sum_t y^*_{ipt})^{1-\rho}. \tag{19}$$

Results for that alternative approach are also shown in section 6.1.

# 6 Results

We first show the results for the basic evaluation and then illustrate the characteristic features of our approach with some simulations. All the results shown are derived using the weighted sample, and are therefore representative of the French population in terms of age, gender and prevalence of hypertension.

## 6.1 Basic results

To evaluate the social welfare functions (18) and (19) for the different strategies, we have to calculate equivalent incomes for all individuals in our sample. The first determinant of these equivalent incomes is self-assessed health. The development of average SAH over time, as simulated with eq. (14), is shown for the three strategies in Table 5. The steady decline of SAH over time is explained by the ageing of our sample, i.e. by the fact that we do not take up young newcomers. Moreover, as explained before, individuals that die

| | t=1 | t=2 | t=3 | t=4 | t=5 | t=6 | t=7 | t=8 | t=9 | t=10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Individuals with hypertension | | | | | | | | | |
| A | 65.053 | 63.437 | 61.801 | 60.083 | 58.346 | 56.586 | 54.788 | 53.002 | 51.254 | 49.524 |
| B | 65.148 | 63.645 | 62.120 | 60.523 | 58.903 | 57.251 | 55.562 | 53.875 | 52.198 | 50.527 |
| C | 65.142 | 63.637 | 62.112 | 60.516 | 58.900 | 57.252 | 55.571 | 53.894 | 52.223 | 50.561 |
| | All individuals | | | | | | | | | |
| A | 71.279 | 70.191 | 69.090 | 67.954 | 66.791 | 65.609 | 64.408 | 63.206 | 62.011 | 60.813 |
| B | 71.309 | 70.256 | 69.190 | 68.091 | 66.964 | 65.817 | 64.650 | 63.479 | 62.306 | 61.126 |
| C | 71.307 | 70.254 | 69.187 | 68.089 | 66.963 | 65.817 | 64.653 | 63.485 | 62.314 | 61.137 |

Table 5: Self-assessed health over time

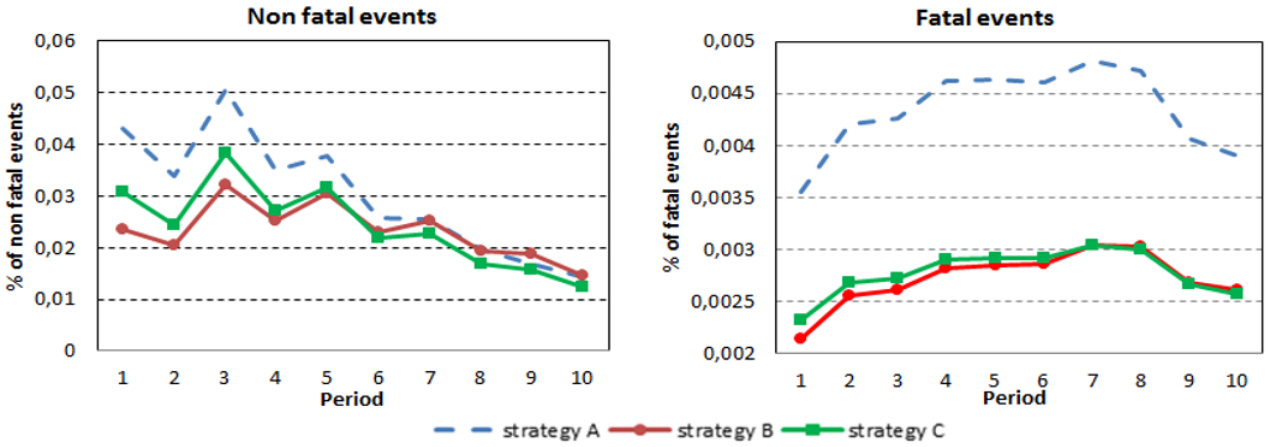



Figure 4: Percentage of non-fatal and fatal events

are kept in the sample with a value of equivalent income equal to zero. Table 5 shows that the placebo strategy A leads to the poorest health results over the whole period and, more importantly, that strategy C is better than strategy B in the second half of the period. This is in line with the findings of HAS. The most important explanation of this pattern is offered by Figure 4, showing the simulated occurrence of fatal and non-fatal events for the three strategies over time. It is clear that strategy C becomes more efficient in avoiding events in the second half of the 10 year-period; however, the differences are rather small.

