ORIGINAL ARTICLES

Valuations of SF-6D health states: Could United Kingdom data be used to select a smaller sample of Hong Kong states

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ABSTRACT

Background: There is interest in the extent of using the combined analysis when we have plenty of data on two countries, but few have considered the combined analysis when we have plenty of data on one country and limited data on another. This kind of analysis may produce better estimation of the second country's population utility function than analysing its data separately.
Methods: The data set is the HK and UK SF-6D valuation studies where two samples of 197 and 249 states defined by the SF-6D were valued by representative samples of the HK and UK general populations respectively, both using the standard gamble technique. We apply a nonparameteric Bayesian method to estimate a utility function applicable across both countries to see whether with a small sample of HK health states, but also drawing extra information from the UK data, we obtain the same accuracy we would get with the full HK sample.
Results: The results suggest that with the use of 100 health states, the HK analysis gets the broad features as the full analysis with all states as far as predicted mean valuations, covariates, interactions, regression parameters and dimension-specific parameters are concerned.
Conclusions: The implications of these results will be hugely important in countries without the same capacity to run large evaluation exercises.

Key Words: Preference-based health measure, Nonparametric methods, Standard gamble, SF-6D

1. INTRODUCTION

There has been an increasing use of preference-based measures of health related quality of life in order to calculate quality adjusted life years (QALYs) for use in cost effectiveness analyses. These preference-based measures are standardised multi-dimensional health state classifications with preference or utility weights elicited from a sample of the general population.[1] There are currently a number of such preference-based measures, including generic measures such as EQ-5D,[2] HUI2 & 3,[3,4] AQoL,[5] and the SF-6D[6] and condition specific measures.[7–10] These measures provide empirically derived health state values that can be used to derive QALYs for use in a cost-effectiveness analysis or cost-utility analysis.[11]

The SF-6D has become a widely used measure of health status and it has been valued in 5 other countries to date.[12–16]

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There is a concern that people in different countries and cultures may value health differently, and so may give different utilities for the same health state descriptions. Such differences will mean that valuations derived in one country cannot be used to give valid cost-effectiveness analyses in another. Earlier research with the EQ-5D found quite small and largely unimportant differences between UK, US and Spain.[17] Data sets using one of the choice-based techniques such as standard gamble (SG) or time trade-off have found important differences between the USA and UK,[18] Japan and UK,[19] and between Portugal and the UK.[20]

Kharroubi et al.[21] extended this work by using a new nonparametric Bayesian method to model the differences between these countries that is simpler, better fitting and more appropriate for the data than the conventional parametric methods on the US vs. UK comparison for EQ-5D.[18] Kharroubi et al.[22,23] have also applied it to the SF-6D HK and UK and Japan and UK valuation data. There are two distinct ways in which such a model for estimating population utility functions for each country may be useful. When we have plenty of data on two countries, good estimates of population utility functions for each country can be obtained by analysing the data from each country separately (using the model of Ref.[24]).

However, when we have plenty of data on one country and limited data on another, we believe the combined analysis may produce better estimation of the second country's population utility function than analysing its data separately. This kind of analysis (borrowing strength from country 1) may allow us to reduce sample sizes in country 2 in order to obtain the same accuracy as we would get with a full-sized study in that country. This will be hugely important in countries without the same capacity to run large evaluation exercises.

Our primary purpose in this article is to demonstrate a powerful approach to see whether with a small sample of HK health states, but also drawing extra information from the UK data, we get results that are as good as those obtained with the full HK sample. To our knowledge, this is something that hasn't been explored properly yet, but is obviously of potential value.

Section 2 of this article provides a brief description of the HK and UK SF-6D valuation surveys and the data used in this article. Section 3 sets out a Bayesian nonparametric model that provides more realistic and flexible inferences for preference functions. Section 4 presents the results of using the Bayesian method to demonstrate the potential for reducing sample sizes using the HK and UK SF-6D data sets. Finally, we conclude with a general discussion of the results in Section 5, including few directions for future research.

2. Methods

2.1 SF-6D data set

The SF-6D, derived from the SF-36, has been described elsewhere.[6,25] It has six dimensions of *physical functioning*, *role limitation*, *social functioning*, *bodily pain*, *mental health* and *vitality*, each with between four and six levels.[6] An SF-6D health state is defined by selecting one statement from each dimension, starting with physical functioning and ending with vitality. Level 1 in each dimension represents no loss of health or functioning in that dimension, so that state 111111 denotes perfect health. The worst possible state is 645655, known as "the pits". A total of 18,000 health states can be defined in this way.

