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Cost-utility analysis or equivalent income approach to evaluate healthcare programs: what impact on allocation recommendations? A tutorial.

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Key words: cost-utility analysis, cost-benefit analysis, microsimulation model

Abstract

Context: Since the late 2000s, various approaches have been explored to adapt health technology assessment methods to take into account distributive principles, in addition to efficiency. This article deals with one of these innovative methods, the Equivalent Income (EI) approach. The EI approach requires individual-level models, as it directly takes into account individual preferences for health by valuing health outcomes in monetary terms and estimate how health states can affect individual incomes. It also allows for varying degrees of societal aversion to health and income inequalities.

Objective: The article proposes a generic Markov microsimulation model to illustrate in a didactic way how the EI approach can be implemented and to what extent it can lead to recommendations that differ from those derived from Cost-Utility Analysis (CUA).

Methods: The model is an adaptation of Krijkamp et al. (2018). It simulates and compares two strategies for treating a hypothetical disease. The first step is to estimate, for each individual in a representative sample of the French population, the evolution of their health status and health care consumption over a 30-year time horizon. The second step is to simulate changes in individual income, willingness to pay for perfect health, health insurance contributions and, finally, individual EI. The individual EIs are then aggregated into a social welfare function (SW) that incorporates different degrees of inequality aversion. Allocation recommendations based on the EI approach and the ACU are compared according to the different scenarios developed to highlight differences between the two approaches. The first scenario (Scenario A) describes a situation where there is no health inequality in the disease prevalence. Conversely, scenario B deals with a situation where the disease is more common among disadvantaged people. In addition, two sensitivity analyses were carried out: the most disadvantaged (the last deciles two of income) do not contribute to compulsory health insurance (sensitivity analysis 1); the probability of death is doubled (sensitivity analysis 2).

Results: The context of health inequality in terms of disease prevalence and health financing system may lead to different recommendations under the EI approach, whereas the CUA is insensitive to such information.

1. Introduction

1.1. Context

In countries where health expenditures are subsidized, regulators in charge of setting prices and deciding reimbursement of health interventions (drugs, medical devices, public health programs) face a number of issues. Since public resources are limited, collective consensus is required to decide which interventions are to be prioritized, raising the dilemma that Daniels formulated as follows: *"Which health needs should be met when it is impossible to meet them all?"* (Daniels, 2007). Addressing this dilemma implies deciding what is the ultimate goal of the healthcare system. Is it to maximize the amount of health benefits for the whole population given budgetary constraints? Is it to reduce health inequalities? Is it both? Hard choices arise as efficiency and equity objectives are likely to be competing in some contexts. Reducing health inequalities can be indeed costly because it requires implementing targeted strategies. For instance, mobile healthcare professionals teams have been demonstrated to be effective to reach out vulnerable populations by improving participation in breast cancer screening campaigns (De Mil et al. 2019 ; Smith et al. 2019). Similarly targeted information programs on papillomavirus vaccination toward families with low socioeconomic status may reduce social inequalities (Moffroid et al., 2023). However, as they require more sophisticated designs, they induce extra-costs. Beyond the trade-off between efficiency and equity objectives, another question has to be addressed : what outcomes should be considered when defining priorities for resource allocations ? Should it be health status, level of capabilities or individual welfare?

Economic evaluation methods used to support decision making for price negotiation and reimbursement of health interventions should be consistent with these above mentioned normative choices. Cost-utility analysis (CUA) is currently the most widely used economic evaluation method. However, this method implies that the sole objective of the healthcare system is to maximize the production of health benefits for the whole population, regardless of the distribution of these benefits. Since the late 2000s, various approaches have been proposed to take into account different distributive principles. Instead of focusing solely on maximizing health gains, they propose to give more or less priority to the improvement of the situation of the most disadvantaged individuals, even if this leads to a decrease in overall health outcomes at the collective level. These approaches are based on social justice models that are widely described as liberal egalitarian (Fleurbaey, 1995; Sen, 1987; Van Parijs, 1991). A first method, called Distributional Cost-Effectiveness Analyses (DCEA), assesses interventions with an objective of equalizing health-adjusted life expectancy (HALE). Tutorials have since been published (Asaria et al., 2015; Cookson et al., 2017, 2020). A second method evaluates interventions with an objective of maximizing or equalizing capabilities using the ICECAP index (Coast et al., 2008; Flynn et al., 2015; Goranitis et al., 2017). The ICECAP index has been increasingly used in clinical trials, especially since it was recommended by NICE for evaluating social care interventions (Afentou & Kinghorn, 2020; NICE, 2016; Proud et al., 2019; Zahirian Moghadam et al., 2023). A third approach assesses interventions with an objective of equalizing a well-being index entitled "Equivalent Income" (EI), making it possible to assess the situation of individuals in terms of both health and income (Fleurbaey, 1995, 2007a; Fleurbaey et al., 2013). Overall, these alternative approaches to CUA are more