While strategy C leads to better health results, it is also more expensive. This is clear from Figure 5 showing the total cost of treatment, hospitalization and follow-ups (see eq. (17)). As explained before, these costs are not paid by the individual patients but are distributed over all individuals in the sample proportionally to their actual contribution to the system

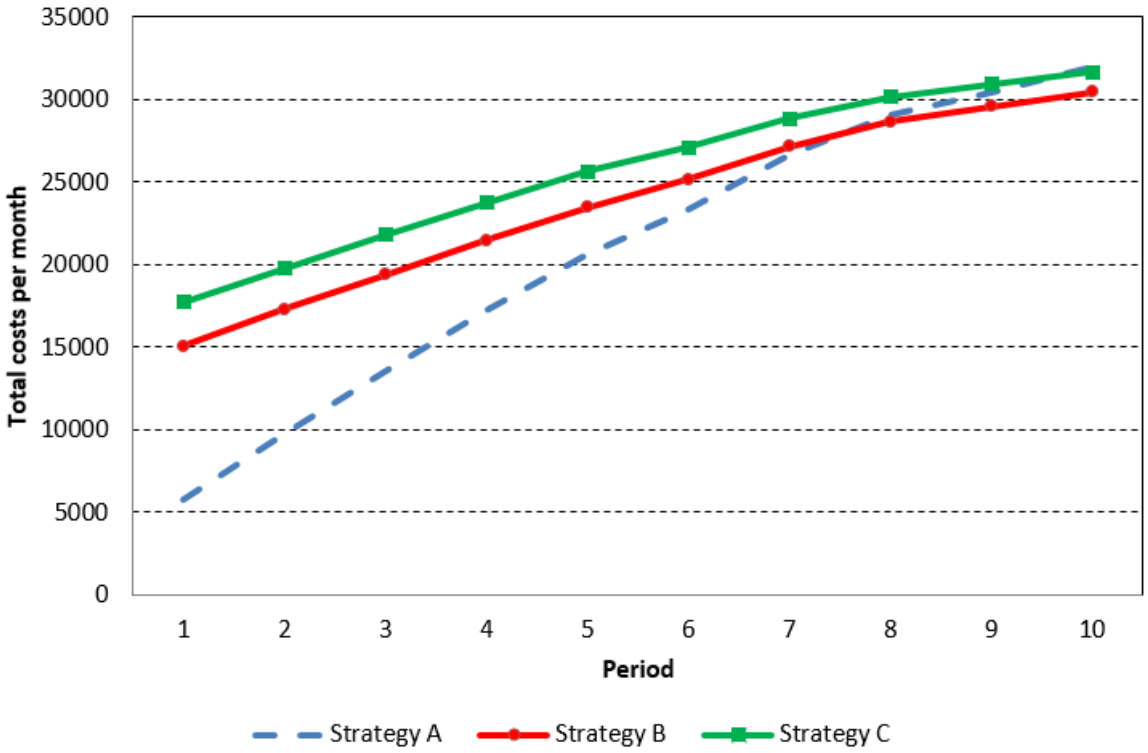



Figure 5: Treatment, hospitalization and follow-up costs (net of out-of-pocket payments)

of health insurance. In addition, the treated individuals have to pay (a small amount of) out-of-pocket costs. Subtracting these costs and implementing the dynamic adjustments described in section 5.3 results in the average equivalised incomes, given in Table 6. To simplify the interpretation, the averages are taken over the surviving individuals only. The larger overall costs of strategy C are reflected in lower individual incomes. Note, moreover, that the placebo strategy A is cheaper in the beginning of the period but leads to lower incomes at the end of the period, due to the increase in treatment and hospitalization costs from the more frequent occurrence of cardiovascular events (look at the results for "all individuals").

Our evaluation criterion integrates these health levels and equivalised incomes into the *equivalent* incomes for all individuals in the sample. The trade-off between health and income is evaluated using individual preferences, differentiated according to age and gender (see eq. (11)). The resulting average equivalent incomes are shown in table 7. Because the number of deceased matters for the social evaluation of the strategies, we did include

| | t=1 | t=2 | t=3 | t=4 | t=5 | t=6 | t=7 | t=8 | t=9 | t=10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Individuals with hypertension | | | | | | | | | |
| A | 1325.78 | 1327.20 | 1328.25 | 1329.42 | 1330.72 | 1331.95 | 1332.98 | 1334.77 | 1334.85 | 1334.02 |
| B | 1322.58 | 1324.53 | 1326.22 | 1328.12 | 1330.01 | 1331.65 | 1333.13 | 1335.24 | 1335.50 | 1334.80 |
| C | 1321.55 | 1323.42 | 1325.02 | 1326.92 | 1328.84 | 1330.53 | 1332.12 | 1334.35 | 1334.73 | 1334.06 |
| | All individuals | | | | | | | | | |
| A | 1335.19 | 1331.45 | 1330.69 | 1331.30 | 1332.17 | 1333.20 | 1333.98 | 1335.56 | 1335.51 | 1334.59 |
| B | 1332.01 | 1328.76 | 1328.65 | 1329.99 | 1331.45 | 1332.89 | 1334.13 | 1336.03 | 1336.15 | 1335.37 |
| C | 1331.02 | 1327.67 | 1327.47 | 1328.79 | 1330.28 | 1331.78 | 1333.12 | 1335.14 | 1335.38 | 1334.64 |

