

**METHODS FOR MAPPING BETWEEN THE EQ-5D-5L AND THE 3L
FOR TECHNOLOGY APPRAISAL**

REPORT BY THE DECISION SUPPORT UNIT

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EXECUTIVE SUMMARY

Background

EQ-5D comprises a descriptive system and a set of values for each health state that can be described. The descriptive system allows respondents to indicate their health state on five dimensions of health: mobility, ability to self-care, ability to undertake usual activities, pain and discomfort, and anxiety and depression. In the 3-level version (3L), respondents indicate the degree of impairment on each dimension according to three levels (no problems, some problems, extreme problems). A new, five-level version (5L) includes five levels of severity for each dimension (no problems, slight problems, moderate problems, severe problems, and extreme problems).

Previous work by the DSU has demonstrated that there are substantial differences between the way in which 3L and 5L estimate gains for health technologies in terms of Quality Adjusted Life Years (QALYs) and, in turn, their cost-effectiveness. These differences occur both in terms of the responses individuals give to the two descriptive systems and the valuation of health states. This means that consistent decisions can only be made if NICE recommends one or other of the instruments. Whichever is recommended, there will be evidence generated in 3L and 5L that forms part of NICE appraisals for many years to come.

This report describes and assesses different options for linking evidence (“mapping”) from 3L to 5L and vice versa. The ability for analysts to do this in a robust and consistent manner is required for NICE to issue guidance that is based on a coherent assessment of available evidence.

Available options

The DSU has developed and described a statistical method for mapping between 3L and 5L, in either direction. The method has been estimated using two different datasets: a EuroQoL dataset (EQG, n=3691) and a National Data Bank for Rheumatic Diseases dataset (NDB, n=5,311). The two DSU models can be used not only to estimate a utility score for one instrument (3L or 5L) from responses to the descriptive system of the other, but can also estimate a utility score for one instrument (3L or 5L) from a utility score of the other. The utility score that is being mapped from does not have to be a value that corresponds to a

particular health state in the descriptive system. It can, for example, represent the mean from a number of patient responses.

van Hout et al estimate 3L from 5L responses using a series of cross-tabulations of responses to the 3L and the 5L for each dimension of health, separately. The approach is based on the same EQG dataset as the DSU approach, but not all the data is used. Responses to the five domains making up each 3L/ 5L paired response are designated as “inconsistent” or “consistent”. “Inconsistent” domain responses are treated as missing.

For those situations where the requirement is to map from 3L to 5L, or to map from 5L utility scores to 3L, the two DSU methods are appropriate. Where the requirement is to map from 5L descriptive system data to 3L utility values, there are three options: the two DSU models and the van Hout et al approach.

Comparing mapping approaches

We compared model predictions to observed data in the two EQG and NDB datasets.

Mapping from the descriptive system of the 5L to the 3L using the EQG dataset is a within sample validation for the van Hout and DSU EQG methods. We found few differences between these two methods and that they largely performed better than the DSU NDB model, for which this is out-of-sample testing. The DSU EQG model performs slightly better than the van Hout method in predicting the responses to the 3L descriptive system. Summary measures of fit to the 3L utility scores slightly favour the van Hout method.

Mapping from the descriptive system of the 5L to the 3L using the NDB dataset showed that the DSU NDB method very closely aligned to the data. There were not large differences in terms of overall fit, either to the response probabilities or the 3L utility scores when comparing the van Hout and DSU EQG methods.

Further investigation demonstrates how standard summary measures of fit are not measuring the same concept, can be contradictory and that differences between the DSU and van Hout methods are masked by such measures. The process of adjusting data in the van Hout method

artificially reduces the error for parts of responses that conform to the defined “consistency” criteria, but at the expense of poorer fit for those that do not.

We also show how the two DSU mapping approaches that permit mapping from 3L to 5L perform exceedingly well in and out of sample.

Discussion and recommendations

For mapping from 3L to 5L, or for mapping from 5L utility values to 3L, there are two currently available options: the DSU EQG or DSU NDB methods. Both of these methods demonstrate very close in-sample fit when mapping from 3L to 5L. Furthermore, there are no significant concerns identified from out-of-sample testing, and biases often seen in mapping studies more generally are not present in the DSU approach (namely the tendency for simple methods to overestimate utility for those in relatively poor health and underestimate it for those in good health). There is little in the analyses we have performed to warrant a preference for one approach over another.

The DSU and van Hout approaches, for mapping from the 5L descriptive system to 3L, do not perform substantially differently from each other when assessed using standard measures of summary fit across the entire data. The DSU approach slightly outperforms van Hout in terms of predicting the category of response. The van Hout method is marginally better for some measures of summary fit to utility scores. However, we outline how these summary measures mask differences between the approaches in different parts of the health distribution. There are concerns about the validity of the pairwise deletion method employed by van Hout et al and how this distorts fit measures.

All of the models we have compared are limited by the available data. Both the EQG and NDB datasets have limitations for the purpose of mapping between 3L and 5L. They are unlikely to be sufficiently large. Given the potential importance of consistent, robust mapping methods, we consider it essential that a well-designed, large-scale new data collection exercise be undertaken in order to estimate a definitive mapping that can be used for decision making in the UK NHS.

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1. INTRODUCTION

The three-level version of EQ-5D (3L) is the most widely used preference based measure used in economic evaluations across NICE's guideline programmes. It is explicitly recommended for reference case analyses in the Guide to the Methods of Technology Appraisal (Section 5.3)¹.

EQ-5D comprises a descriptive system that allows respondents to indicate their health state on five dimensions of health: mobility, ability to self-care, ability to undertake usual activities, pain and discomfort, and anxiety and depression. In the 3L version, respondents indicate the degree of impairment on each dimension according to three levels (no problems, some problems, extreme problems).

A new, five-level version of the instrument has been developed. EQ-5D-5L (5L from this point) includes five levels of severity for each dimension (no problems, slight problems, moderate problems, severe problems, and extreme problems). The 5L was produced with the intention of improving the instrument's sensitivity and reducing ceiling effects². The current NICE Methods Guide was written at a time when the descriptive system of the 5L instrument was available but no separate valuation had reported. The guide states:

“The EQ-5D-5L may be used for reference-case analyses. The descriptive system for the EQ-5D-5L has been validated, but no valuation set to derive utilities currently exists. Until an acceptable valuation set for the EQ-5D-5L is available, the validated mapping function to derive utility values for the EQ-5D-5L from the existing EQ-5D (-3L) may be used”(5.3.12)

Increasingly, the 5L instrument is being applied in clinical studies and, whilst an English valuation set for the 5L³ now exists, this should still be considered interim whilst the work is under submission to a peer reviewed journal for publication. Furthermore, previous work by the DSU has demonstrated that there are substantial differences between the 3L and 5L⁴. These differences occur both in terms of the responses individuals give to the two descriptive systems and the valuation of health states. In combination, these lead to very substantial differences in estimated gains for health technologies in terms of Quality Adjusted life years (QALYs) and, in turn, their cost-effectiveness. This suggests that the option of using both 5L and 3L in NICE appraisals, as if they were interchangeable, may not be an appropriate position.

However, whatever the position eventually adopted by the Institute, evidence will inevitably be submitted in the future in support of technologies based on both forms of the EQ-5D. Current clinical studies in development include either 3L or 5L (or neither). Existing evidence of valuations for relevant health states exists in terms of 3L and will only be replaced by 5L values in a piecemeal manner, as the evidence base develops over a very long period. The use of evidence in Health Technology Assessment also needs to distinguish between those situations where there is access to full patient level data in terms of the descriptive system of the 3L or 5L instrument (as, for example, in evaluations conducted as part of a clinical trial), and those situations where there is simply a utility value for a given health state (typically the mean). There are, of course, many examples where the full evidence base is comprised of both types of evidence. This distinction is important because there are different options currently available for linking 3L and 5L depending on the available data. Table 1 below shows these options.

