Health care policy evaluation: empirical analysis of the restrictions implied by Quality Adjusted Life Years

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Preliminary – not for quotation
Health care policy evaluation

• Resource allocation decisions in health care increasingly based on cost-effectiveness analysis
  – Australia
    • Pharmaceutical Benefits Advisory Committee (PBAC)
    • Medicare Services Advisory Committee (MSAC)
  – United Kingdom
    • National Institute of Clinical Excellence (NICE)
  – Canada (Ontario), Denmark, Finland, Netherlands, Sweden
    • All have formal requirements for economic evaluation for reimbursement decisions for pharmaceuticals
  – United States
    • Discussion of a PBAC type process for new pharmaceuticals
Example: Pharmaceutical Benefits Scheme

• PBAC required by legislation to consider cost-effectiveness (among other factors)
• Company seeking PBS listing for a drug must submit an economic evaluation
  – Evidence of clinical effectiveness
  – Estimate potential health gain from new drug relative to current treatment (measure of effectiveness)
  – Estimate additional cost of new drug relative to current treatment
    • proposed price for new drug
    • standardised “prices” for other health services
  – Calculate incremental cost-effectiveness ratio
Examples of PBAC Decisions

Incremental cost per additional Quality Adjusted Life Year gained “league table”

<table>
<thead>
<tr>
<th>Submission</th>
<th>$/QALY</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$4,690</td>
<td>Recommend</td>
</tr>
<tr>
<td>2</td>
<td>$5,244</td>
<td>Recommend</td>
</tr>
<tr>
<td>3</td>
<td>$8,570</td>
<td>Recommend</td>
</tr>
<tr>
<td>4</td>
<td>$10,530</td>
<td>Recommend</td>
</tr>
<tr>
<td>5</td>
<td>$13,121</td>
<td>Recommend</td>
</tr>
<tr>
<td>6</td>
<td>$17,937</td>
<td>Not Recommend</td>
</tr>
<tr>
<td>7</td>
<td>$21,225</td>
<td>Recommend</td>
</tr>
<tr>
<td>8</td>
<td>$24,343</td>
<td>Recommend</td>
</tr>
<tr>
<td>9</td>
<td>$133,337</td>
<td>Reject</td>
</tr>
</tbody>
</table>

Measures of health gain (effectiveness)

- Ideally want measures that are comparable across different diseases and treatments
- “Intermediate”/ “surrogate” (clinical) outcome not comparable
- Life years saved
- Quality adjusted life years saved (QALYs)
Estimating health gain

• Decision tree framework
• Epidemiological information used to identify
  – disease states
  – outcomes of treatment
  – probability of different outcomes (proportion of a population experiencing the outcome)
  – survival (durations) associated with different outcomes
  – quality of life associated with different outcomes
• Estimate expected life years associated with each alternative (new treatment, current treatment)
• Not all years of life have the same value (quality)
Quality Adjusted Life Years

- “Quality Adjustment” reflects valuation of poorer health states relative to “full health”
- QALYs calculated by weighting survival time associated with each treatment outcome by a QALY weight
- QALY weight of 1 for a year of life in “full health”
- QALY weights generally lie between 0 (death) and 1 (full health)
  - “Worse than death” health states permissible
- QALYs measure strength of preference for survival and quality of life and trade-offs between the two
## Example: QALY Weights

<table>
<thead>
<tr>
<th>Condition</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIDS, CD4 count range 0-50</td>
<td>0.79</td>
</tr>
<tr>
<td>Arthritis, before treatment</td>
<td>0.609</td>
</tr>
<tr>
<td>Arthritis, after treatment</td>
<td>0.647</td>
</tr>
<tr>
<td>Cancer, breast, after surgery, first recurrence</td>
<td>0.85</td>
</tr>
<tr>
<td>Cancer, breast, after surgery, third recurrence</td>
<td>0.3</td>
</tr>
<tr>
<td>Cancer, prostate, metastatic, early progressive disease</td>
<td>0.83</td>
</tr>
<tr>
<td>Proctitis/cystitis after radiation therapy for prostate cancer</td>
<td>0.9</td>
</tr>
<tr>
<td>Stroke, severe, motor deficit</td>
<td>0.03</td>
</tr>
<tr>
<td>Stroke, mild cognitive deficit</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Source: Tengs, T and Wallace A. One Thousand Health-Related Quality of Life Estimates