Table 6: Equivalised income (after substracting out-of-pocket and treatment costs)

| | t=1 | t=2 | t=3 | t=4 | t=5 | t=6 | t=7 | t=8 | t=9 | t=10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Individuals with hypertension | | | | | | | | | |
| A | 1214.86 | 1188.78 | 1161.76 | 1133.11 | 1104.35 | 1075.19 | 1045.18 | 1015.47 | 984.28 | 952.81 |
| B | 1213.54 | 1189.70 | 1164.95 | 1138.74 | 1112.17 | 1084.90 | 1056.82 | 1028.74 | 998.62 | 968.03 |
| C | 1212.46 | 1188.48 | 1163.59 | 1137.35 | 1110.82 | 1083.63 | 1055.70 | 1027.83 | 997.90 | 967.41 |
| | All individuals | | | | | | | | | |
| A | 1260.80 | 1249.88 | 1236.36 | 1226.31 | 1213.52 | 1202.93 | 1186.73 | 1168.50 | 1149.75 | 1131.47 |
| B | 1258.36 | 1248.40 | 1235.96 | 1227.02 | 1215.27 | 1205.53 | 1190.22 | 1172.72 | 1154.42 | 1136.53 |
| C | 1257.46 | 1247.44 | 1234.95 | 1226.02 | 1214.33 | 1204.66 | 1189.45 | 1172.08 | 1153.87 | 1136.07 |

Table 7: Average equivalent incomes

the dead in the calculation of the averages: as explained before, they are ascribed zero equivalent income. Table 7 shows that the larger costs with strategy C weigh more heavily in the individual preferences than the resulting better health. This reflects the flatness of the indifference curves in Figure 2. Average equivalent incomes are larger with strategy B than with strategy C in all periods.

Table 7 can also be interpreted as the evaluation of the social welfare functions (18) and (19) for $\rho = 0$. Indeed, with zero inequality aversion social welfare becomes the sum of equivalent incomes. Since the population remains constant in our calculations, the sum and the average yield identical rankings. Strategy B yields a higher level of social welfare than strategy C, and both are better than the placebo treatment A, except in the first periods. The differences between the values of the social welfare function for the three strategies are represented graphically in the left panel of Figure 6.

The question now arises as to whether the ranking of the strategies changes with increasing inequality aversion. The middle and right panels of Figure 6 show that this is not the

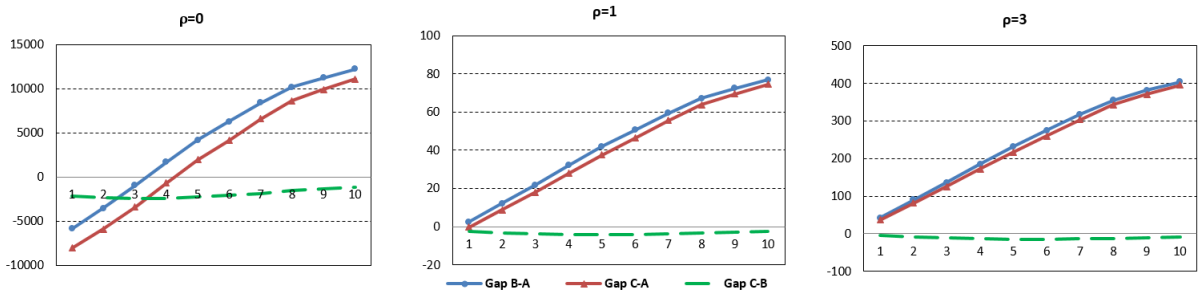



Figure 6: Differences in social outcomes for different values of $\rho$

case for $\rho = 1$ and $\rho = 3$.[39] Strategy B is better than strategy C in all periods. To take into account the correlation between the outcomes of different years (and the resulting issue of multiple deprivation) we also calculated the value of eq. (19) for different values of $\rho$. The results in Table 8 again show that strategy B is preferred over strategy C (and that both are preferred over placebo).