Table 1: Options for linking 3L and 5L

		TO	
		3L	5L
FROM	3L		
	Descriptive system	NA	DSU NDB / DSU EQG
	Utility score	NA	DSU NDB / DSU EQG
	5L		
	Descriptive system	Van Hout / DSU NDB / DSU EQG	NA
	Utility score	DSU NDB / DSU EQG	NA

Notes: NA – Not applicable, van Hout et al⁵ is the EuroQoL Group mapping, DSU NDB – Decision Support Unit mapping based on National Data Bank for Rheumatic Diseases, DSU EQG – Decision Support Unit mapping based on EuroQoL Group data.

A previous DSU report demonstrated a method for mapping between 3L and 5L, in either direction⁴. This method was originally developed and described fully by Hernandez and Pudney⁶ using a single dataset from the National Data Bank for Rheumatic Diseases (NDB). This method is currently in press at the Journal of Health Economics, a peer reviewed journal. In addition, the DSU commissioned two independent referees to review the Hernandez and Pudney method. One referee also examined the statistical code that underlies the modelling and results presented in this report. The general approach was subsequently replicated in Wailoo et al⁴ and extended to a EuroQol Group dataset (EQG). Thus, there are 2 DSU models: one based on the NDB data and one based on the EuroQol data (the latter dataset was also used

by van Hout et al.). The two DSU models can be used not only to estimate a utility score for one instrument (3L or 5L) from responses to the descriptive system of the other, but can also estimate a utility score for one instrument (3L or 5L) from a utility score of the other. The utility score that is being mapped from does not have to be a value that corresponds to a particular health state in the descriptive system. It can, for example, represent the mean from a number of patient responses. Table 1 therefore shows that both versions of the DSU mapping models can be used to map either from 3L to 5L, or vice versa, and from either responses to the descriptive system of either instrument, or from a utility score.

One alternative approach exists for mapping from responses to the descriptive system of the 5L to the valuations for the 3L. This is the approach reported in van Hout et al⁵, which was coordinated by the EuroQoL Group and was intended to serve as an interim solution to enable the use of the 5L descriptive system whilst work was ongoing to produce a 5L value set.

The purpose of this report is to:

1. Provide evidence of the performance of the DSU models in estimating the mean of the distribution of 5L utility scores from the 3L.
2. Provide evidence of the performance of the DSU models in estimating the mean of the distribution of 3L utility scores from the 5L.
3. Examine the performance of the van Hout mapping approach in estimating 3L utility scores from the 5L.

In undertaking this work we have updated and amended a Stata command, *eq5dmap*. A full accompanying paper for the command is under submission with “The Stata Journal” and the program will be available directly within Stata software if accepted. In the meantime, the command and accompanying user notes are provided on the DSU website. We first describe in more detail the samples used for the three different mapping approaches and the modelling methods used. We then demonstrate how each method performs both in-sample and out-of-sample.

2. DATA AND METHODS

2.1. DATA

Two datasets are available where respondents have completed both the 3L and the 5L instruments.

2.1.1. *EuroQoL Group coordinated study (EQG)*

The data source for both van Hout et al and the DSU EQG mapping is identical, though how those data are then used differs substantially. Between August 2009 and September 2010, the EuroQoL Group coordinated and partly funded a data collection study. Its main aim was to collect data on both versions of EQ-5D, the 3L and 5L, to compare them in terms of their measurement properties and to generate an interim value set for 5L using a mapping (or cross-walk) approach. The questionnaire introduced the 5 level version of EQ-5D first, followed by a few background questions (age, gender, education, etc), then the 3 level version of EQ-5D, the EQ-5D visual analogue scale, a set of five dimension specific rating scales and finally the WHO (five) Well-Being index. The study was carried out in 6 countries: Denmark, England, Italy, the Netherlands, Poland and Scotland and included eight broad patient groups (cardiovascular disease, respiratory disease, depression, diabetes, liver disease, personality disorders, arthritis, and stroke) and a student cohort (healthy population). Each country used the official EQ-5D language versions and data was mainly collected through specialist hospitals/centres and patient recruitment agencies. All countries used paper and pencil questionnaires, apart from England, which used an online version. In all countries, except Italy, a screening protocol was used to ensure a wide range of severity across all the 5L and 3L dimensions.

Limited, published information on the data collection can be found in Janssen et al (2013)⁷ and van Hout et al (2012)⁵.

2.1.2. *The NDB dataset*

The NDB is a register of patients with rheumatoid disease, primarily recruited by referral from US and Canadian rheumatologists. Information supplied by participants is validated by direct reference to records held by hospitals and physicians (a minority of cases come by self-referral, with medical details obtained by NDB in the same way). Full details of the recruitment process are given by Wolfe and Michaud (2011)⁸. The EQ-5D responses and other patient-supplied data are collected by various means, primarily postal and web-based questionnaires completed

directly by patients. Data collection began in 1998, and continues to the present, in waves administered in January and July of each year. In 2011, there was a switch from 3-level to the 5-level version of EQ-5D and both versions were collected during the January 2011 wave. The NDB questionnaire is 27 pages long and it includes many general as well as rheumatoid disease specific questions. EQ-5D-5L and EQ-5D-3L are on pages 11 and 22 of the questionnaire respectively.

2.2. METHODS

2.2.1. The DSU approach

The DSU response mapping model is fully described by Hernandez Alava and Pudney⁶. It has been estimated using both the EQG and NDB data. The approach involves a joint statistical model of the responses to the five questionnaire items for EQ-5D-3L and the five items for EQ-5D-5L; so it is based on a 10-equation econometric model¹. That model is specified to provide a very flexible treatment of the 3L/5L pair of responses within each health domain, allowing the responses to be strongly correlated, but the strength of their dependence to vary if necessary, with the severity of illness. The nature of the relationship between 3L and 5L responses is also allowed to be quite different in each health domain, and the model allows for background correlation between the responses in the five health domains. The 3L and 5L responses may be influenced by age and gender in different ways.

The analyses were undertaken using all data, in both datasets, separately. Observations did not enter into the analyses if they did not have complete 3L or 5L responses, or if there were missing data on age or gender.

The predictions from the model can be calculated simply via a Stata function. This allows a user to translate 3L or 5L response data or utility data simply and instantly to either 3L or 5L utility estimates. The command converts an entire set of patient responses in one batch and therefore adds little complexity or time to any analysis, including those that include large amounts of patient level data.

¹ In technical terms, it is a multi-equation linear ordinal response model, with each pair of residuals having a distribution with normal mixture marginals and bivariate copula of Gaussian, Frank, Clayton, Gumbel or Joe form, chosen on goodness-of-fit grounds. The five pairs of equations are linked by a random factor with a normal mixture distribution.

2.2.2. *The van Hout et al approach*

The approach described in van Hout et al is based on a series of cross-tabulations of responses to the 3L and the 5L for each dimension of health, separately. Unlike the DSU approach, these calculations are not made conditional on age, gender or any other covariates.

Table 2: Crosstab of feasible responses to 3L and 5L, within each health dimension

		3L		
		1	2	3
5L	1	P ₁	P ₂	P ₃
	2			
	3			
	4			
	5			

The probability of a 3L response at level 1, 2 or 3, for any dimension, conditional on an observed 5L response, can be calculated from the observed proportions of responses in the data. By calculating these proportions for all 5 dimensions of health, and assuming independence between the 5 dimensions, the probability of each of the 243 states described by the 3L instrument can be calculated, conditional on the 5L state observed. And by attaching the relevant tariff scores to the 3L health states (in this case, the UK tariff), the expected tariff score for each 5L health state can be calculated.

van Hout et al do not use the observed data to calculate these probabilities. They define a response as “inconsistent” if it does not meet the following criteria, and it is then excluded from the analysis.