*Medical Care* 38(6) 583-637, 2000
Economic underpinnings of QALYs

• Health care can be characterised as lotteries over profiles of consumption and health

\[ U = U(\left( h_1^1, c_1^1 \right), \ldots, \left( h_T^1, c_T^1 \right), p_1, \ldots, \left( h_1^m, c_1^m \right), \ldots, \left( h_T^m, c_T^m \right), p^m) \]

• Treatments modify the set of lotteries

• Individuals will have preference orderings over alternative treatments

• QALY model implies restrictions on form of utility function
Outline

• Describe methods used to derive QALYS
• Outline the restrictions on preferences imposed by the QALY model
• Describe a discrete choice experiment designed to investigate preferences for health care
• Test restrictions on preferences implied by the QALY model
QALYs

- Measure the value of a particular health state relative to full health, ignoring consumption
- Under the QALY model
  \[
  U(h_1, h_2, \ldots, h_T) = \sum_{t=1}^{T} v(h_t)
  \]
  where \( v(h_t) \) is the quality (utility) weight of health state in period \( t \)
- ie identical additive separable function in each period
Quantifying QALY weights

• Involves experiments using standard gambles and time trade-offs

• These rely on restrictions on preferences over consumption and health status over time.
QALY model: Standard gamble

A \ h^1 \text{ for time } T

B

\begin{itemize}
  \item Specify \ h^1 \\
  \item Find \ p \text{ such that utility of the gamble, } B, \text{ is equal to } A - \text{the certainty of health state } h^1 \text{ for } T \text{ years}
  \item \text{ie}
  \begin{align*}
  p \cdot v(FH)T + 0 &= v(h^1)T \\
  \Downarrow
  p &= \frac{v(h^1)}{v(FH)}
  \end{align*}
  \item Normalise: \ v(FH) = 1
\end{itemize}
QALY model: Time trade-off

- Find $x$ such that utility of the health state 1 for time $T$, $h^1$ is equal to the utility of full health for a proportion $x$ of $T$ years, i.e.

$$v(h^1)T = v(FH)xT$$

$$\downarrow$$

$$x = \frac{v(h^1)}{v(FH)}$$
Note:

- Only attributes of the health state and time enter the experiment

- In both cases the experiment sets $T$

- Individual responses are averaged to determine the QALY weight attached to health state 1
QALY model: Application

- Say a treatment improves health status for a proportion, $p_1$, of the population undergoing the treatment from
  - $h_1$ (with QALY weight $Q_1$) to
  - $h_2$ (with QALY weight $Q_2$) and
  - lengthens expected survival time from $T_1$ to $T_2$
- The effectiveness per individual in terms of QALYs gained is equal to $p_1 (Q_2 T_2 - Q_1 T_1)$

- $p_1, h_1, h_2, T_1, T_2$ are derived from clinical data

- $Q_2$ and $Q_1$ are derived from the TTO/SG experiment;
  - $T$ in the experiment is unrelated to $T_1$ or $T_2$;
  - $p$ in the experiment unrelated to $p_1$. 
QALYs: Policy Evaluation

• Effectiveness measured by QALY gain combined with cost to give a C/E ratio.

• If the C/E ratio lies below some threshold level, the intervention is accepted.

• The threshold indicates willingness to pay per QALY.

• Setting the threshold effectively monetises effectiveness.
QALY Restrictions

Under what restrictions on preferences is cost-effectiveness analysis based on QALYs likely to lead to health care resource allocation that reflects individuals’ preferences?
Literature

- Pliskin, Shephard and Weinstein (1980)
- Bleichrodt, Wakker and Johannesson (1997)
- Miyamoto, Wakker, Bleichrodt and Peters (1998)
  - Preferences defined over a constant health state and survival
- Bleichrodt and Quiggin (1997)
  - Preferences defined over non-constant health states over time
  - Expected utility and Rank dependent expected utility
- Bleichrodt and Quiggin (1999)
  - Preferences defined over non-constant health states and consumption over time
QALY restrictions: B&Q (1999)

- VNM expected utility
- Marginality
- Symmetry
- Standard gamble invariance
- Zero condition
QALY restrictions: marginality

• Let \( y_G = ($20, H_1); y_B = ($5, H_2); \quad H_1 > H_2 \)

• With marginality an individual is indifferent between
  – G1: \( (y_B, y_B) \) with prob=1/2 and \( (y_G, y_G) \) with prob=1/2
  – G2: \( (y_B, y_G) \) with prob=1/2 and \( (y_G, y_B) \) with prob=1/2

• Both G1 and G2 have the same probability of \( y_G \) in both periods and of \( y_B \) in both periods.