2.1.1 *UK*

A selection of 249 states defined by the SF-6D have been valued by a representative sample of 836 members of the UK general population using the standard gamble (SG) valuation technique. The selection of respondents and the selection of health states are discussed elsewhere.[6] Each respondent was asked to rank and then value six SF-6D health states using the McMaster "ping pong" variant of SG, where respondents are iterated towards their point of indifference.[26] The SG valuation task asked respondents to value each of five SF-6D health states against perfect health and "pits". Respondents were then asked in the sixth SG question to value "pits". See Ref.[6] for more details.

Of the original 836 respondents, 225 were excluded for a number of reasons, the most important being that 130 did not provide a value for the "pits" state and so their data could not be used. Out of the remaining 611 individuals included in the data set there were 148 missing values from 117 individuals. This results in 3,518 (6×611 - 148) observed SG valuations across 249 health states. The details of the valuations for each of the 249 SF-6D UK health states are in Ref.[6]

2.1.2 *Hong Kong*

The HK study used a sample of 197 health states and valued them using the same valuation methods as in the UK study.[15] The selection of respondents and the selection of health states follow the same UK procedures. Each respondent was asked to rank and value eight health states. As in Ref.,[6] the states were stratified into a block system in order to ensure each person valued a range of health states from very mild to very severe. The interview procedure was modelled on that used in the UK study.

Of the original 641 respondents, 59 were excluded from the analysis using the same exclusion criteria as in the UK study.[6] Out of the remaining 582 individuals included in the data set there were 60 missing health state values. This results in 4,596 (8×582 - 60) observed SG valuations across

197 health states. The details of the valuations for each of the 197 SF-6D HK health states are in Ref.[15]

For combined analysis, we pool the HK and UK data into a single dataset with *m* = 1,193 (611 + 582) respondents. For *j* = *1, 2, . . . , m* let n_j be the number of health states that were valued by the *j*th respondent. The total number of observations is *n* = $\sum n_j$. Note that *n* = 8,114 (3,518 + 4,596) for full HK/UK dataset. For *i* = *1, 2, . . . ,* n_j and *j* = *1, 2, . . . , m*, let $\mathbf{x}_{ij}$ be the *i*th health state valued by respondent *j*, and let y_{ij} be the SG valuation given by respondent *j* for that health state. Finally, let $\mathbf{t}_j$ be a vector of covariates representing individual characteristics of respondent *j*.

2.2 Modelling

Kharroubi et al.[21] proposed a nonparametric Bayesian approach to handle a pooled US-UK EQ-5D dataset. This method to modelling has been applied to the HK-UK SF-6D valuation data[22] and to Japan and UK valuation data.[23] Here we follow on from the work of Kharroubi et al.[22] to estimate a utility function to see whether with range of sample sizes of HK health states (25, 50 or 100 states), but also drawing extra information from the UK data, gets the same broad features as the full HK sample.

The *i*th valuation by respondent *j* is modelled as:

$$y_{ij} = 1 - exp(\gamma' h(\mathbf{t}_j + \alpha_j) + \{1 - u_c(\mathbf{x}_{ij})\} + \varepsilon_{ij} \quad (1)$$

where $h(\mathbf{t}_j)$ is a vector of functions of the covariates $\mathbf{t}_j$ and γ is a vector of parameters that together determine the principal effect of the covariates on respondents' valuations, α_j is a zero-mean random respondent effect, ε_{ij} is a zero-mean random error, $u_c(\mathbf{x})$ is a function of the health state vector $\mathbf{x}$ and the subscript c represents the respondent's country. As discussed in Kharroubi,[22] $u_c(\mathbf{x})$ is interpreted as a base utility function in the sense that if the population expectation of $exp(\gamma' h(\mathbf{t}_j + \alpha_j)$ is 1 then $u_c(\mathbf{x})$ is the population utility measure, where *c* = *1* if respondent *j* is in the HK sample, and *c* = *0* if he/she is in the UK sample.