and more considered for evaluating health care programs. However, these approaches are indeed more challenging to understand than cost-effectiveness analysis. Their use may also require more complex data and calculation methods, in particular DCEA and Equivalent income approach.

1.2. Objective

The present research presents how the EI approach can be implemented in a didactic way and to what extent it can lead to recommendations different from those when using CUA. For this purpose, we provide a generic Markov microsimulation model and simulate different scenarios considering a hypothetical disease.

2. Methods

2.1. The Equivalent Income index

The “Equivalent income” (EI) is an individual welfare index assessing the situation of individuals both in terms of health and income. It corresponds to the level of income that would put the individuals in an equivalent situation, from their point of view, if they were in perfect health rather than in their actual health states. It is computed by subtracting to the individual’s income the willingness to pay to be in perfect health rather than in the current state of health of this individual. Hence, if an individual is in perfect health, his equivalent income should be identical to his monthly income. On the contrary, the equivalent income of an individual with very low health status should be much lower than his monthly income, provided that he gives some value to his health. For further details on the theoretical foundation of this approach, refer to (Fleurbaey, 2007b).

Unlike standard cost-benefit analysis, which solely uses health care expenditures and willingness-to-pay to be in perfect health to provide recommendations, the EI index retains information on individual income. This inclusion allows for a more comprehensive assessment of the consequences of various interventions. Indeed, similarly to other approaches, EI-based economic evaluations can account for the effects of interventions on individuals' health status and healthcare costs. But on top of these effects, EI-based economic evaluations also consider how changes in health and expenditures impact individual incomes. Changes in health can indeed directly influence a person's ability to work and to generate incomes, and additional expenses are often borne by individuals through out-of-pocket payments or health insurance contributions, which also impacts individual welfare. Such an approach requires consequently to include in the analysis every contributor to health insurance, in addition to the beneficiaries of the evaluated health care intervention.

If it is relevant, the impact of illness on individuals' professional career and income could be estimated and included in the model. For instance, the impact of a cancer episode on professional career and incomes is documented, for instance cf. Yabroff et al.

2.2. Data

Our microsimulation model is based on the information provided by a survey conducted in 2009 on a representative sample of the French population (3331 individuals), funded by Paris-Dauphine University.

Individuals were asked, during face-to-face interviews, questions about their health status (medical events experienced during the last 12 months and Self-Assessed Health (SAH) using a scale between 0 to 100), income and preferences regarding trade-off between health and income,. They were also asked how much of their monthly income they would accept to give up in exchange for having been in perfect health in the last 12 months, rather than experiencing health status they just have been declared (WTP).

Data collected in the survey are used to characterize the sample upon which the simulations are carried out in the present work, in terms of age, income, health status and other socio-economic characteristics. The simulated sample is presented in table 1 regarding these variables of interest. We excluded 215 individuals due to missing variables.

[Table 1 about here]

2.3. Modeling method

The present work simulates and compares two strategies to treat an hypothetical disease: a strategy with a standard treatment (annual cost €4,000) and a strategy with an innovative treatment which is more expensive (additional annual cost €20,000) and more effective.

Resource allocation recommendations are elaborated after simulating the evolution of an hypothetical cohort representative of the French population over a 30-year time horizon, using a discount rate of 2.5%. The initial situation of this hypothetical cohort is the situation of the individuals interviewed in the 2009 survey in terms of age, gender, income and health status. For the sake of clarity, we assume that healthcare expenses are covered at 100% by a compulsory health insurance scheme. We therefore do not model out-of-pocket expenses in our tutorial.