For infinite inequality aversion, i.e. $\rho \to \infty$, we obtain the maximin-criterion focusing only on the worst-off individuals. In our case, this worst-off individual is (in all periods and for all strategies) someone who is dead, and the maximin criterion therefore would be indifferent between all strategies.[40] Moreover, as acknowledged in the literature, for all operational applications, it is better to consider the outcomes of an entire group of the worst-off, rather than focusing on the worst-off individual. This can be interpreted as a realistic distributional stance focusing on poverty. Table 9 shows the sum of the equivalent incomes of the 30% worst-off in the different scenarios. In the left panel of the table, the deceased are included (with equivalent incomes = 0): in that case strategy B is the best in all periods (and strategy C is better than the placebo strategy from period 6 onwards). Strategy B is also the best if we use the sum of the equivalent incomes over the ten periods to identify the worst-off. Since we care about the number of deceased, these are the most relevant results. For illustrative purposes, however, we also show in the right panel of the table the results when we exclude the dead, i.e. when we consider in each period (and for the sum of the ten periods) those 30% surviving individuals with

[39] For $\rho = 1$, eq. (18) reduces to $\sum_s \sum_i \pi_{is} lny^*_{is\tau}$. A similar result also holds for eq. (19). To calculate the value of the social welfare function, individuals with zero equivalent incomes have been ascribed an equivalent income of 0.1.

[40] The leximin criterion would simply rank the different strategies in terms of the number of dead.

| | $\rho = 0$ | $\rho = 1$ | $\rho = 2$ | $\rho = 3$ |
|---|---|---|---|---|
| A | 27 879 022 592 | 22 902 018 | -52 167.72 | -25 903.41 |
| B | 28 083 286 016 | 22 951 950 | -49 316.86 | -24 480.64 |
| C | 28 055 119 872 | 22 945 796 | -49 663.11 | -24 653.46 |

Table 8: Evaluation in terms of life-cycle

| Dead individuals are included | | | | Dead individuals are excluded | | | |
|---|---|---|---|---|---|---|---|
| Period | A | B | C | Period | A | B | C |
| 1 | 17 305 | 17 307 | 17 295 | 1 | 18 317 | 18 277 | 18 264 |
| 2 | 16 464 | 16 517 | 16 475 | 2 | 18 498 | 18 462 | 18 411 |
| 3 | 15 431 | 15 573 | 15 580 | 3 | 18 587 | 18 558 | 18 505 |
| 4 | 14 540 | 14 633 | 14 604 | 4 | 18 679 | 18 659 | 18 644 |
| 5 | 13 398 | 13 411 | 13 367 | 5 | 18 774 | 18 753 | 18 751 |
| 6 | 12 500 | 12 623 | 12 612 | 6 | 18 949 | 18 932 | 18 917 |
| 7 | 11 400 | 11 590 | 11 567 | 7 | 19 010 | 18 970 | 18 966 |
| 8 | 10 336 | 10 543 | 10 547 | 8 | 19 062 | 19 096 | 19 084 |
| 9 | 9 268 | 9 449 | 9 459 | 9 | 19 127 | 19 128 | 19 116 |
| 10 | 8 204 | 8 447 | 8 442 | 10 | 19 202 | 19 204 | 19 193 |
| sum over 10 years | 146 107 | 147 051 | 146 937 | sum over 10 years | 188 805 | 188 670 | 188 532 |

Table 9: Results for the 30% worst-off

the lowest equivalent incomes. Under this assumption, the placebo-condition (resulting in higher equivalised incomes) is the best strategy up until period 8. From then onwards, the better health situation and the smaller health care costs (see Figure 5) for strategy B make the latter the preferable strategy from the point of view of the 30% worst-off living individuals. If we take the sum over the ten periods, the placebo-treatment is the best for the worst-off - but remember that this is only an illustrative result, as the more relevant evaluation is the one that takes into account the number of dead.

All the results described until now are derived under the assumption that individuals that die are kept in the sample with an equivalent income equal to zero. It could be hypothesized that this underestimates the value of longevity. This is especially worrying in our setting, since concern about the long-run consequences of disease and the resulting anxiety about dying are probably not well captured in our survey of preferences. We therefore performed a robustness check within the life-cycle approach, in which we give all individuals that die during the 10-year period an overall equivalent income of 0.1 (rather than the sum of the equivalent incomes during the years in which they lived, which was the

| | $\rho = 0$ | $\rho = 1$ | $\rho = 2$ | $\rho = 3$ |
|---|---|---|---|---|
| A | 24 393 338 880 | 17 010 086 | - 5 861 306 | - 29 305 498 |
| B | 24 740 663 296 | 17 327 042 | - 5 589 048 | - 27 944 194 |
| C | 24 717 901 824 | 17 318 696 | - 5 595 014 | - 27 974 022 |

Table 10: Life cycle well-being - robustness check for longevity

assumption underlying Table 8). As shown in Table 10, the ranking of the strategies does not change under this alternative assumption.