Kharroubi et al.[22] assigned independent normal distributions to the respondents residual and error terms,

$$\alpha_j \sim N(0, \tau^2) \text{ and } \varepsilon_{ij} \sim N(0, \upsilon^2)$$

Further, Kharroubi et al.[22] model the relationship between the two base utility functions through

$$u_0(\mathbf{x}) = \mu_0 + \beta_0'\mathbf{x} + d(\mathbf{x}) \quad (2)$$

$$u_1(\mathbf{x}) = (\mu_0 + \mu_1) + (\beta_0' + \beta_1')\mathbf{x} + d(\mathbf{x}) \quad (3)$$

where $u_0(\mathbf{x})$, $u_1(\mathbf{x})$, β_0 and β_1 are unknown parameters and d($\mathbf{x}$) represents a deviation from the simple linear trend. As in Kharroubi et al.,[22] the expression $\mu_0 + \beta_0'\mathbf{x}$ in (2) expresses a belief that the underlying utility function $u_0(\mathbf{x})$ for UK respondents will tend to behave like a simple linear combination of the elements of the health state description vector $\mathbf{x}$. The coefficients β_0 represent rates at which utility generally declines when we increase the level in the corresponding dimension of $\mathbf{x}$. The comparable expression in (3) modifies these underlying trend variables with additional coefficients β_1 to reflect dimension-specific differences between the HK and UK, but notice they share the same $d(\mathbf{x})$ function.

Finally we let conventional noninformative prior distributions for μ_0, μ_1, β_0, β_1, $\tau^2$and υ^2. However,

$$\text{d}(\mathbf{x}) \sim N(0, \sigma^2)$$

for all $\mathbf{x}$ and

$$cov(d(\mathbf{x}), d(\mathbf{x}')) = exp\left\{-\sum B(x_d - x_d')^2\right\} \quad (4)$$

See Kharroubi et al.[24] for more justification of this part of the model. Note that the population utility function in country *c* is

$$\bar{u}_c(x) = 1 - \bar{\alpha}_c\{1 - u_c(\mathbf{x})\} \quad (5)$$

where $\bar{\alpha}_c$ is the population mean/median respondent effect for that country and $u_c(\mathbf{x})$ is the corresponding base utility function. The fact that in general $\bar{\alpha}_c \neq 1$ and the population utility is not the base utility influences how we interpret the utility slope parameters β_0 for the UK and (β_0 + β_1) for the HK. The change in utility for an increase of one level in a particular dimension is represented (as an underlying trend) not by the corresponding slope parameter but by this parameter multiplied by $\bar{\alpha}_c$. For this analysis *h*(**t**) is set to be (HK, Sex, Age, Age2) where HK is a dummy variable to differentiate respondents' national identity (1 if HK respondent; 0 if UK respondent) and Age^2 is squared age.

3. Results

3.1 25 HK health states

We start our analysis by looking at 25 HK health states together with the 249 UK health states. The sample of 25 HK health states was chosen as follows: we first sort HK health state in terms of UK mean utilities and then divide them into 25 groups. One health state was then selected at random from each of the 25 groups. Care was taken in selecting the HK sample to ensure it is reasonably well balanced in terms of having high and low levels on each of the 6 dimensions.

Table 1 shows the observed sample mean health state utility and the posterior mean and standard deviation for population mean utility of the 25 health states valued in the HK and UK data (to be referred as HK/UK from now on) and in the HK data on its own (to be referred as HK only from now on). The predicted mean valuations for these states ranged from 0.0196 (pits) to 1 (perfect) for the (HK/UK) population and from 0.0544 (pits) to 1 (perfect) for the (HK only) population. Figure 1 presents the predicted mean health state valuations (green line) for the (HK/UK) along with the predicted mean health state valuations (red line) for the (HK only) and the observed sample mean health state utility of the 25 health states (blue line). The purple line represents the difference between the two predicted (HK/UK) and (HK only) valuations. As can be seen from Figure 1, although both valuations are very similar for the majority of the health states, the two valuations are underestimating the observed ones.