Modeling at the individual level is required when using the EI approach because it requires taking into account preferences that vary according to the socio-economic characteristics of individuals and measuring the impact of the disease and interventions on the income of all individuals in the sample. In addition, the microsimulation modeling is consistent with theoretical prerequisites of EI approach, which implies conducting the evaluation from an *ex post* perspective. The aim is to take into account aversion to inequalities arising from bad luck, i.e. the occurrence of events that have a very low probability of occurring but which have a severe negative impact on the well-being of individuals, so that inequalities that result from pure chance are also taken into account (Fleurbaey et al., 2013; Samson et al., 2018). Consistently with this prerequisite, the present individual simulation makes it possible to follow for each individual during his/her lifetime in order to estimate at each cycle their health state, their healthcare consumption, their level of income, WTP and contributions.

Our model is an adaptation of (Krijkamp et al., 2018), which is a tutorial to encourage the use of R software to perform microsimulations when implementing CUA. It simulated and compared two strategies to treat a hypothetical disease with ACU. Our model provides in addition recommendations using the EI approach.

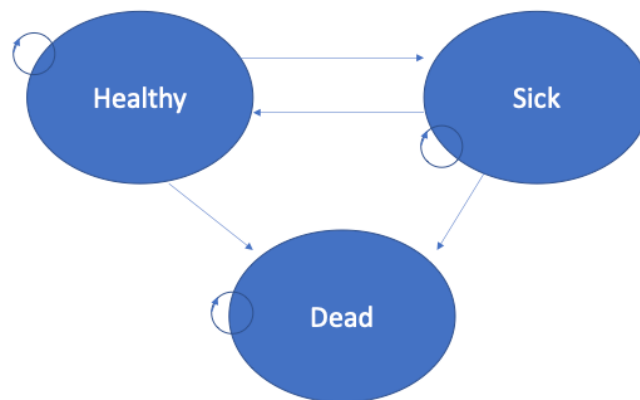
In this section, the different steps to implement the EI approach are detailed.

Step 1: Simulations of changes in individual health states and health care consumptions.

This first step aims to estimate, for each individual during the considered time horizon, the evolution of his/her health status (health-related quality of life (HRQoL) and mortality), as well as health care costs at each cycle. This step is similar for both ACU and EI approaches.

Changes in the health status are simulated using an individual-level Markov model. Three health states are considered: "Healthy", "Sick" and "Dead". We assume that all sick individuals will be treated. In our tutorial, we assume that patients in the "Sick" health state receive treatment at every cycle.

Figure 1 : Markov model



At the beginning of the modeling, individuals are randomly assigned in the healthy and sick health states depending on the prevalence of the disease (see table 2). Including healthy people in the modeling is required when using the EI approach since their EI is impacted by a change of strategy due changes in their contribution to the mandatory health insurance.

Then, at each cycle, individual health status may change depending on the probability of getting sick, the probability of recovery and the probability of death. These probabilities do not depend here on individual characteristics in our model, even if the individual-level Markov model would allow it. The model parameters are presented in table 2. HRQoL is estimated for each individual at each cycle, based on changes in health status and individual history. A utility score of 0 refers to the utility score associated with the "death" health state and 1 to "perfect health". Individual health care costs are also calculated for each individual at each cycle depending on the current health state and the considered strategy.

[Table 2 about here]

Different levels of relative effectiveness of the innovative treatment compared with the standard of care are considered (from 1 (similar effectiveness), up to 10 times more effective)

in order to investigate the changes in the allocation recommendations with the EI approach or the ACU depending on the innovative nature of the evaluated technology.

Step 2: Simulations of changes in individual income, WTP, contribution to the mandatory health insurance and calculation of the equivalent income.

To implement the EI approach, additional estimations are required every cycle, compared to ACU. Estimations of individual incomes and WTP are based on estimated parameters of the 2009 survey (Samson et al., 2018; Schokkaert et al., 2013). However, it would be possible to use estimates derived from other surveys and to take into account other factors to estimate them. Similarly for the impact of health expenditures on individual income, we used parameters that represent the level of contributions of the French mandatory health insurance (Jusot et al., 2017). Such parameters have to be adapted according to the considered health care system.