- If the 5L response is level 1 (“no problems”) for that health dimension, then 3L is assigned as being at level 1 (“no problems”).
- If the 5L response is level 3 (“moderate problems”), then 3L is assigned to level 2 (“moderate problems”).
- If the 5L response is level 5 (“extreme problems”), then 3L is assigned to level 3 (“extreme problems”).
- If the 5L response is level 2 (“slight problems”), only responses to 3L at levels 1 or 2 of the 3L are included. Any responses of level 3 on the 3L are dropped (not the whole observation, only the part of the observation for that specific health dimension).
- If the 5L response is level 4 (“severe problems”), only responses to 3L at levels 2 and 3 are included. Any responses of level 1 on the 3L are dropped.

Note that it is not the whole response of an individual that is defined as inconsistent and dropped, but only the response item for the specific health dimension concerned. This is therefore a type of data manipulation because it drops parts of the data from observations to

artificially create the relationships described above. This is known as “pairwise deletion” rather than “listwise deletion” and is often regarded as a potentially dangerous practice. Whilst a respondent may provide a response that is considered “incorrect”, it is only part of the response that is removed. This assumes that the respondent or response remains reliable and one can safely remove just part of a response.

Table 3 shows the numbers of consistencies made by the EQG sample. In total, 427/3691 (11.6%) respondents provided a response pair that was inconsistent in at least one domain. We can see that 7 respondents provided a response deemed inconsistent for 4 of the 5 domains, yet the pairwise deletion approach would retain the part of their response for the 5th domain. Therefore, the probabilities for each dimension are calculated using different subsamples of the EQG data: there is no common sample.

Table 3: Number of inconsistencies in the EQG dataset

Number of inconsistencies (individuals)	n	%
0	3264	88.43
1	363	9.83
2	40	1.08
3	17	0.46
4	7	0.19

The table below highlights the impact of this process in relation to which probabilities are informed by data, and which by assumption.

Table 4: Crosstab of 3L 5L within dimension responses showing those informed by real data in van Hout et al

		3L		
		1	2	3
5L	1	1	0	0
	2			0
	3	0	1	0
	4	0		
	5	0	0	1

Only the probabilities in the shaded red cells are based on data in the van Hout mapping. All other probabilities are either 1 or 0, as indicated, by assumption.

Of the potential 759,375 pairs of 5L/3L responses, the van Hout et al mapping assigns a probability of zero to 97.8% of them. This is in part due to the analytical approach but, of course, some combination pairs may not occur in the data.

Table 5 shows the percentages of responses that were considered inconsistent, according to the van Hout et al method. The greatest proportions of inconsistent responses tended to happen amongst those respondents that indicated level 5 on the 5L instrument, but level 1 or 2 for the 3L. Relatively high proportions were observed for all domains, with the highest (19%) being for the mobility domain.

Table 5: Responses considered inconsistent in the van Hout et al mapping

	"Inconsistent" responses				
5L response	1	2	3	4	5
3L response	2,3	3	1,3	1	1,2
Mobility	1.66%	0.15%	3.30%	0.24%	19.42%
n (responses at this 5L level)	1812	672	606	417	139
Self-care	1.83%	1.01%	5.72%	3.36%	4.11%
	2514	495	332	149	146
Usual	3.29%	0.84%	6.15%	2.16%	5.91%
	1429	831	699	417	254
Pain/discomfort	5.54%	0.38%	4.56%	1.49%	10.87%
	1192	1065	877	404	92
Anxiety/depression	3.29%	0.28%	6.36%	3.01%	8.82%
	1398	1063	739	332	102

2.3. COMPARISONS OF MAPPING APPROACHES

As highlighted in Table 1 above, there is likely to be a need to map between 3L and 5L in the future. Where the requirement is to map from 3L to 5L health states, there are currently two available options (the DSU approach using EQG data or the DSU approach using NDB data). These two options also exist if the requirement is to map between 5L and 3L health utility values. Where the need is to map from 5L to 3L health states, the van Hout et al approach provides a third option. All DSU models include age and gender as covariates whereas the van Hout et al method does not.

We first compare the performance of these three approaches using a variety of standard fit statistics to the EQG and NDB datasets. First, we consider fit to the descriptive system. Plots showing the probability of responding at level 1, 2 or 3 on the 3L, for each of the 5-dimensions

are shown for the observed and predicted data. We then illustrate fit in relation to health utilities. These include measures of Mean Error (ME) Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), plots of mean observed versus mean predicted values and cumulative distributions plots. See Box 1 for a description of these measures. A similar approach is used to then demonstrate the performance of the DSU models in estimating 5L from 3L.

Box 1: Summary measures of fit

$$\text{Mean error} = \frac{\sum_{i=1}^n y_i - \hat{y}_i}{n}$$

$$\text{Mean absolute error} = \frac{\sum_{i=1}^n |y_i - \hat{y}_i|}{n}$$

$$\text{Root mean squared error} = \sqrt{\frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{n}}$$

Where y_i is the observed value and \hat{y}_i the prediction. Mean error is the average distance between observed and predicted values. Overprediction and underprediction will cancel out. Mean absolute error is the average of the absolute errors. All are measured on the same scale as the variable being measured. RMSE gives a greater weight to large errors than MAE.

3. COMPARISON RESULTS

3.1. 5L TO 3L: EQG DATASET

The full EQG dataset (n=3691) was used. Excluding any missing values for 3L or 5L, age or gender and observations for respondents aged under 16 years left a sample of 3539. Therefore, this is largely “within sample” for both the van Hout and DSU approaches that are estimated from the EQG data. The difference between the estimation data and this validation data for the van Hout et al approach is due to data that are dropped or amended in the estimation. The DSU EQG estimation sample differs very slightly because respondents aged below 16 were included in the estimation.

We first consider responses to the discrete response data. We compare the probabilities of responding at level 1, 2 and 3 for each of the 5- dimensions between the model predictions and the observed data. Figure 1 displays these differences. It shows that there are not substantial differences between models in terms of the absolute probabilities. The van Hout et al and DSU EQG models yield probabilities closer to the data than the DSU NDB model, for which this data is “out-of-sample”. For the two within sample models, we find that the DSU EQG model performs marginally better than the van Hout et al model for all dimensions and levels, except the anxiety/depression dimension.

Figure 1: Difference between observed (EQG data) and predicted probabilities for mapping models.



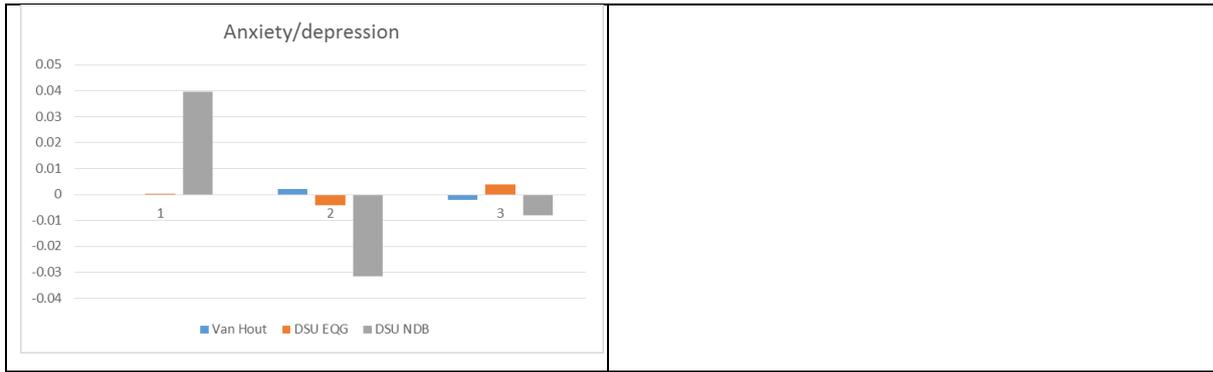


Table 6: Overall fit in the EQG dataset

	ME	MAE	RMSE
van Hout	0.000	0.089	0.143
DSU EQG	0.005	0.096	0.145
DSU NDB	-0.008	0.104	0.152

Overall fit to the utility data was very similar between the different methods. The van Hout et al approach had slightly better overall fit within the EQG sample (Table 6). The fit between the van Hout and DSU EQG data was very similar; both overall and when examined for age/gender subgroups (see Table 7). The DSU NDB method tended to have slightly worse fit, which is unsurprising since this is entirely out of sample.