Table 1. Posterior estimates for the 25 sampled health states

Health States	Observed mean	HK data ONLY		25 HK & UK data		Difference
		Predicted mean	Predicted STD	Predicted mean	Predicted STD	
111111	1	1	0	1	0	0
115211	0.7951	0.7632	0.0334	0.7788	0.0493	-0.0156
135312	0.7	0.6648	0.0281	0.6786	0.0441	-0.0138
244353	0.6976	0.5668	0.0322	0.5761	0.0613	-0.0093
434211	0.6601	0.6238	0.0315	0.668	0.0504	-0.0442
435335	0.6579	0.5733	0.0304	0.5485	0.0634	0.0248
135435	0.655	0.6004	0.0303	0.6016	0.0558	-0.0012
432621	0.6423	0.5545	0.0307	0.5432	0.0569	0.0113
343425	0.6307	0.578	0.0297	0.5543	0.0566	0.0237
641114	0.6165	0.582	0.0319	0.5716	0.057	0.0104
145621	0.6093	0.5814	0.0328	0.6214	0.0511	-0.04
341251	0.6023	0.5882	0.0321	0.5504	0.0609	0.0378
611621	0.5816	0.5301	0.0324	0.4899	0.0635	0.0402
145645	0.5814	0.5158	0.0334	0.5319	0.0613	-0.0161
443215	0.5719	0.5798	0.0276	0.5528	0.0512	0.027
641154	0.545	0.4952	0.0344	0.4604	0.0694	0.0348
445641	0.5364	0.4497	0.0345	0.4472	0.0671	0.0025
145652	0.5291	0.4513	0.0359	0.4593	0.064	-0.008
642453	0.5104	0.4143	0.0341	0.4093	0.0692	0.005
545353	0.5103	0.4024	0.0341	0.3829	0.0711	0.0195
633122	0.4986	0.4906	0.0291	0.4623	0.053	0.0283
615614	0.4344	0.4654	0.0329	0.4935	0.0598	-0.0281
644631	0.416	0.4152	0.0328	0.3849	0.0681	0.0303
645441	0.4085	0.4032	0.0323	0.3623	0.0655	0.0409
613625	0.3453	0.4022	0.0311	0.3308	0.0667	0.0714
645655	0.067	0.0544	0.0232	0.0196	0.0715	0.0348

Note. Abbreviation: STD, standard deviation.

Figure 2 shows the posterior distributions of the covariates (HK, Sex, Age and Age^2) for the (HK/UK) population. As can be seen, these distributions are concentrated away from zero which indicates that these covariates have important effects. In comparison with Figure 3, the sex effect is of opposite sign and about the same magnitude as the main effect for the (HK only) population. Figure 4 and Figure 5 show the mean SG utility values for the pits state for the (HK/UK) and (HK only) populations respectively. As can be seen, both valuations are very similar.

Figure 6 and Figure 7 show the posterior distributions of the underlying regression parameters μ_0 and β_1 of the (HK/UK) and (HK only) respectively. The first distribution is the coefficient of the constant term μ_0, but the other 6 elements represent slopes of β_1 as each of the 6 dimensions (physical functioning, role limitation, social functioning, bodily pain, mental health and vitality) increases. As can be seen, all of the 6 coefficients in Figure 7 are negative, so the fitted parametric relationship for the HK only satisfies monotonicity. Whereas in Figure 6, there does seem to be interplay in the β_1 parameters. For dimensions 2 and 3, the coefficients are concentrated around zero. This may suggest that a sample of 25 HK health state is small and so more HK health states are then needed to obtain results that are as good as those obtained with the full HK sample.

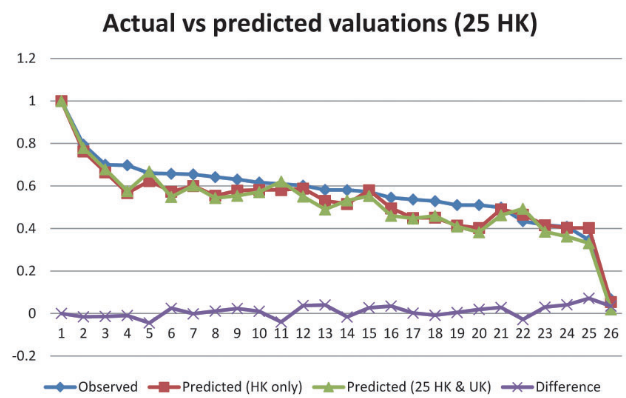

Figure 1. Actual and predicted mean health state valuations for the 25 sampled health states