First, the EI approach requires to simulate the evolution of individual monthly income. As it was modeled in Samson et al. (2018), the individual monthly income y_{it} depends on the income of the previous year (y_{it-1}), on the variations in HRQol (measured *via* variations in SAH) and having an additional year of professional experience. It is estimated from the following equation: $y_{it} = y_{it-1} + 2.844 \times (SAH_{it} - SAH_{it-1}) + 17.35$. The coefficients used in this equation were estimated using the 2009 survey from a linear regression. For more details, see Samson et al. (2018, online appendix). From 66 years old, individuals are assumed to be retired and keep the same income from one year to the next, whatever variations in their HRQoL. The annual income is then calculated by multiplying the monthly income by 12.

Second, the EI approach requires to assess the variations of the Willingness to pay to be in perfect health WTP_{it} at every cycle t , which depends on the individual income, the HRQol, their age and gender. WTP_{it} is estimated from the estimates provided by Schokkaert et al. (2013), also based on the 2009 survey using polynomial functions. The monthly WTP can be computed as follows:

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

$$\alpha_i = \alpha_0 + \alpha_{Age_i} + \alpha_{Mmale_i}$$

$$\beta_i = \beta_0 + \beta_{Age_i} + \beta_{Mmale_i}$$

$$\gamma_i = \gamma_0 + \gamma_{Age_i} + \gamma_{Mmale_i}$$

$$\delta_i = \delta_0 + \delta_{Age_i} + \delta_{Mmale_i}$$

, with $\mu_i = \mu_0 + \mu_{Age_i} + \mu_{Mmale_i}$.

We directly use the estimated coefficients that can be found in their table 2 of (Schokkaert et al., 2013).

Contribution to the mandatory health insurance is calculated from the total health care expenditures associated with each strategy at each cycle. Health care costs that are reimbursed by the mandatory health insurance are distributed across individuals from the contribution rate of each decile income. French contribution rates are taken from (Jusot et al., 2017) ().

Finally, the model estimates an individual annual EI for each cycle as described in the following equation $EI_{it} = 12 \times y_{it} - Contrib_{it} - 12 \times WTP_{it}$, where y_{it} is the monthly individual

equivalised income, $Contrib_{it}$ is the annual contribution to the health insurance that depend on individual income, WTP_{it} is the willingness-to-pay. When there are out-of-pocket payments, they can be included in the calculation of the individual EI by subtracting them to the income, as the contribution to health insurance. Negative EI are set to zero. Individuals who die have a null EI, during the year of the death and during the following years (other valuation choices could be done in the model).

2.4 Providing recommendations according to CUA and EI approach

Using CUA: estimation of the ICER.

When implementing a CUA, two variables have to be estimated for each strategy: E_i and C_i , respectively, as the discounted effectiveness (measure in terms of Quality Adjusted Life Years gained, QALY) and costs associated with strategy i.

When considering the policy switch from standard strategy (denoted S) to innovative strategy (denoted I), the differential cost can be written as $(C_I - C_S)$. Differential effectiveness amounts to $(E_I - E_S)$. Allocation recommendations are elaborated from the calculation of the Incremental Cost-Effectiveness Ratio of this policy switch which is $ICER(S \rightarrow I) = \frac{C_I - C_S}{E_I - E_S} \in$ and measure the cost of each additional QALY generated by the innovative strategy.

Allocation recommendations then depend on the WTP of the society for an additional QALY. If the ICER is below the WTP, the innovative strategy is recommended. If the ICER is above the WTP, the standard treatment is preferred. In the present modeling, HRQol is measured using the rescaled individual SAH scores between 0 and 1. In our tutorial, we used self-assessed health, instead of standard utility weights derived from a recommended preference-based questionnaire, as the EQ-5D, since answers to such a questionnaire were not collected in the 2009 survey.

Using EI approach: estimation of the social welfare function.

Providing recommendations with the EI approach requires defining a social welfare function (SW). The latter aggregates individual EI, weighted at a given level of inequality aversion (ρ),

such as $SW = \frac{1}{1-\rho} \sum_{i=1}^N EI_i^{1-\rho}$. This Atkinson specification of the SW implies that the higher the value of ρ , the greater the inequality aversion incorporated in the evaluation.

The program maximizing social welfare is to be recommended. Hence, the innovative program is recommended if $SW_I > SW_S$, i.e. if the SW when the innovative strategy is implemented is greater than the SW when the standard strategy is implemented.