We considered how the three models fit across the range of ill health measured by EQ-5D utility (Figure 2 and Figure 3). These plots further demonstrate only slight differences between model results. There are no perceptible differences between the van Hout et al and DSU EQG approaches. Where the plots seem to indicate poorer fit for both models around utility of zero (see Figure 2), it should be noted the lack of data in this range leads to wide confidence intervals around the estimates. It should also be noted that the out-of-sample fit for the DSU NDB model also demonstrates very close fit to the data.

Figure 3 shows that the predictive distribution function using the van Hout et al model is marginally better than the two other models in the 3L range 0.2 to 0.5, but conversely the predictive distribution function for the DSU EQG approach is superior between 0.5 and 0.7. The out of sample DSU NDB model demonstrates improved fit over the other methods in some areas, for example for utility values above 0.75.

Table 7: Ranking of model fit compared with the EQG data by Mean Error, Mean Absolute Error and Root Mean Squared Error

Patient group	N	%	ME			MAE			RMSE		
			van Hout	DSU EQG	DSU NDB	van Hout	DSU EQG	DSU NDB	van Hout	DSU EQG	DSU NDB
female <=25	495	13.99	2	1	3	1	2	3	1	2	3
female (25-35]	176	4.97	1	2	3	1	2	3	1	2	3
female (35-45]	159	4.49	1	2	3	1	2	3	1	2	3
female (45-55]	222	6.27	2	3	1	1	2	3	1	2	3
female (55-65]	326	9.21	2	3	1	1	2	3	1	2	3
female (65-75]	259	7.32	2	1	3	1	2	3	2	1	3
female >75	236	6.67	2	1	3	1	2	3	1	2	3
male <=25	166	4.69	3	2	1	1	2	3	1=	1=	3
male (25-35]	117	3.31	3	2	1	1	2	3	1	2	3
male (35-45]	182	5.14	1	2	3	1	2	3	1	2	3
male (45-55]	302	8.53	3	2	1	1	2	3	1	2	3
male (55-65]	429	12.12	1	3	2	1	2	3	2	1	3
male (65-75]	296	8.36	1	3	2	1	2	3	1	2	3
male >75	174	4.92	1	2	3	1	2	3	2	1	3
Total	3,539	100									

Figure 2: Mapping from EQ-5D-5L to EQ-5D-3L, observed versus predicted values in the EQG dataset, by EQ-5D-5L group.

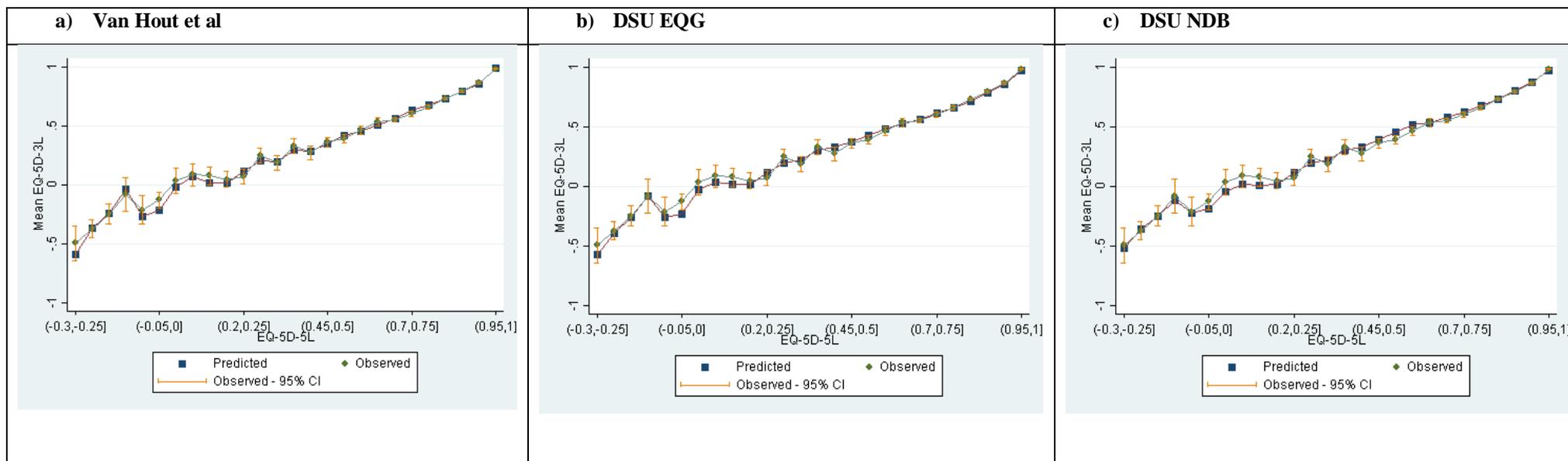
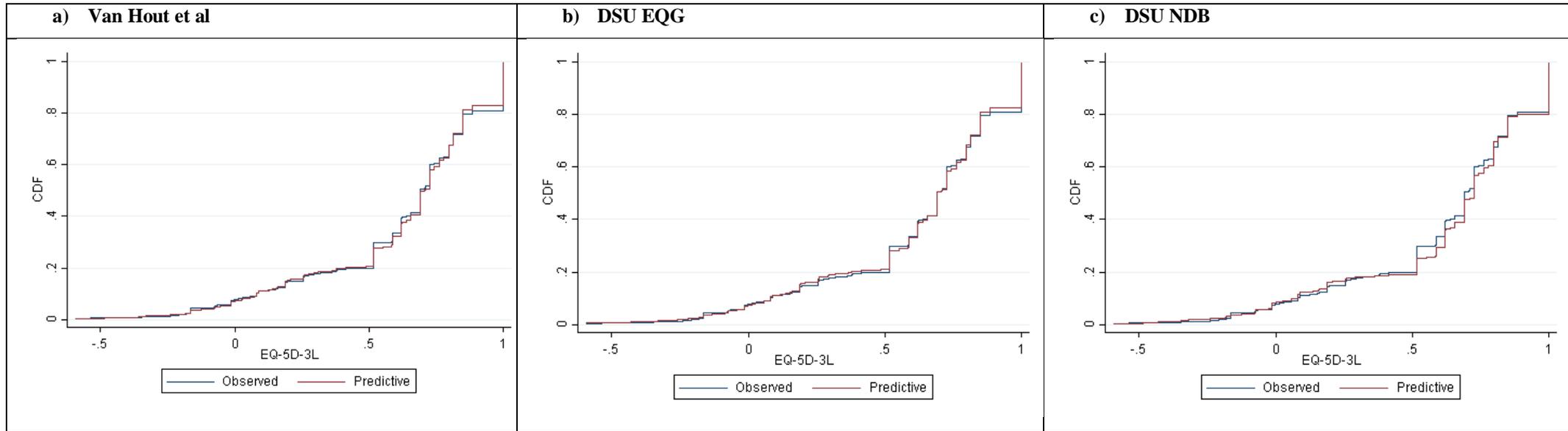


Figure 3: Observed versus predictive cumulative distribution function – EQG dataset, mapping from 5L to 3L



3.2. 5L TO 3L: NDB DATASET

It is worth noting there are clear differences between the EQG and NDB datasets. For example, there were 11.6% of individuals that provided at least one “inconsistent” response (as defined by Van Hout et al) in the EQG dataset. In the NDB dataset this percentage rises to 17.8%. There is more separation between the 3L and 5L questions in the NDB than the EQG studies. It may be that the higher proportion of “inconsistent” responses is due to the fact that respondents are completing the questions with less recall of their previous responses, and therefore the NDB is more appropriate for mapping. Other explanations are possible though. For example, this could be a result of respondent fatigue.