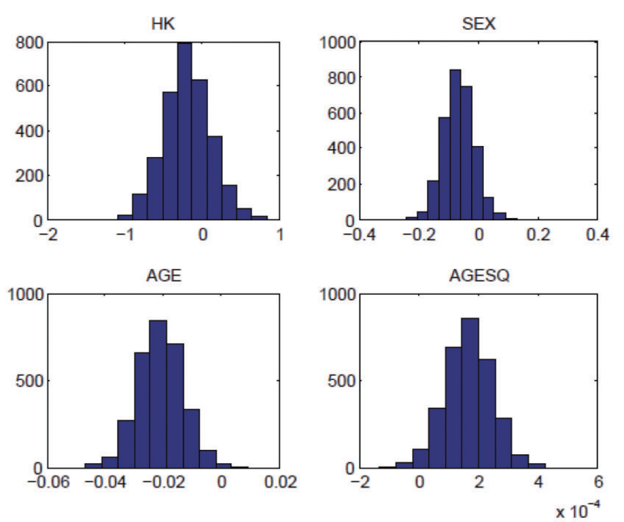

Figure 2. Posterior distribution of the covariates (HK/UK)

3.2 50 HK health states

We continue our analysis by looking at 50 HK health states together with the UK health states. The way of sampling the 50 HK health states is similar to the one mentioned in Section 3.1.

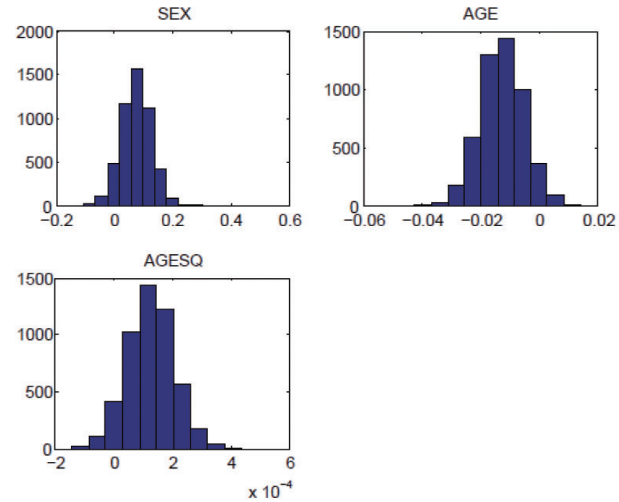

Figure 3. Posterior distribution of the covariates (HK separate fit)