In our study, we will consider allocation recommendations for different levels of inequality aversion scores, starting from 0 and up to 4, increasing by half point. 0 corresponds to the absence of aversion to inequality, 4 to an extremely strong aversion to inequality. The choice of a rho value is a normative decision that is beyond the competence of economists. It should result from collective and democratic decisions, as is the setting of the cost-effectiveness threshold. The rho value can be determined by a procedural process, as it was done for the well-known cost/effectiveness threshold set by NICE (2008) or the tutelary value set by Quinet report in France (2013). Empirical surveys can be carried out to assess the social preferences

of the population in terms of redistribution to inform public debate (Cf. literature review proposed by Cookson et al. 2021 chapter 13, section 13.3).

If the hierarchy of strategies changes according to the rho value, this means that the reimbursement decision raises redistributive issues which have to be addressed. On the other hand, if the hierarchy between strategies does not change depending on the value of rho, then it follows that there is no conflict between an objective of efficiency and equity.

2.5 Simulating different scenarios for allocation recommendations

Allocation recommendations based on the EI approach and the ACU will be compared according to different scenarios elaborated to highlight differences between the two approaches. For each scenario, we consider a disease with a prevalence of 5.5%. Such a prevalence is equivalent to the public health burden of diabetes in France (Santé Publique France, 2021).

The first scenario (Scenario A) describes a situation where there is no health inequality in the disease prevalence: 5.5% for the entire population. Conversely, scenario B deals with a situation where the disease is more frequent among disadvantaged people. We still consider a situation where total prevalence remains 5.5%, but where the disease is observed in 10% of the individuals with an income below the French second decile (€13,170), 1% for others.

In addition, we performed two sensitivity analyses: the most disadvantaged (the two last deciles of income) do not contribute to compulsory health insurance (sensitivity analysis 1); the probability of death is doubled (sensitivity analysis 2). The first sensitivity analysis aims to illustrate how the contribution for the health insurance can impact the recommendations provided by the EI approach. The second sensitivity analysis investigates the difference in allocation recommendations for a more severe disease.

3. Results

Base-case analysis

The allocation recommendations resulting from the EI approach and the ACU are presented in table 3. As expected, allocation recommendations using ACU are very close, whether there is health inequality in the disease prevalence or not. In a nutshell, whatever the health inequality context, the more effective the innovative treatment, the lower its ICER is, and therefore the more it is recommended with increasingly lower WTPs.

Conversely, the allocation recommendations using the EI approach can depend on the health inequality context and the inequality aversion score of the society. Depending on the relative effectiveness of the innovative treatment compared with the standard one, the recommendation depends on the trade-off between losses in welfare due to increased costs and consequently increased individual contributions and gains in welfare due to improved health and related increased incomes when using the innovative treatment compared with the standard one. Whatever the distribution of the prevalence of the disease, for a relative effectiveness of the innovative treatment below 6, the losses always outweigh the benefits, whatever the inequality aversion score (ρ) of the society, implying that the innovative treatment is simply too expensive

compared with the benefit it can provide. From a relative effectiveness of 6, depending on the level of incomes, the trade-off between gains and losses is less homogeneous in the society inducing changes in recommendation according to the weight we grant to the most disadvantaged individuals. When the disease is uniformly distributed in the population, recommendations in favor of the innovative treatment are possible mainly when ρ is below a given threshold, indicating that individuals with lower incomes tend to lose more welfare than they gain welfare with the new treatment, probably due to the increased contributions. The greater the relative effectiveness, the greater the ρ has to be to not recommend the innovation. Conversely, in scenario B where the disease is more prevalent among the individuals with the lowest incomes, from a relative effectiveness of 6, the recommendations in favor of the innovative treatment are possible mainly when ρ is above a given threshold, indicating that individuals with lower incomes tend to gain more welfare than the other members of the society.

[Table 3 about here]

[Table 4 about here]

Sensitivity analysis 1: when the poorest individual do not contribute to the health insurance funding

Results of this sensitivity analysis are presented in table 4. In the absence of contributions for mandatory health insurance for individuals with the lowest income, the recommendations from CUA are unchanged compared with those presented in Table 3. On the other hand, with the EI approach, the recommendation depending on the distribution of the disease becomes very similar: from a relative effectiveness of 3, the innovative treatment can be preferred from a given value of ρ . The greater the relative effectiveness, the lower the ρ has to be to recommend the innovative treatment.