The conclusion from this section is clear: for all degrees of inequality aversion and regardless of whether we take a period-by-period or a life cycle approach, strategy B (which is the cheapest strategy) is to be preferred over strategy C (which is most effective in health terms), and both are preferred over placebo. We have derived this conclusion within a rich welfare framework that (a) takes into account distributional considerations, (b) uses a definition of individual outcomes that is broader than health and that respects individual differences in preferences, and (c) takes an ex post-perspective. To get a better understanding of the implications of these normative choices, we will show in the next section the results of some simulation exercises.

## 6.2 Some simulation exercises

We first compare the ex post- and the ex ante-perspectives, we then show the results of a more traditional cost-effectiveness approach, and we finally analyse the relevancy of distributional issues by an estimation of the welfare effects of a social insurance system compared to *laissez-faire*.

### 6.2.1 Ex ante versus ex post

We explained the reasons to opt for an ex post-approach in section 2.3. However, we also have in our data all the information that is needed to evaluate the ex ante-criterion (8). Remember that in principle both criteria give the same outcome for $\varepsilon = \rho = 0$.[41]

[41]This is not perfectly true in our calculations because we simplified the calculations of the ex ante-approach by allocating the costs on the basis of the expected incomes of the individuals.

| Using $\varepsilon = 0$ | | | | Using $\varepsilon = 2$ | | | |
|---|---|---|---|---|---|---|---|
| Period | A | B | C | Period | A | B | C |
| 1 | 3 043 379 | 3 039 263 | 3 037 576 | 1 | -294.65 | -286.23 | -287.26 |
| 2 | 3 018 448 | 3 016 819 | 3 015 133 | 2 | -600.69 | -582.69 | -584.39 |
| 3 | 2 987 154 | 2 987 921 | 2 986 182 | 3 | -914.23 | -886.93 | -889.20 |
| 4 | 2 964 329 | 2 967 367 | 2 965 681 | 4 | -1241.94 | -1204.85 | -1207.50 |
| 5 | 2 934 495 | 2 939 601 | 2 937 992 | 5 | -1581.87 | -1535.48 | -1538.36 |
| 6 | 2 910 105 | 2 916 957 | 2 915 478 | 6 | -1931.34 | -1876.38 | -1879.36 |
| 7 | 2 872 039 | 2 880 688 | 2 879 402 | 7 | -2288.92 | -2225.47 | -2228.25 |
| 8 | 2 828 801 | 2 838 940 | 2 837 871 | 8 | -2649.32 | -2578.32 | -2580.72 |
| 9 | 2 783 791 | 2 794 816 | 2 793 892 | 9 | -3012.48 | -2936.14 | -2938.24 |
| 10 | 2 739 971 | 2 751 831 | 2 751 076 | 10 | -3380.00 | -3299.22 | -3300.92 |

Table 11: Ex ante evaluation (values of the social welfare function) for $\rho = 0$

| Using $\varepsilon = 0$ | | | | Using $\varepsilon = 2$ | | | |
|---|---|---|---|---|---|---|---|
| Period | A | B | C | Period | A | B | C |
| 1 | -0.00373 | -0.00383 | -0.00386 | 1 | -18 500 000 | -19 000 000 | -18 800 000 |
| 2 | -0.00379 | -0.00388 | -0.00391 | 2 | -6 188 390 | -6 330 165 | -6 290 433 |
| 3 | -0.00402 | -0.00409 | -0.00413 | 3 | -2 889 736 | -2 958 383 | -2 940 238 |
| 4 | -0.00429 | -0.00435 | -0.00439 | 4 | -1 470 065 | -1 503 356 | -1 495 035 |
| 5 | -0.00463 | -0.00466 | -0.00470 | 5 | -857 624 | -877 893 | -872 949 |
| 6 | -0.00503 | -0.00505 | -0.00509 | 6 | -533 121 | -546 459 | -543 332 |
| 7 | -0.00556 | -0.00554 | -0.00558 | 7 | -293 869 | -301 815 | -300 126 |
| 8 | -0.00625 | -0.00620 | -0.00624 | 8 | -190 308 | -195 594 | -194 540 |
| 9 | -0.00720 | -0.00711 | -0.00716 | 9 | -133 953 | -137 714 | -136 984 |
| 10 | -0.00865 | -0.00850 | -0.00855 | 10 | -98 730 | -101 511 | -101 006 |

Table 12: Ex ante evaluation (values of the social welfare function) for $\rho = 3$

These results are reproduced in the left part of Table 11. The right part shows the results produced if we increase the degree of risk aversion $\varepsilon$ in eq. (9) to 2. Increasing risk aversion improves the relative welfare evaluation of strategy B, which avoids some of the negative health consequences of the placebo-strategy.