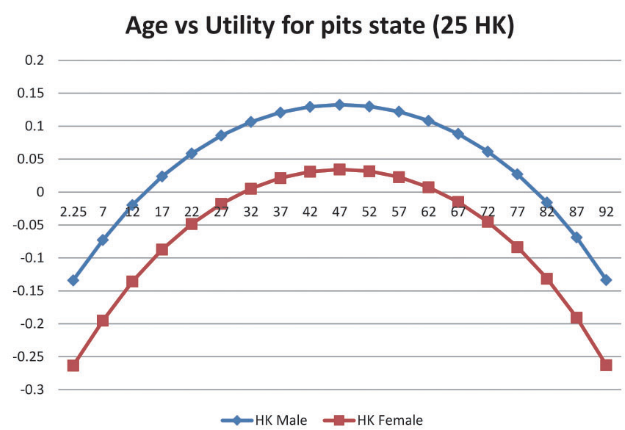

Figure 4. Mean SG utility values by age for pits state: HK/UK

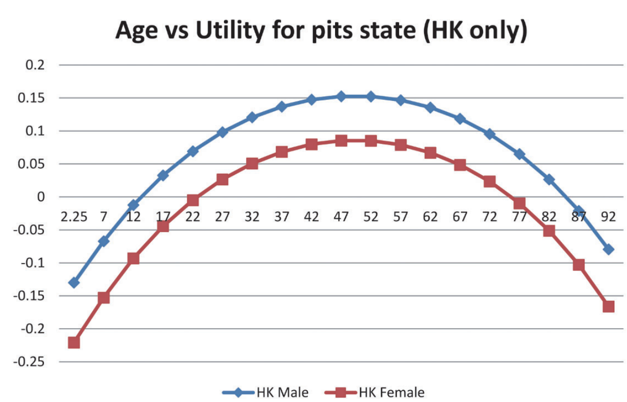

Figure 5. Mean SG utility values by age for pits state: HK only

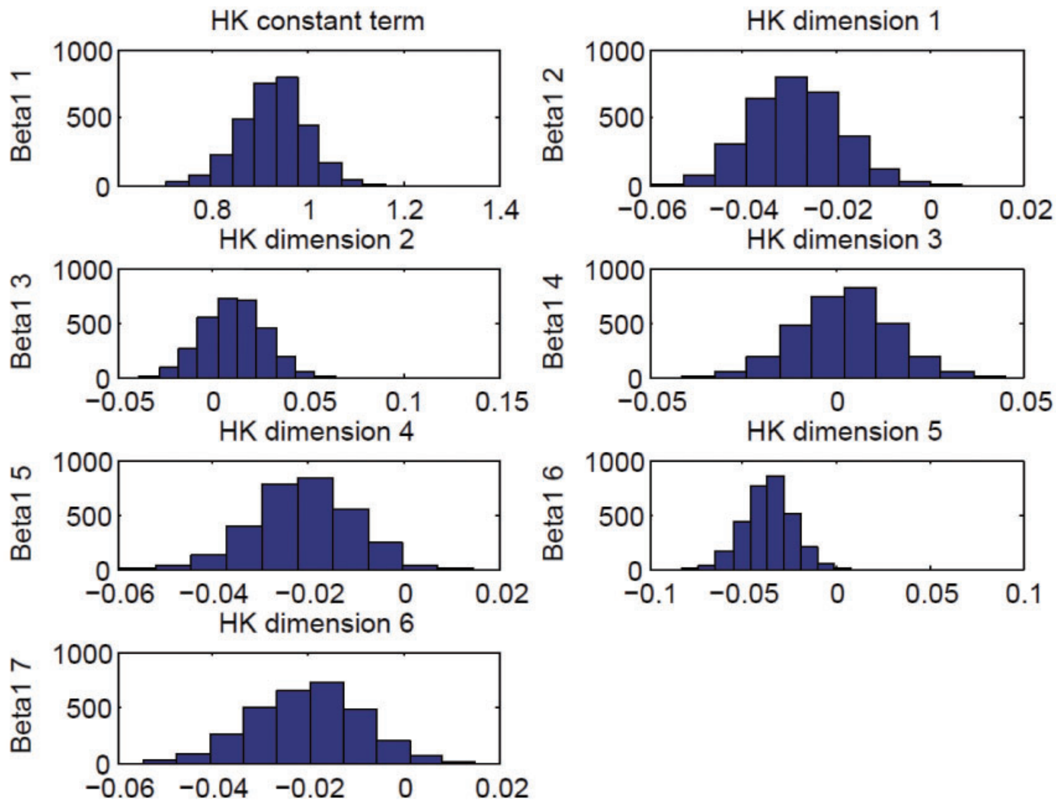

Figure 6. Posterior distribution of the regression parameters γ and β (HK/UK)