Sensitivity analysis 2 : when the disease is more severe

Results of this sensitivity analysis are presented in table 5. If we consider a more severe disease than the one described in the reference analysis (doubled probability of death when sick), the ICERs are reduced, implying that the innovative treatment is recommended from lower WTPs. Disease severity has also an impact on the EI recommendations. The EI approach is less demanding in terms of relative effectiveness gains for recommending the innovative treatment. In addition, the inequality aversion score of the society is seldom used to define the recommended strategy.

4. Discussion

Our article aimed to illustrate with hypothetical scenarios the added value of EI approach compared with CUA, which is routinely used by decision-makers when considering the efficiency of an innovative treatment. Compared with CUA, the EI approach elaborates recommendations from a broader perspective by including additional information such as individuals' preferences between their health and their income, individuals' ability to generate income and the consequences of reimbursement decisions on individual contributions to

mandatory health insurance. Conversely to the CUA, the EI approach directly takes into account individual preferences regarding health and incorporates varying degrees of societal aversion to health and income inequalities. In addition, this index of well-being can integrate the consequences of health interventions in an extensive way such as the consequences of health status on the individuals' income or the impact of health expenditures on individuals' income through variations of social contributions. Like the DCEA, the EI approach incorporates an inequality aversion score into a social welfare function. On the other hand, unlike the DCEA, this approach does not involve the use of a cost-effectiveness threshold value, and proposes to integrate individual preferences in terms of health and income trade-offs directly into the evaluation.

It also has the disadvantage of only partially considering the preferences of individuals affected by healthcare programs.

In the base-case scenario considered in our article, the innovative strategy is recommended with the EI approach only from a significant increase in effectiveness and below a certain level of aversion to inequality. When the disease prevalence is higher among the poorer individuals and the relative effectiveness of the innovative treatment is extremely greater, the innovative treatment can be recommended whatever the inequality aversion. Such a result can be explained by the used SW, that takes into account at the same time : 1) health gains for the individuals who are affected by the disease (through a lower WTP to be in perfect health due to an improved health status and greater incomes) ; 2) the impact of an expensive treatment on income via higher contributions (and consequently, equivalent income) of every individual within the general population. Consequently, to recommend an innovative but expensive treatment, valuations of health gains have to outweigh the additional contributions required by the reimbursement of this new treatment. The individual balance is different depending on the income level and health status. When inequality aversion increases, the weight given to the improvement (in terms of health and/or income) of most disadvantaged people increases. For this subpopulation, the negative consequences of a new expensive treatment (which increases the amount of contributions to health insurance) may outweigh the value given to health gains, unless the innovative treatment is very effective and/or more frequent in this subpopulation and/or very severe (sensitivity analysis 2) and/or they do not contribute to it (sensitivity analysis 1). The EI approach may thus reach different allocation recommendations depending on the funding system of the mandatory health insurance, for the same treatment at the same cost.

Our study nevertheless has limitations, mostly due to the 2009 survey we had to use for our tutorial. However, since the objective of our article is methodological and not to provide current recommendations for a specific treatment, this limitation should not significantly challenge our results. First, the evolution of the income and WTP was estimated from the 2009 survey. Future research aiming at using the EI approach for allocation recommendation would have to use more recent data since these estimations depend on the economic context which can significantly change over time. Second, the HRQoL was measured from the SAH, instead of EQ-5D questionnaire, in the 2009 survey. We had thus to compute QALYs from unusual HRQoL measurement, departing from most HTA bodies recommendations. Third, the monetary valuation of health gains, estimated in the 2009 survey, were very low, which explains part of the results of the present simulation. The treatment has indeed to be highly effective to provide

health gains that increase the SW offsetting the negative impact on the incomes of those who contribute to the financing of health insurance. These very low values can be explained by the method used in the 2009 survey to assess trade-offs between health and income, which may not fully capture the value individuals attribute to the improvement of their health. The survey was based on a contingent valuation method: individuals were directly asked about the amount of their income they would be willing to forego in order to be in perfect health. It is possible that the question, framed as such, has not been perfectly comprehended by respondents, or that the estimation is cognitively difficult to make. For this reason, a new survey is currently being launched. It includes a preliminary phase that aims to test different preference revelation methods, in order to identify which is the most effective at capturing people's preferences.