More striking results are found when we introduce inequality aversion into the social welfare function. The results for $\rho = 3$ are shown in Table 12. Consider first the results for $\varepsilon = 0$. Moving from an ex post- to an ex ante-perspective has a strong effect on the evaluation of the placebo-strategy A, which now becomes the preferred strategy up until period 7 (and remains better than strategy C even in that period). This result illustrates the differences between the two perspectives. The absence of antihypertensive treatment

increases the number of individuals that experience a cardiovascular event ex post - this increased number of worst-off individuals is weighted heavily in an inequality averse ex post social welfare function. However, in an ex ante perspective, this is not interpreted as a larger number of sick individuals but as a larger probability of getting sick. The differences in the *expected* outcomes between placebo and treatment strategies will be less pronounced (the lowest expected health outcome will definitely be larger than the lowest actual health outcome), leading to a weaker effect of the inequality aversion in the social welfare function. In the first periods (with the lowest probabilities of cardiovascular events) the much smaller costs of strategy A (see figure 5), which are divided over the whole population, may therefore dominate. This effect becomes even stronger when the risk aversion parameter $\varepsilon$ is set equal to 2. Under that assumption, the placebo strategy becomes the best in all periods (and strategy C is now preferred over strategy B). The conclusion is clear. As soon as one introduces distributional weighting into the evaluation, the difference between the ex ante and ex post perspectives does matter.

### 6.2.2 A cost-effectiveness analysis

The most popular criterion in cost-effectiveness analysis is the incremental cost-effectiveness ratio (ICER) with the cost difference in the numerator and the health gains in the denominator. Our data allow us to closely mimic this approach. Since the placebo treatment A is dominated by strategies B and C, we focus on the comparison of the latter two strategies and more specifically on the question of whether the incremental health gains resulting from strategy C justify its larger cost. The traditional approach measures outcomes in terms of the (unweighted) sum of QALY-gains. We do not have QALYs in our data, but for this illustration they can be reasonably well approximated by our measure of self-assessed health, which lies between 0 and 1 and has a value for each year. There is a large amount of literature on the pros and cons of discounting. Again, since this is only an illustration we will discount neither costs nor benefits. We can then approximate the ICER for C with respect to B as

$$ICER = \frac{\sum_{\tau=1}^{10}(TC_{\tau}^{C} - TC_{\tau}^{B})}{\sum_{\tau=1}^{10}\sum_{i}(SAH_{i,\tau}^{C} - SAH_{i,\tau}^{B})}. \tag{20}$$

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | **Global** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ICER | - | - | - | - | - | 2 888.559 | 266.545 | 109.633 | 71.522 | 47.573 | **481.867** |

Table 13: Incremental cost-effectiveness ratios (health measured as SAH)

The result is shown in the last column of Table 13. Strategy B is preferable over strategy C as long as one year in perfect health (i.e. with $SAH = 1$) is valued at less than €481,867. This value is much larger than the values that are commonly taken as the threshold in CEA: cost-effectiveness analysis therefore also suggests that it is not worthwhile to opt for the more expensive strategy C.

The other numbers in Table 13 show results for ICER year-by-year. Results in the first five periods are not meaningful since strategy C is dominated by strategy B in these periods: it is more costly without leading to larger health gains. Since the differences in costs become smaller over time and the health gains larger, the period-by-period ICER for strategy C gets smaller over time. Extrapolating these results suggests that the overall ICER for strategy C would decrease if we used a longer time horizon.

### 6.2.3 The welfare effects of social insurance

It has become sufficiently clear in the previous sections that distributional considerations can be easily integrated in our evaluative framework. In our base case, they have only a minor effect on the ranking of the different strategies. This is not a general result, but it is explained by the specific characteristics of our problem: the relatively small cost of the antihypertensive treatments (both for society and from the point of view of the patient) and the distribution of the total cost over all citizens (roughly in proportion to income). The small out-of-pocket costs and the division of the total cost are both characteristic features of the French system of social insurance, which we have taken as given in our analysis. However, one advantage of using a broader evaluative framework is that we can also simulate more drastic distributional policies. Such simulations are instructive if we want to formulate a judgement on broader institutional questions.