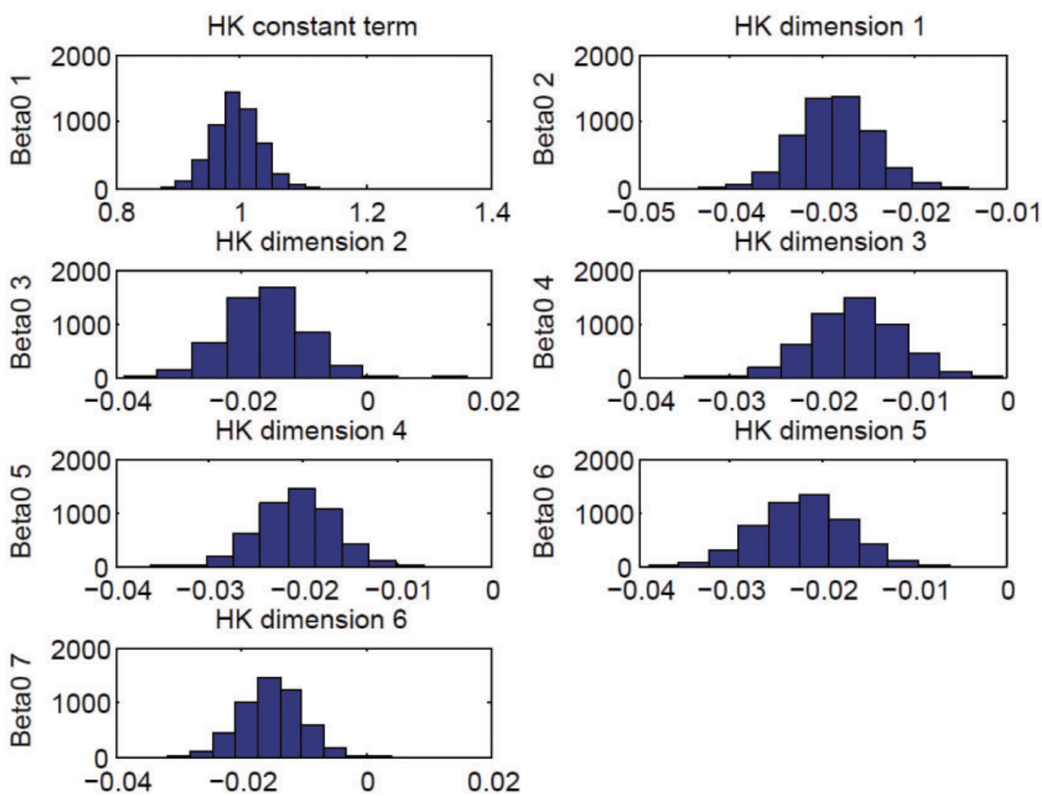

Figure 7. Posterior distributions of the corresponding γ and β (HK only)

Table 2. Posterior estimates for the 50 sampled health states

Health States	Observed mean	HK data ONLY		50 HK & UK data		Difference
		Predicted mean	Predicted STD	Predicted mean	Predicted STD	
111111	1	1	0	1	0	0
115211	0.7951	0.7632	0.0334	0.7656	0.0426	-0.0024
115131	0.7243	0.7068	0.0309	0.7225	0.0451	-0.0157
522321	0.7164	0.6689	0.0272	0.6193	0.0343	0.0496
141215	0.7089	0.6765	0.032	0.6579	0.048	0.0186
414522	0.7007	0.6081	0.0314	0.5398	0.0388	0.0683
135312	0.7	0.6648	0.0281	0.6528	0.0385	0.012
244353	0.6976	0.5668	0.0322	0.5411	0.0479	0.0257
122233	0.6894	0.6726	0.0286	0.6227	0.0347	0.0499
113615	0.6685	0.6125	0.0346	0.5601	0.0538	0.0524
434211	0.6601	0.6238	0.0315	0.6435	0.0436	-0.0197
435335	0.6579	0.5733	0.0304	0.5281	0.0469	0.0452
135435	0.655	0.6004	0.0303	0.5911	0.0459	0.0093
111621	0.6492	0.6136	0.0316	0.6023	0.0373	0.0113
432621	0.6423	0.5545	0.0307	0.5363	0.0444	0.0182
345411	0.6347	0.6118	0.0315	0.565	0.045	0.0468
343425	0.6307	0.578	0.0297	0.5334	0.0448	0.0446
324155	0.6248	0.5301	0.0349	0.4494	0.0518	0.0807
211615	0.6206	0.6275	0.0333	0.5961	0.0465	0.0314
631333	0.6175	0.521	0.0329	0.4871	0.0467	0.0339
641114	0.6165	0.582	0.0319	0.5792	0.0454	0.0028
145621	0.6093	0.5814	0.0328	0.5892	0.0452	-0.0078
315515	0.6064	0.5474	0.0314	0.5253	0.0405	0.0221
341251	0.6023	0.5882	0.0321	0.5543	0.0474	0.0339
132524	0.5983	0.5742	0.0271	0.523	0.0381	0.0512
611154	0.5961	0.5321	0.0343	0.5658	0.0458	-0.0337
611621	0.5816	0.5301	0.0324	0.5048	0.0489	0.0253
145645	0.5814	0.5158	0.0334	0.5222	0.0487	-0.0064
631315	0.5806	0.5188	0.0334	0.4785	0.0503	0.0403
443215	0.5719	0.5798	0.0276	0.5486	0.0376	0.0312
641154	0.545	0.4952	0.0344	0.4755	0.0489	0.0197
445641	0.5364	0.4497	0.0345	0.4331	0.0515	0.0166
415651	0.5347	0.4622	0.0353	0.4354	0.0535	0.0268
145652	0.5291	0.4513	0.0359	0.4402	0.0519	0.0111
541451	0.5194	0.502	0.0301	0.4725	0.0454	0.0295
545115	0.5171	0.5385	0.031	0.5353	0.0435	0.0032
642453	0.5104	0.4143	0.0341	0.4048	0.0506	0.0095
545353	0.5103	0.4024	0.0341	0.3636	0.0507	0.0388
415313	0.5055	0.5463	0.0283	0.5793	0.0378	-0.033
633122	0.4986	0.4906	0.0291	0.482	0.0364	0.0086
645154	0.4948	0.3667	0.0351	0.3486	0.0521	0.0181
635651	0.4884	0.3501	0.0397	0.352	0.0587	-0.0019
641132	0.4794	0.4942	0.0327	0.4441	0.046	0.0501
631355	0.4479	0.4507	0.0299	0.4277	0.0393	0.023
323644	0.4377	0.4304	0.03	0.3166	0.0384	0.1138
615614	0.4344	0.4654	0.0329	0.4935	0.0452	-0.0281
644631	0.416	0.4152	0.0328	0.3867	0.0492	0.0285
645441	0.4085	0.4032	0.0323	0.3572	0.0485	0.046
421455	0.4016	0.4961	0.0283	0.4467	0.0414	0.0494
613625	0.3453	0.4022	0.0311	0.3535	0.0473	0.0487
645655	0.067	0.0544	0.0232	0.0301	0.0331	0.0243