5. Conclusion

Our tutorial presented the different steps to follow to implement the EI approach. The EI approach requires an individual-based modeling. It also requires data from representative individuals of the considered health care system to estimate and simulate the evolution of income, WTP and contributions to health insurances of these individuals.

Providing recommendations from the usual CUA or the EI approach can have a significant impact on reimbursement decisions. With CUA, the natural history and the severity of the considered disease and the effectiveness and the costs of the evaluated strategies are the main information included in the analysis. With the EI approach, the health inequality context of the considered disease and the health care funding system are additional information to be taken into account.

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Tables**Table 1 Basic features of the data (n=3116)**

Variable	Mean	Standard deviation	Min	Max
Female	0,55		0	1
Age	52,91	17,84	18	90
Pers. Income	1 348,87	1347,78	0	56 000
Equivalised Income	1 436,82	1034,29	0	20 000
Active	0,38		0	1
SAH	71,81	20,91	0	100

Table 2: Model parameters

Parameters	Value
Epidemiological parameters	
Prevalence of the disease at baseline	5.5%
Probability to develop the disease	1%
Probability to recover when sick with standard of care	5%
Probability to die when healthy	0.5%
Rate ratio of death in sick vs healthy	5
Relative effectiveness of the innovative treatment compared with the standard treatment	From 1 to 9 depending on scenarii
Health-related quality of life (HRQol) parameters	
Loss in HRQol when becoming sick	0.10
Loss in HRQol for an additional year being sick	0.02
Methodological parameters	
Discount rate	2.5%
Time horizon	30 years
Cost parameters	
Treatment cost for standard of care	4000€
Treatment cost for the innovative treatment	24 000€

Table 3 : Allocation recommendations when where there is no health inequality in the disease prevalence (scenario A)

Relative effectiveness	Recommendations with EI approach			Recommendations with CUA		
	Base case analysis	Sensitivity analysis 1	Sensitivity analysis 2	Base case analysis	Sensitivity analysis 1	Sensitivity analysis 2
1	Standard, $\forall \rho$	Standard, $\forall \rho$	Standard, $\forall \rho$	Standard, \forall WTP	Standard, \forall WTP	Standard, \forall WTP
2	Standard, $\forall \rho$	Standard, $\forall \rho$	Innovative if $\rho \geq 2$, standard otherwise	Standard if WTP < 165 578€/QALY, innovative otherwise	Standard if WTP < 165 578 €/QALY, innovative otherwise	Standard if WTP < 96 230 €/QALY, otherwise innovative
3	Standard, $\forall \rho$	Innovative if $\rho \geq 2.5$, standard otherwise	Innovative if $\rho \geq 1.5$, standard otherwise	Standard if WTP < 76 268€/QALY, otherwise innovative	Standard if WTP < 76 268 €/QALY, otherwise innovative	Standard if WTP < 52 472, otherwise innovative
4	Standard, $\forall \rho$	Innovative if $\rho \geq 2$, standard otherwise	Innovative if $\rho \geq 1$, standard otherwise	Standard if WTP < 45124€/QALY, otherwise innovative	Standard if WTP < 45124€/QALY, otherwise innovative	Standard if WTP < 33243, otherwise innovative
5	Standard, $\forall \rho$	Innovative if $\rho \geq 1.5$, standard otherwise	Innovative if $\rho \geq 0.5$, standard otherwise	Standard if WTP < 32005€/QALY, otherwise innovative	Standard if WTP < 32 005€/QALY, otherwise innovative	Standard if WTP < 24209, otherwise innovative
6	Innovative if $\rho = 1.5$, standard otherwise	Innovative if $\rho \geq 1$, standard otherwise	Innovative, $\forall \rho$	Standard if WTP < 21 962€/QALY, otherwise innovative	Standard if WTP < 21 962€/QALY, otherwise innovative	Standard if WTP < 17990, otherwise innovative
7	Innovative if $1 \leq \rho \leq 2$, standard otherwise	Innovative if $\rho \geq 0.5$, standard otherwise	Innovative, $\forall \rho$	Standard if WTP < 16 507€/QALY, otherwise innovative	Standard if WTP < 16 507€/QALY, otherwise innovative	Standard if WTP < 13875€/QALY, otherwise innovative
8	Innovative if $\rho \leq 2.5$, standard otherwise	Innovative, $\forall \rho$	Innovative, $\forall \rho$	Standard if WTP < 12 137€/QALY, otherwise innovative	Standard if WTP < 12 137€/QALY, otherwise innovative	Standard if WTP < 10 56€/QALY, otherwise innovative
9	Innovative if $\rho \leq 2.5$, standard otherwise	Innovative, $\forall \rho$	Innovative, $\forall \rho$	Standard if WTP < 9 451€/QALY, otherwise innovative	Standard if WTP < 9 451€/QALY, otherwise innovative	Standard if WTP < 8 613€/QALY, otherwise innovative