As an example, suppose that we basically remove the social insurance system and evaluate the hypothetical situation where individual patients are required to pay the full cost of their

treatment themselves as long as their income remains positive. More specifically, if $y_i$ is the income of individual $i$ and $c_i$ is his treatment cost, we assume that the patient has to pay $min(c_i, y_i)$ and society takes care of the remainder. These remaining costs are divided over the top two deciles of the income distribution, in proportion to their income. We interpret this situation as that of a *laissez-faire* society, where the rich show sufficient charity to pay for the health care expenses of the poor, but only after the latter have first exhausted their own income. The results are shown in Table 14. The left part of the table repeats the results from the previous section, while the right part of the table shows the welfare effects in the *laissez-faire* situation. The ranking of the three strategies does not change drastically when they are introduced into this hypothetical setting: strategy B remains the best (except in the first periods for $\rho = 0$). More interesting is the comparison between the social insurance baseline and the *laissez-faire* results. If society does not care about ex post-inequality ($\rho = 0$), the *laissez-faire* is slightly better than the social insurance system. However, this finding is completely reversed for $\rho = 3$. For all strategies (even for the placebo-strategy) a large welfare gain is realised by introducing a social insurance system. As a matter of fact, whereas most of the health economic analysis (for good reasons) focuses on a comparison of strategies B and C, Table 14 shows that the distributional effects of introducing social insurance are of a much larger order of magnitude. Strategy B is better than strategy C, even if patients have to pay their own expenses, but strategy C in a system of social insurance is much better than strategy B in the *laissez-faire.* Introducing distributional considerations through a broader notion of well-being points therefore to the crucial importance of the broader institutional setting.

# 7 Conclusion

Formal health technology assessment is currently almost always restricted to cost-effectiveness analysis, i.e. the calculation of incremental cost-effectiveness ratios with the cost increase in the numerator and the health gains in the denominator. Broader ethical considerations, including questions of fairness, are then taken up in the decision-making process in an informal and *ad hoc* way. This choice of a narrow approach can be explained partly by the intuitive reluctance to introduce a monetary valuation of health into the analysis. If the only alternative to CEA was traditional cost-benefit analysis, this reluctance would be

| $\rho = 0$ | | | | | | | |
|---|---|---|---|---|---|---|---|
| Social Insurance (baseline) | | | | Patients pay their own expenses | | | |
| Period | A | B | C | Period | A | B | C |
| 1 | 3 042 303 | 3 036 432 | 3 034 252 | 1 | 3 042 410 | 3 038 062 | 3 036 238 |
| 2 | 3 015 956 | 3 012 392 | 3 010 064 | 2 | 3 016 310 | 3 014 817 | 3 012 983 |
| 3 | 2 983 345 | 2 982 376 | 2 979 942 | 3 | 2 984 248 | 2 985 378 | 2 983 476 |
| 4 | 2 959 082 | 2 960 789 | 2 958 391 | 4 | 2 960 513 | 2 964 249 | 2 962 399 |
| 5 | 2 928 233 | 2 932 443 | 2 930 174 | 5 | 2 929 759 | 2 935 894 | 2 934 069 |
| 6 | 2 902 677 | 2 908 942 | 2 906 837 | 6 | 2 904 426 | 2 912 641 | 2 910 902 |
| 7 | 2 863 568 | 2 871 990 | 2 870 152 | 7 | 2 865 075 | 2 875 516 | 2 873 901 |
| 8 | 2 819 588 | 2 829 769 | 2 828 224 | 8 | 2 820 760 | 2 833 022 | 2 831 549 |
| 9 | 2 774 343 | 2 785 605 | 2 784 281 | 9 | 2 774 983 | 2 788 290 | 2 786 809 |
| 10 | 2 730 230 | 2 742 457 | 2 741 328 | 10 | 2 730 174 | 2 744 549 | 2 743 162 |
| $\rho = 3$ | | | | | | | |
| Social Insurance (baseline) | | | | Patients pay their own expenses | | | |
| Period | A | B | C | Period | A | B | C |
| 1 | -1712.19 | -1670.04 | -1675.16 | 1 | -1734.79 | -1684.48 | -1688.72 |
| 2 | -3242.70 | -3152.69 | -3161.18 | 2 | -3277.70 | -3174.33 | -3181.29 |
| 3 | -4810.61 | -4674.07 | -4685.40 | 3 | -4849.69 | -4698.06 | -4707.87 |
| 4 | -6449.39 | -6263.91 | -6277.13 | 4 | -6496.60 | -6292.36 | -6303.94 |
| 5 | -8149.22 | -7917.24 | -7931.64 | 5 | -8201.34 | -7948.61 | -7961.56 |
| 6 | -9646.54 | -9371.70 | -9386.58 | 6 | -9704.05 | -9406.54 | -9420.01 |
| 7 | -11435.03 | -11117.74 | -11131.63 | 7 | -11500.73 | -11157.50 | -11170.20 |
| 8 | -13237.56 | -12882.56 | -12894.55 | 8 | -13302.56 | -12922.11 | -12933.45 |
| 9 | -15053.92 | -14672.19 | -14682.71 | 9 | -15117.19 | -14711.08 | -14722.03 |
| 10 | -16892.07 | -16488.16 | -16496.63 | 10 | -16961.03 | -16530.91 | -16540.02 |