• Marginality excludes all complementarity across time periods, such as a dislike for variation or a desire to avoid a bad outcome in both periods.
QALY restrictions: symmetry

- Requires that resequencing does not change utility:
  \[
  U(y^1, y^2, \ldots, y^T) = \sum_{t=1}^{T} U(y^t)
  \]
- Inconsistent with positive time preference.
QALY restrictions: standard gamble invariance

• For all levels of consumption, \( c \) and \( c' \)

\[
(c, h) \succ [(c, h'), p ; (c, h''), 1 - p]
\]

\[
\Rightarrow
\]

\[
(c', h) \succ [(c', h'), p ; (c', h''), 1 - p]
\]

• Utility derived from the health state unaffected by the level of consumption
QALY restrictions: zero condition

- Less controversial

\[ U(c, \text{death}) = U(c', \text{death}) = 0 \]
Under QALY restrictions

\[ U = U \left( \left( h_1^1, c_1^1 \right), \ldots, \left( h_T^1, c_T^1 \right), p^1, \ldots, \left( h_1^m, c_1^m \right), \ldots, \left( h_T^m, c_T^m \right), p^m \right) \]

\[ = \sum_{i=1}^{m} p_i \sum_{t=1}^{T} z(c) v(h_t) \]

- \( z(c) \) a constant
- i.e. Implies constant consumption over time
Implications of QALY restrictions
EU: linear in probabilities

• Evaluation function for gambles is linear in probabilities.
• No complementarity across time periods.
• The utility function over sequences of consumption and health state is additively decomposable over time
• One-period utility functions are the same.

RDEU: probability weighting function

• Changes the marginality condition to generalised utility independence – less strict.
Discrete choice experiments and health care

• DCEs widely used in transport economics, environmental economics and marketing

• Used in health economics to:
  – Explore trade-offs between attributes of health care interventions
  – Provide monetary valuations of health care interventions
  – Predict uptake of new programs

• Discrete choice experiments can provide data to explore the underlying utility function for health and health care, particularly trade-off between quality of life and survival (QALYs)
DCE Methods

• Stated preference surveys
• Choose preferred alternative from a series of hypothetical choice sets
• Alternatives described in terms of attributes
• Attributes varied over plausible range of levels of analytical interest
• Experimental design principles used to choose a sample of choice sets to allow for efficient estimation of parameters of interest
DCE Methods: Binary Choice

\[ P_i(j) = \Pr(U_{ij} \geq U_{ik}) \]

\[ U_{ij} = V_{ij} + \varepsilon_{ij} \]

\[ P_i(j) = \Pr\left( (V_{ij} + \varepsilon_{ij}) \geq (V_{ik} + \varepsilon_{ik}) \right) \]

\[ = \frac{e^{\mu V_{ij}}}{e^{\mu V_{ij}} + e^{\mu V_{ik}}} \]

\[ = \frac{e^{\mu \beta' x_{ij}}}{e^{\mu \beta' x_{ij}} + e^{\mu \beta' x_{ik}}} \]
Discrete choice experiment to investigate health care preferences

- Choice between two alternatives: treatment (TR) and non-treatment (NT) for a hypothetical health condition.
Attribute levels

- Each alternative has three, four-level, alternative-specific attributes.
- Cost of “non treatment” is zero.
- Health state from treatment is full health or death.