Table 8: Difference between observed (NDB data) and predicted probabilities for mapping models.

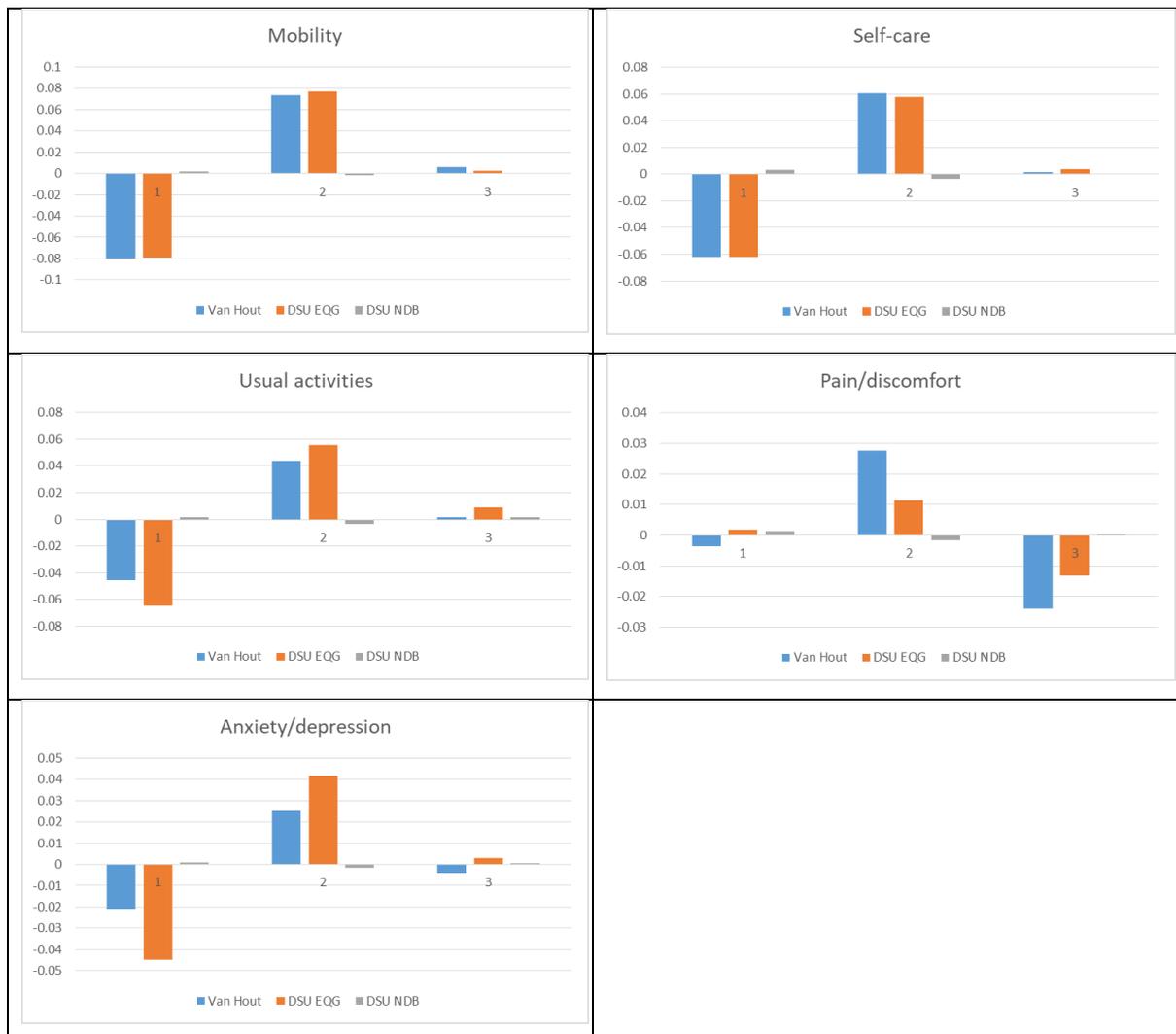


Table 8 shows the differences between the probabilities of being in each of the three response categories and the observed data in the NDB, for the five health domains. It shows that the DSU NDB model closely aligns to the observed data. Comparing the DSU EQG and van Hout approaches, both of which were estimated using the EQG data, shows that the DSU approach fits more closely for all response levels within the pain/discomfort domain. The van Hout method fits more closely for all levels in the usual activities domain. Other domains are mixed or very similar between the two approaches.

Table 9: Overall summary fit in the NDB dataset

	ME	MAE	RMSE
van Hout	0.009	0.094	0.149
DSU EQG	0.020	0.100	0.148
DSU NDB	0.001	0.100	0.147

As with the EQG dataset, there are not large differences between any of the three measures when considering summary fit statistics (Table 9). The DSU NDB method, for which these figures represent a form of in-sample validation, has the best fit measured by ME and RMSE, but the van Hout et al approach has a lower MAE.

A similar pattern is seen when considering the same measures by age and gender subgroups, reported in Table 10. The DSU NDB method tends to perform better on measures of ME and RMSE whilst the van Hout et al method does better on the MAE measures. It should again be reiterated that these differences between the models are typically very small.

Figure 4 and Figure 5 show the closeness of fit for the DSU NDB model. In particular the cumulative distribution plot shows very close in-sample fit.

Table 10: Ranking of fit compared to the NDB data by Mean Error, Mean Absolute Error and Root Mean Squared Error

Patient group	N	Percent	ME			MAE			RMSE		
			van Hout	DSU EQG	DSU NDB	van Hout	DSU EQG	DSU NDB	van Hout	DSU EQG	DSU NDB
female <=25	25	0.48	2	1	3	1	2	3	1	2	3
female (25-35]	111	2.13	2	3	1	1	2	3	3	1	2
female (35-45]	252	4.84	1	3	2	1	2	3	1	2	3
female (45-55]	708	13.6	2	3	1	1	3	2	3	2	1
female (55-65]	1,300	24.98	2	3	1	1	3	2	3	2	1
female (65-75]	1,186	22.79	2	3	1	1	2	3	3	1	2
female >75	628	12.07	2	3	1	1	2	3	1	3	2
male <=25	1	0.02									
male (25-35]	5	0.1									
male (35-45]	19	0.37									
male (45-55]	123	2.36	3	1	2	1	2	3	2	1	3
male (55-65]	303	5.82	2	3	1	1	3	2	2	3	1
male (65-75]	335	6.44	1	3	2	1	2	3	2	3	1
male >75	209	4.02	2	3	1	1	2	3	3	2	1
Total	5,205	100									

Figure 4: Mean EQ-5D-3L by mean EQ-5D-5L, observed versus predicted values in the NDB dataset.