Sensitivity analysis 1: Allocation recommendations when the disadvantaged people do not contribute to the health insurance

Sensitivity analysis 2: Allocation recommendations in the French health care system for a more severe disease

Table 4: Allocation recommendations when the disease is more frequent among disadvantaged people (scenario B)

Relative effectiveness	Recommendations with EI approach			Recommendations with CUA		
	Base case analysis	Sensitivity analysis 1	Sensitivity analysis 2	Base case analysis	Sensitivity analysis 1	Sensitivity analysis 2
1	Standard, $\forall \rho$	Standard, $\forall \rho$	Standard, $\forall \rho$	Standard, \forall WTP	Standard, \forall WTP	Standard, \forall WTP
2	Standard, $\forall \rho$	Standard, $\forall \rho$	Innovative if $\rho \geq 2$, standard otherwise	Standard if WTP <175 582€/QALY,, otherwise innovative	Standard if WTP <175 582€/QALY, otherwise innovative	Standard if WTP <143 837, otherwise innovative
3	Standard, $\forall \rho$	Innovative if $\rho \geq 2$, standard otherwise	Innovative if $\rho \geq 1.5$, standard otherwise	Standard if WTP <76 704€/QALY, otherwise innovative	Standard if WTP <76 704€/QALY, otherwise innovative	Standard if WTP <64822, otherwise innovative
4	Standard, $\forall \rho$	Innovative if $\rho \geq 2$, standard otherwise	Innovative if $\rho \geq 1$, standard otherwise	Standard if WTP <44 990€/QALY,, otherwise innovative	Standard if WTP <44 990€/QALY, otherwise innovative	Standard if WTP <39262, otherwise innovative
5	Standard, $\forall \rho$	Innovative if $\rho \geq 1.5$, standard otherwise	Innovative if $\rho \geq 1$, standard otherwise	Standard if WTP <31 620€/QALY, otherwise innovative	Standard if WTP <31 620€/QALY, otherwise innovative	Standard if WTP <28702 otherwise innovative
6	Innovative if $\rho \geq 1.5$, standard otherwise	Innovative if $\rho \geq 1$, standard otherwise	Innovative if $\rho \geq 0.5$, standard otherwise	Standard if WTP <21 831€/QALY, otherwise innovative	Standard if WTP <21 831€/QALY, otherwise innovative	Standard if WTP <20601, otherwise innovative
7	Innovative if $\rho \geq 1$, standard otherwise	Innovative if $\rho \geq 1$, standard otherwise	Innovative, $\forall \rho$	Standard if WTP <16 624€/QALY, otherwise innovative	Standard if WTP <16 624€/QALY, otherwise innovative	Standard if WTP <15 830€/QALY, otherwise innovative
8	Innovative if $\rho \geq 0.5$, standard otherwise	Innovative if $\rho \geq 0.5$, standard otherwise	Innovative, $\forall \rho$	Standard if WTP <12 856€/QALY, otherwise innovative	Standard if WTP <12 856€/QALY, otherwise innovative	Standard if WTP <12 849€/QALY, otherwise innovative
9	Innovative, $\forall \rho$	Innovative, $\forall \rho$	Innovative, $\forall \rho$	Standard if WTP <10 147€/QALY, otherwise innovative	Standard if WTP <10 147€/QALY, otherwise innovative	Standard if WTP <10 072€/QALY, otherwise innovative

Sensitivity analysis 1: Allocation recommendations when the disadvantaged people do not contribute to the health insurance

Sensitivity analysis 2: Allocation recommendations in the French health care system for a more severe diseases