<table>
<thead>
<tr>
<th>PTR</th>
<th>TTR Life expectancy if survive</th>
<th>PRICE Price of treatment</th>
<th>PNT Probability of survival without treatment</th>
<th>TNT Life expectancy without treatment</th>
<th>HS Health state without treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>54%</td>
<td>10 years</td>
<td>$20,000</td>
<td>39%</td>
<td>10 years</td>
<td>HS1</td>
</tr>
<tr>
<td>69%</td>
<td>20 years</td>
<td>$40,000</td>
<td>59%</td>
<td>20 years</td>
<td>HS2</td>
</tr>
<tr>
<td>84%</td>
<td>30 years</td>
<td>$60,000</td>
<td>79%</td>
<td>30 years</td>
<td>HS3</td>
</tr>
<tr>
<td>99%</td>
<td>40 years</td>
<td>$80,000</td>
<td>99%</td>
<td>40 years</td>
<td>HS4</td>
</tr>
</tbody>
</table>
Health states

- Generic health states from EQ-5D multi-attribute utility instrument
- Selected to be ordered, cover the range of health states and to “make sense”

<table>
<thead>
<tr>
<th></th>
<th>HS1</th>
<th>HS2</th>
<th>HS3</th>
<th>HS4</th>
<th>FH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Self care</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Usual Activities</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pain/Discomfort</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Anxiety/Depression</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
You have a health condition that affects your quality of life and your life expectancy. There is a treatment available for your condition and you must decide whether to have treatment or not.

<table>
<thead>
<tr>
<th>If you do have treatment</th>
<th>If you do not have treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>The out of pocket cost to you is $20,000</td>
<td>There is no out of pocket cost to you</td>
</tr>
<tr>
<td>The chances of having successful treatment or dying are:</td>
<td>The chance of surviving or dying with this condition are:</td>
</tr>
<tr>
<td>Chance of dying as a result of treatment 16%</td>
<td>Chance of dying within one month 21%</td>
</tr>
<tr>
<td>Chance of successful treatment 84%</td>
<td>Chance of surviving 79%</td>
</tr>
<tr>
<td>If treatment is successful your life expectancy is 30 years</td>
<td>If you survive your life expectancy is 20 years</td>
</tr>
<tr>
<td>Successful treatment will give you full health which means you have:</td>
<td>Your health is affected by this condition in the following ways:</td>
</tr>
<tr>
<td>No problems in walking about</td>
<td>Some problems in walking about</td>
</tr>
<tr>
<td>No problems with self care</td>
<td>No problems with self care</td>
</tr>
<tr>
<td>No problems performing usual activities</td>
<td>Some problems in performing usual activities</td>
</tr>
<tr>
<td>No pain or discomfort</td>
<td>Moderate pain or discomfort</td>
</tr>
<tr>
<td>Not anxious or depressed</td>
<td>Moderately anxious or depressed</td>
</tr>
</tbody>
</table>

Would you have treatment?  

Yes [ ] No [ ]
Survey design and data collection

- Six 4-level attributes = 4096 choice sets, 64 for each alternative
- 192 choice sets selected from the full factorial
- Blocked into 12 separate questionnaires, each with 16 choice sets
- Random sample aged 18-60 from Sydney metropolitan area
- door-to-door recruitment; self-completion questionnaires
- 347 respondents in total
Data

- Treatment was the preferred alternative in 65.1% of observations
- Two choice sets for which 100% of respondents chose treatment
- 9.6% of respondents always chose treatment
- 3.7% of respondents always chose no treatment
- Remaining respondents responsive to changing alternatives
Methods: Testing QALY model
QALY restricted specification

- Expected utility is given by the sum of the product of probability, time and QALY weight.
- In log form and imposing the QALY restrictions gives
  \[
  \ln U_j = \ln P_j + \ln T_j + \varphi_j(H_j) + \kappa(C_j) + \varepsilon_j \quad \text{where } j = \begin{cases} \text{TR} \\ \text{NT} \end{cases}
  \]
- For rank dependent expected utility $P$ is replaced by a probability weighting function $g(P)$; the simplest specification is
  \[
  \ln g(P) = \gamma \ln P
  \]
Methods: Testing QALY model
Unrestricted specification

• With the zero condition the general form is

\[ \ln U_j = \ln g(P_j) + \nu_j(H_j, T_j, C_j) + \varepsilon_j \quad \text{where } j = \begin{cases} \text{TR} \\ \text{NT} \end{cases} \]

with

\[ \nu_j(.) = \alpha_j + \beta_{jT} \ln T_j + \sum_k \beta_{jH_k} H_{jk} + \beta_{jC} C_j + \sum_k \beta_{jH_kT} H_{jk} \ln T_j + \sum_K \beta_{jH_kC} H_{jk} C_j + \beta_{jCT} C_j \ln T_j + \beta_C^2 C_j^2 \]
Notes