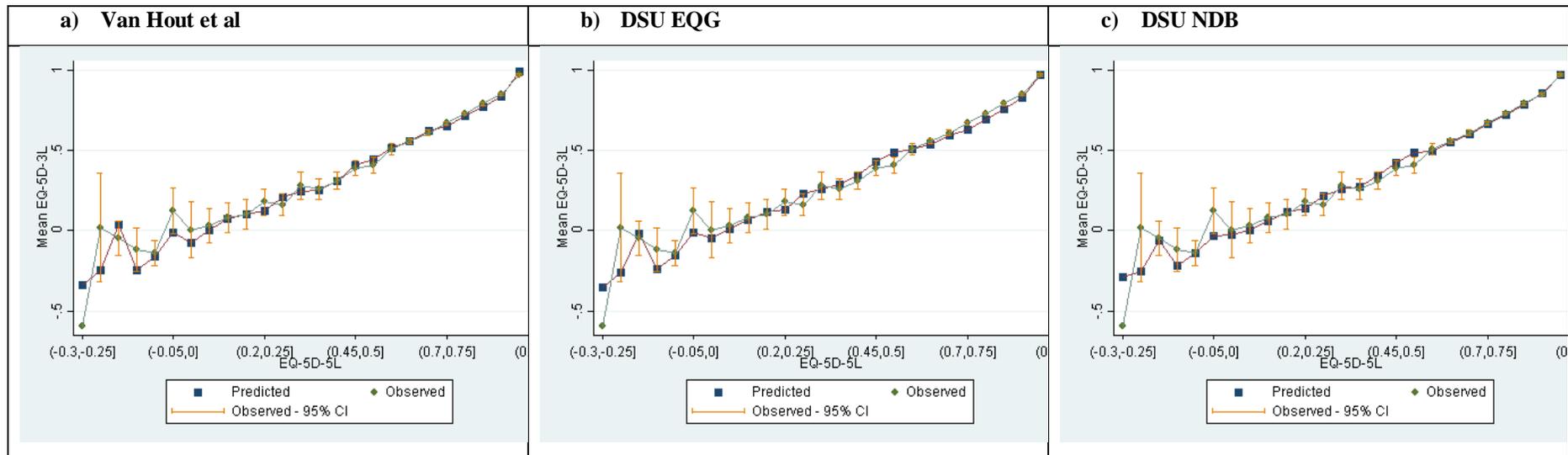
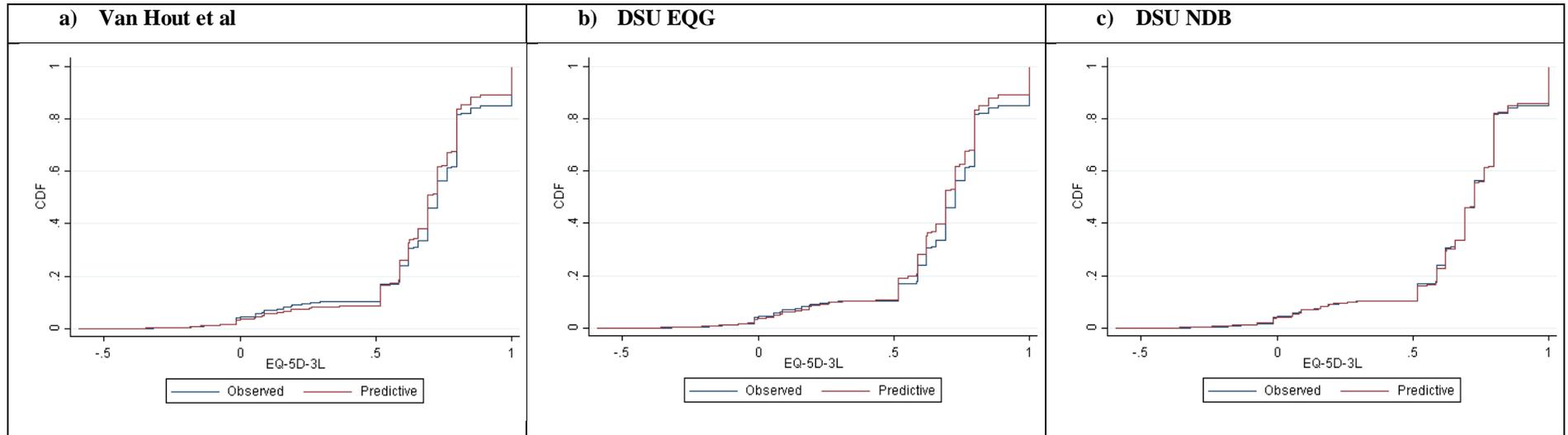


Figure 5: Observed versus predictive cumulative distribution function – NDB dataset



3.3. ADDITIONAL COMPARISONS OF 5L TO 3L.

To further understand the drivers of the results, we calculated three new versions of the crosswalk. First, we replicated the same methods as the van Hout et al “crosswalk” but used the NDB dataset. Second, we created an amended version of the van Hout et al method but instead of amending all the “inconsistent” responses, we use the original data (we refer to this as the “unconstrained” method). We did this in both the EQG datasetⁱⁱ and the NDB dataset. In total, this creates 6 different methods for mapping between 5L descriptive system data and 3L:

- 1) DSU copula model (estimated using EQG data)
- 2) DSU copula model (estimated using NDB data)
- 3) Crosswalk (EQG, unconstrained)
- 4) Crosswalk (EQG, constrained) – this is the van Hout et al method.
- 5) Crosswalk (NDB, unconstrained)
- 6) Crosswalk (NDB, constrained)

We calculated MAE and RMSE for all 6 methods, applied to both datasets. The rank correlation coefficient between MAE and RMSE was 0.14, indicating very low correlation between these two measures. This shows that MAE and RMSE are measuring different things. They cannot be seen as measures of a single concept of “model fit”: there is no such single concept.

We concentrate on the case which is more likely to replicate how the models will be used in practice. We use the models estimated using the EQG as the reference dataset and compare the out-of-sample predictions on the NDB dataset, which can be thought of as having parallels with the use of mapping in a clinical study. The following rankings were observed (where \succ denotes the preferred model).

MAE: (4) \succ (3) \succ (1)

RMSE (1) \succ (3) \succ (4)

Thus, MAE and RMSE rank the models in the complete reverse order. RMSE penalises large errors more heavily and favours the DSU copula model whereas MAE favours the constrained crosswalk.

ⁱⁱ To abstract from differences arising from the small differences in samples between the models estimated using the EQG dataset due to missingness EQ-5D-3L and -5L individual dimensions, age and gender, we estimated all the models in the same sample as the DSU copula model (3,551). There are no significant differences in the transition probabilities between the original crosswalk model and the one estimated in the common sample.

We investigated the reasons why the performance of the van Hout et al model is very good in terms of MAE, but less good in terms of RMSE. We identified a further issue when using measures of fit based on errors in models where the underlying data has been amended as has been done in the van Hout analysis. Probabilities equal to 1 (or 0) refer to a situation where something is known with complete certainty. In such situations, there is no need for statistical modelling. Setting a number of probabilities equal to 1 in the van Hout et al analysis implies that any EQ-5D-5L health state description including any combination of levels equal to 1, 3 or 5 and identified as consistent will automatically have a zero error associated with it. These zero errors artificially drive down measures of fit like MAE and RMSE. The effect of this is greater the larger the proportion of these health states in the dataset.

In contrast, all statistical models which use sample probabilities will tend to look worse in comparison unless the improvements in the errors for the rest of the observations are sufficiently large to outweigh the inevitable increase in the error for the “consistent” observations with health state descriptions combining the levels 1, 3, and 5.

To illustrate this further, consider respondents who give a 5L health state of 11111 ($n=537$ in the EQG dataset). 500 (93.1%) of these in the EQG dataset also respond that they are in 11111 for the 3L health state. Using the van Hout et al approach, these individuals will have a zero error associated with their response pairs. And the remaining 6.9% will have some error associated with them. This large proportion of observations with zero errors will tend to drive the MAE down but this will also cause the RMSE to rise, if imposing these restrictions negatively affects the fit for other observations.

In contrast, any model based approach will try to replicate the full data. Thus, the 93.1% of respondents will all have a small error associated with their observation pairs (it is not the case that respondents at level 1 for the 5L will indicate with total certainty they are at level 1 for the 3L, as reported in Table 5). It is this which drives the performance of the approaches in terms of summary fit and the apparent contradictory findings when using MAE compared to RMSE.

There are 716 respondents in the EQG dataset that answer either 1, 3 or 5 on the 5L for each dimension and provide 3L responses that van Hout et al define as “consistent” (that is, they answer 1 if $5L = 1$, 2 if $5L = 3$ and 3 if $5L = 5$). MAE for these respondents using the van Hout

method is 0. The DSU EQG model has a MAE of 0.028. The DSU NDB model has a MAE of 0.036. RMSE for the van Hout, DSU EQG and DSU NDB are 0, 0.037 and 0.050 respectively.