Table 14: Welfare effect of social insurance

easy to understand. Taking the unweighted sum of individual willingnesses-to-pay as a social welfare criterion is indeed theoretically incoherent and ethically unattractive. However, a richer approach to CBA is possible, in which individual preferences are respected without becoming subjectively welfarist (by using the notion of equivalent income) and in which an adequate specification of the social welfare function is used to tackle fairness issues. In this paper we have shown how such a richer framework can be implemented.

Our paper therefore also counters another argument which is sometimes offered in defence of CEA, i.e. that it is unrealistically ambitious to combine the detailed and complex medical information needed for a careful analysis of different treatments into a rich (and therefore also complicated) evaluative approach. Our evaluation of alternative antihypertensive treatments in France shows that this idea of overambition is misplaced. It is possible to use all necessary medical information to link the treatments to health outcomes and to costs, and at the same time use survey knowledge to gather information on the preferences of citizens concerning health and income. The former type of information is application-specific, as is also the case in traditional CEA. The latter type of information, however, is generic. It is not necessary to organise a new survey of the population for each specific application. It is enough to regularly update the available information. The pragmatic argument (that CEA should be used because the alternative richer evaluative framework requires too much information) is therefore not defensible. As a matter of fact, this also shows that the social welfare based interpretation of cost-benefit analysis can as easily be applied as the narrow version that is most popular now. Pragmatic arguments in favour of the simplistic approaches are not justified. There is room for a true ethical debate on the underlying assumptions. That is the main message of this paper.

One can wonder if introducing more and more considerations into the formal evaluation does not reduce decision making to a purely technocratic exercise, with economists taking over the power from democratically elected politicians. This fear is misplaced. Even a richer evaluative framework will not include all relevant ethical issues. This is obviously the case for deontological considerations which are often of crucial importance, especially in the health care sector, and which may override the kind of consequentialist calculations that we presented in this paper. Moreover, before the formal analysis there is the initial step of defining the list of possible (and ethically acceptable) policy alternatives. This step should be taken through democratic decision-making. Last but not least, important

choices still must be made within the evaluative framework. Obvious examples are the choice of a specific value for the parameter of inequality aversion and the choice between the ex ante and the ex post-approach, where the latter takes into account the consequences of bad luck in the measurement of inequality. As illustrated by our application, sensitivity analysis gives the decision makers useful information for making a well-informed decision and makes it possible to focus the discussion on the crucial ethical choices.

We do not believe that the results in this paper can be applied as such in a real-world decision-making process. Our aim was to show that it is in principle feasible to do better than CEA or traditional CBA. Since implementation of our distribution-sensitive evaluative framework is not an unrealistic goal, it is useful to work further in order to improve the methodology for future applications. The main challenge is a better estimation of individual preferences concerning income, health and (ideally) other dimensions of life. In this paper we explored the potential of contingent valuation. There are, however, alternative approaches, such as the derivation of marginal rates of substitution from happiness equations (see Decancq et al., 2015b). It would be worthwhile to compare the results of these different approaches. There are reasons to think that the willingness-to-pay values in our survey do not fully reflect the health-income preferences of the individuals. We asked the retrospective willingness-to-pay to be in perfect health for the last 12 months. It is possible that, to a limited degree, respondents include in their responses on SAH and willingness-to-pay the long-run effects of the illnesses they suffered from in the past 12 months, including their effect on life expectancy (and the anxiety about life expectancy). Yet it still remains highly likely that our survey has yielded a severe underestimate of the true willingness-to-pay to be in perfect health for a problem like hypertension, for which the long-run effects are essential. This may explain why the cost effects are seemingly larger than the health effects in our application. Of course, the standard CEA-approach also relies on techniques such as the standard gamble or time trade-offs to measure the subjective value of health. These techniques are not immune to "biases" either. Improving the estimation of individual preferences should be one of the first priorities on the research agenda.

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