• Health states under non-treatment are ordered and dummy-effects-coded in the estimation.
• Loss of consumption is proxied by cost of treatment.
• Constant is zero for non-treatment.
• Cost is zero for non-treatment.
• The impact of full health with treatment is in the constant.
• Expansion is up to quadratic terms.
## Logit results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1 (unrestricted)</th>
<th>Model 2 (QALY)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef</td>
<td>P&gt;</td>
</tr>
<tr>
<td>Cons</td>
<td>-0.3292</td>
<td>0.701</td>
</tr>
<tr>
<td>LnPtr</td>
<td>1.6919</td>
<td>0.000</td>
</tr>
<tr>
<td>LnTtr</td>
<td>0.7157</td>
<td>0.000</td>
</tr>
<tr>
<td>Cost</td>
<td>-0.0104</td>
<td>0.362</td>
</tr>
<tr>
<td>LnTtr_Cost</td>
<td>-0.0018</td>
<td>0.500</td>
</tr>
<tr>
<td>Costsq</td>
<td>0.0001</td>
<td>0.310</td>
</tr>
<tr>
<td>LnPnt</td>
<td>1.4504</td>
<td>0.000</td>
</tr>
<tr>
<td>LnTnt</td>
<td>0.5933</td>
<td>0.000</td>
</tr>
<tr>
<td>HS1</td>
<td>-0.2192</td>
<td>0.537</td>
</tr>
<tr>
<td>HS2</td>
<td>0.4063</td>
<td>0.210</td>
</tr>
<tr>
<td>HS3</td>
<td>-0.4169</td>
<td>0.185</td>
</tr>
<tr>
<td>LnTnt_HS1</td>
<td>-0.2050</td>
<td>0.068</td>
</tr>
<tr>
<td>LnTnt_HS2</td>
<td>-0.1841</td>
<td>0.075</td>
</tr>
<tr>
<td>LnTnt_HS3</td>
<td>0.2573</td>
<td>0.010</td>
</tr>
<tr>
<td>LnProb</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LnTime</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-3226.699</td>
<td></td>
</tr>
</tbody>
</table>
Tests of QALY model restrictions

- Equal coefficients on common TR and NT variables
- No interaction effects
- Jointly test zero coefficients on interaction variables
- Coefficients on probability and time variables = 1
Test of equal coefficients on common TR and NT variables

(1) $\beta_{P_{tr}} = \beta_{P_{nt}}$

$\chi^2(1) = 2.36$
Prob > $\chi^2 = 0.1241$ \hspace{1cm} CANNOT REJECT

(2) $\beta_{T_{tr}} = \beta_{T_{nt}}$

$\chi^2(1) = 0.62$
Prob > $\chi^2 = 0.4300$ \hspace{1cm} CANNOT REJECT
LR test on interaction effects

$H_0$: No interaction effects

Full model \[ \text{Log L} = -3226.6992 \]
Constrained model \[ \text{Log L} = -3232.6693 \]

LR test: \[ \chi^2 = 11.9402 \]

\[ \chi^2_{\text{crit},0.05} = 11.0705 \]

REJECT
Test for zero interactions in constrained model

- Coefficients on interaction terms = 0
  - lnrttr_rcost
  - rcostsq
  - lnrtnt_hsfx1
  - lnrtnt_hsfx2
  - lnrtnt_hsfx3

- $\chi^2(5) = 10.83$
  
  Prob > $\chi^2 = 0.0549$  
  REJECT (JUST)
Test: utility function linear in probability and time

(1) $\ln(Prob) = 1$
   
   $\chi^2(1) = 39.56$
   
   $\text{Prob} > \chi^2 = 0.0000$  REJECT

(2) $\ln(Time) = 1$

   $\chi^2(1) = 46.95$

   $\text{Prob} > \chi^2 = 0.0000$  REJECT
Conclusions

- Empirical analysis of this DCE does not provide support for the QALY restrictions.
- Suggests a more general evaluation function is required for resource allocation in health.

Why the dominance of QALY model?

- Monetary measures of welfare gain seen as ethically troubling.
- B&Q: QALY model does not avoid ethical judgements.
- Explicit treatment of distribution is preferable.