There are 84 respondents that answer either 1, 3 or 5 on the 5L for each dimension and provide “inconsistent” responses for at least one dimension. MAE is 0.201, 0.175 and 0.168 for the van Hout, DSU EQG and DSU NDB models respectively. RMSE is 0.260, 0.232, and 0.222 for the same models. The ordering of the models is totally reversed compared to the fit of the models in the “consistent” data.

There are 48 respondents that provide 5L responses at levels 2 or 4 for every dimension. MAE for the same three models is 0.194, 0.184 and 0.178 respectively. RMSE is 0.260, 0.232 and 0.222 respectively.

This highlights that comparisons of summary measures of fit across the entire range of health for mapping approaches mask differences between the methods. In particular, there are differences in the methods between health states that are predominantly answered in a manner that is defined as “consistent” in the van Hout approach, versus those that have a greater number of “inconsistent” responses.

3.4. 3L TO 5L

The two DSU copula based models are capable of estimating 5L utilities from 3L responses. We present summaries of how the two models perform below. In the previous sections, there was a common out of sample comparison that could be made between the van Hout et al approach and the DSU EQG model. There is no common out-of-sample comparison that can be made here as there are only two datasets.

Figure 6 and Figure 7 show the in-sample plots for the EQG and NDB copula based models. For both models, there is very close alignment between observed and fitted data. There appears to be a poorer fit, in both cases, around 0.4–0.5 on the 3L scale. However, the large error bars indicate the paucity of data at these points. In the NDB, there is no error bar because there is a single observation at this point.

Figure 6: DSU EQG in-sample

a) Mean 5L utility by mean 3L	b) Cumulative distribution
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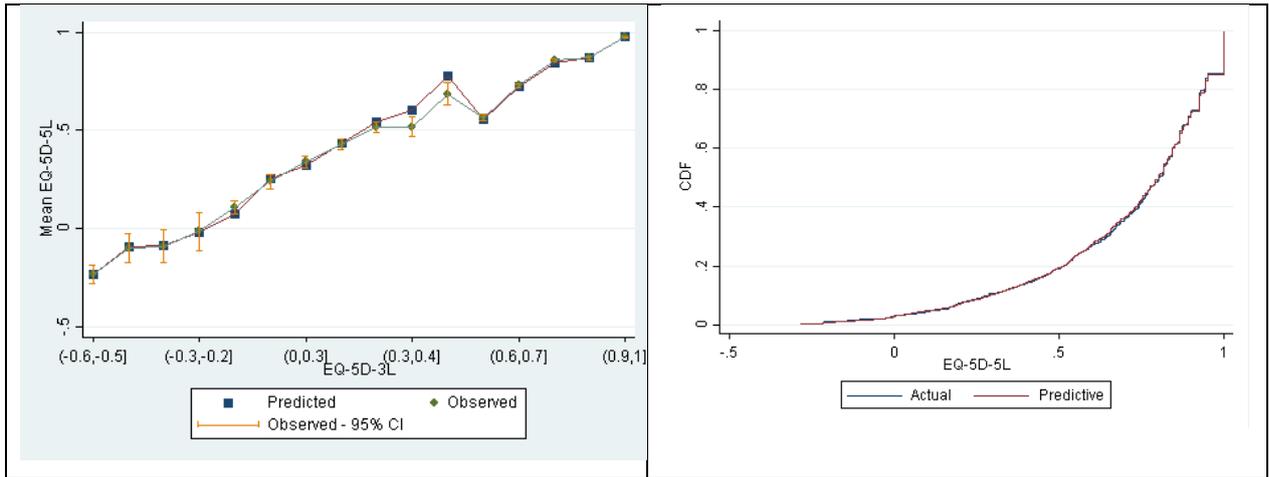
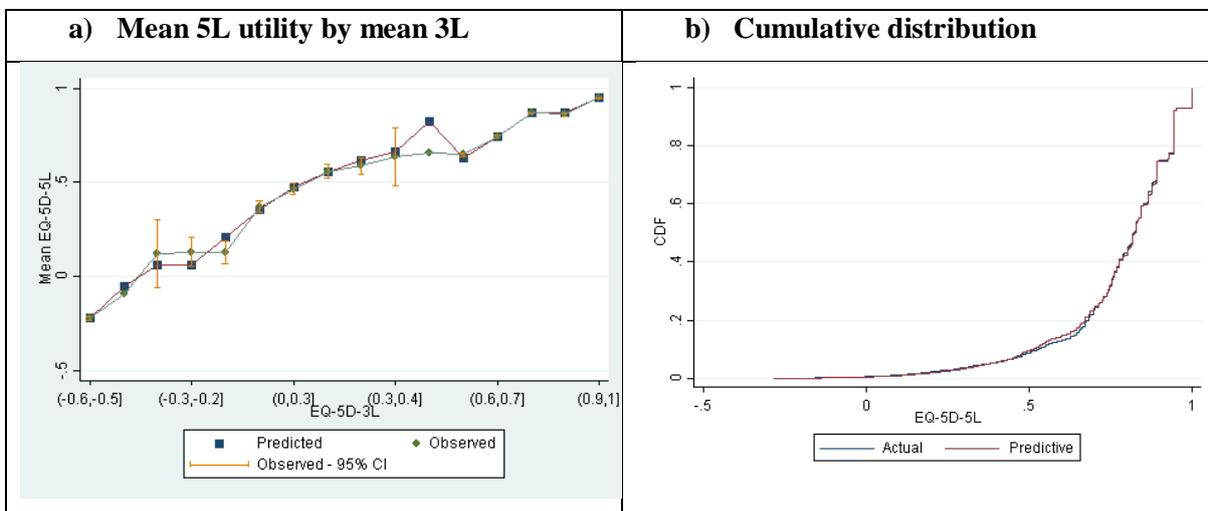
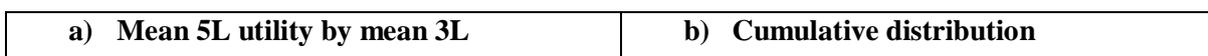


Figure 7: DSU NDB in-sample



Out-of-sample fit is demonstrated, for both models, in Figure 8 and Figure 9. These plots again demonstrate good performance of both approaches, though as for any out-of-sample examination, fit is not as good as in-sample. For the DSU EQG approach, there is some evidence that mean predicted values are lower than mean observed values (in the NDB dataset) for 3L scores around zero. For the DSU NDB approach, predicted 5L values based on the EQG model are slightly higher than the observed means around 3L values of -0.1 and 0.2-0.3.

Figure 8: DSU EQG out-of-sample



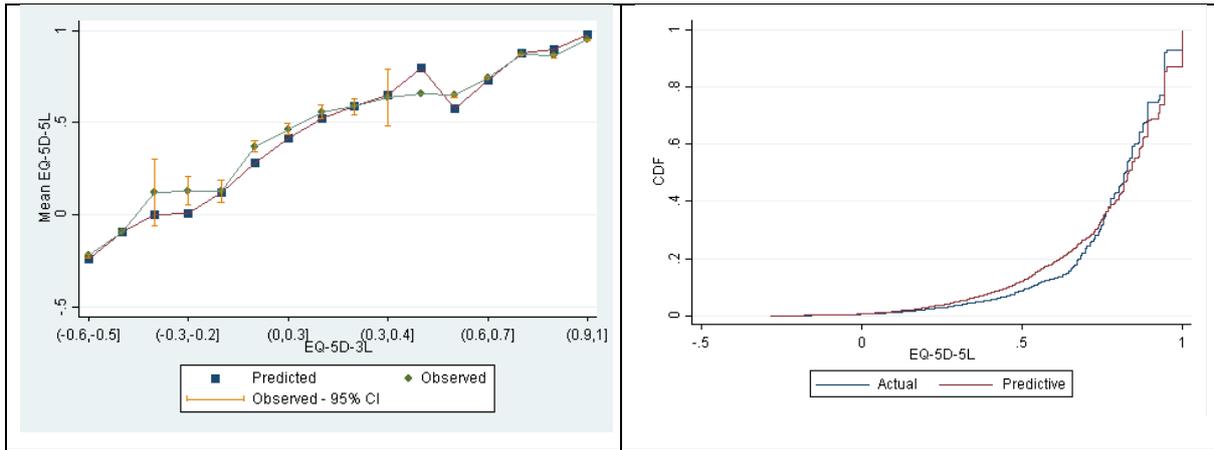
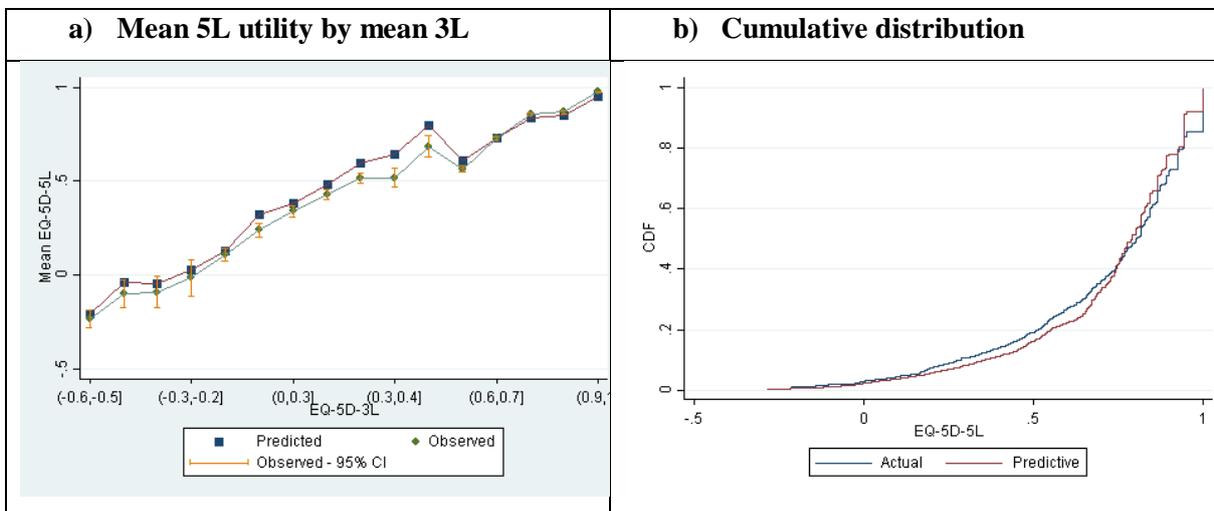


Figure 9: DSU NDB out-of-sample



4. DISCUSSION AND RECOMMENDATIONS

For mapping from 3L to 5L, or for mapping from 5L utility values to 3L, there are two currently available options: the DSU EQG or DSU NDB methods. Both of these methods demonstrate very close in-sample fit when mapping from 3L to 5L. Furthermore, there are no significant concerns identified from out-of-sample testing, and biases often seen in mapping studies more generally are not present in the DSU approach (namely the tendency for simple methods to overestimate utility for those in relatively poor health and underestimate it for those in good health). There is little in the analyses we have performed to warrant a preference for one approach over another. There are differences between the EQG and NDB datasets concerning issues of study design (e.g. the degree of separation of questions, the mode of administration, the language in which the questionnaires were conducted, and the sampling methods). These differences mean that there is not an unambiguously preferred dataset for mapping. However, the nature of the sampling frameworks, in particular the inclusion of patients with a variety of medical conditions in the EQG data, may make this a preferable selection for use in NICE appraisals at the current time.

We have also demonstrated that there is no single method to assess goodness of fit and different measures favour different mapping approaches. When considering the relationship between the discrete, descriptive system data and the different models, there are small differences observed. In general, the DSU models perform slightly better than the van Hout et al approach. We have shown how commonly used measures of fit for continuous data, MAE and RMSE, give very different answers but are marginally better in general for the Van Hout method. RMSE places a greater penalty on larger errors. More importantly, the method of adjusting data that is deemed to be “inconsistent” in the van Hout et al approach, artificially drives down these measures of fit overall and makes comparisons with methods that use the real data questionable. Observations are adjusted in that some parts of an observation are retained and other parts ignored. There are real differences between the mapping methods and how they fit parts of the data, even though summary measures of fit across the spectrum of ill health may only be marginally different.

All of the models we have compared are limited by the available data. We have concerns about the appropriateness of both datasets for the purpose of mapping between 3L and 5L in a UK context and across different diseases and technologies. It is not known whether the ordering of

3L and 5L in a survey influences responses, or the extent of separation between them to achieve independent responses. The NDB is restricted to a US/Canadian population with rheumatic disease. The respondents are predominantly female (81%) and in much better health than the respondents in the EQG data. Figure 5 shows that just 10.34% of the NDB sample report 3L scores below 0.5.

Available information about the EQG study are much less detailed than the NDB approach, in part because it was formed as a combination of add-ons to several separate studies in different countries. There was relatively little separation between patients being asked the 3L and the 5L, substantially less than the NDB, and this may result in patients providing responses that are not biased by recall of their responses to the 3L.

Many may think that these datasets are relatively large at 3,691 and 5,299 respectively. However, we consider them to be insufficient. In the EQG data only 119 of the possible 233 EQ-5D-3L utility values are observed. 29.30% of respondents report the same level in all dimensions, 19.10%, 9.69% and 0.51% of respondents reported being in states 11111, 22222 and 33333 respectively. In the NDB only 83 of the 233 EQ-5D-3L utility values are observed and 21.67% of respondents report the same level in all dimensions, 15.18%, 6.46% and 0.04% reported being in states 11111, 22222 and 33333 respectively. This could indicate that responses are given without full consideration. We know that most of the 233 utility values do appear in real patient records. For example, in the PROMS 2010-2014 data for knee replacement procedures (n=320,000) we find 189 out of 233 possible utility values, and, although econometric modelling is used to extrapolate to the areas where we do not have data, better coverage in the data would provide greater confidence in the results.

Whatever future decisions are taken by NICE, and other decision making bodies, regarding the 3L and 5L instruments, there will be a requirement to map between them for many years to come. Given the potential impact, we consider it essential that a well-designed, large-scale new data collection exercise be undertaken in order to estimate a definitive mapping that can be used for decision making in the UK NHS.

5. CONCLUSIONS

NICE needs to recommend one approach for mapping in order to avoid complicating the appraisal process and reduce opportunities for gaming.

If the 5L is recommended by NICE, mapping from 3L health states to 5L utility values should be conducted using the DSU EQG based model. The current alternative is to use the DSU NDB based model. Our recommendation is based solely on the belief that the EQG dataset is more generalizable to the range of conditions NICE is likely to encounter.

Mapping from either 3L or 5L utility scores to their counterpart utility scores should also be conducted using the DSU EQG based model, for the same reasons.

Standard measures of fit across the distribution of health do not reveal significant differences in the performance of methods for mapping from 5L health states to 3L utility scores. However, the manner in which data is deemed “inconsistent” and elements of it then ignored in the van Hout et al approach does cause concern. The result of this approach is that it generates zero errors for some parts of responses, and thus very good summary measures of fit across the distribution, but it also results in larger errors in other areas. There are differences in the results generated between the DSU approaches and the van Hout approaches that are masked by summary measures of fit.

NICE may wish to recommend a consistent approach to mapping whether to 3L from 5L, or vice versa, or from utility values rather than health state descriptions. It should be noted that the DSU approach for mapping is a single model for all of these options, estimated jointly. In this sense, it provides a completely consistent approach.

We also believe that all these mapping functions should be considered interim because of limitations in the data. Given the importance of a single, robust approach to mapping, a reference case dataset should urgently be commissioned with a detailed consideration of study design to overcome deficiencies in existing data sources. That data collection needs to consider the ordering of 3L and 5L, the degree of separation required, the sample size and sampling frame, *inter alia*.

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