Note. Abbreviation: STD, standard deviation.

Table 2 shows the observed sample mean health state utility and the posterior mean and standard deviation for population mean utility of the 50 health states in the (HK/UK) together with the HK valuations (HK only). The predicted mean valuations for the health states ranged from 0.0301 (pits) to 1 (perfect) for the HK (HK/UK) population. Figure 8 shows the predicted mean health state valuations (green line) for the HK population (HK/UK) along with the predicted mean health state valuations (red line) for the HK (HK only) population and the observed sample mean health state utility of the 50 health states (blue line). The purple line represents the difference between the two predicted HK valuations. Notice that both valuations are very similar for the majority of the health states. Although both valuations are underestimating the observed valuations, we can see from Figure 8 that the combined HK/UK valuations are below the HK only ones for the majority of health states. This may suggest that a sample of 50 HK health states is still small to produce results that are as good as those obtained with the full HK sample.

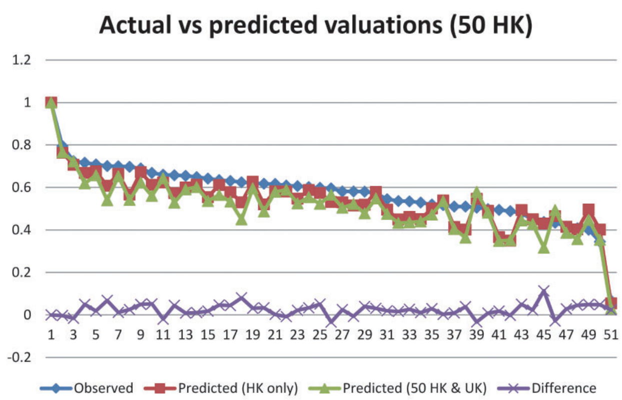

Figure 8. Actual and predicted mean health state valuations for the 50 sampled health states

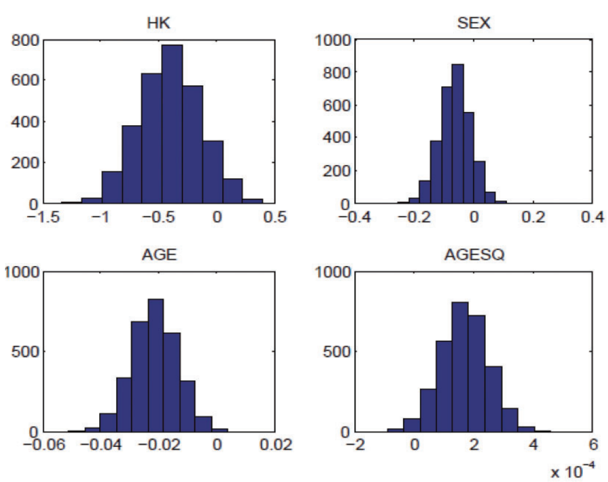

Figure 9. Posterior distribution of the covariates (HK/UK)

Figure 9 shows the posterior distributions of the covariates (HK, Sex, Age and Age^2) for the (HK/UK) population. As can be seen, these distributions are concentrated away from zero, so these covariates have important effects. In comparison with Figure 3, the sex effect is of opposite sign and about the same magnitude as the main effect for the HK (HK only). Figure 10 shows the mean SG utility values for the pits state for the (HK/UK. In comparison with Figure 5, we see that both valuations are very similar. Figure 11 shows the posterior distributions of the underlying regression parameters γ and β_1 of the HK/UK. In comparison with Figure 7, we see that all of the 6 coefficients in both figures are almost negative, so the fitted parametric relationship for the both analysis satisfy monotonicity.

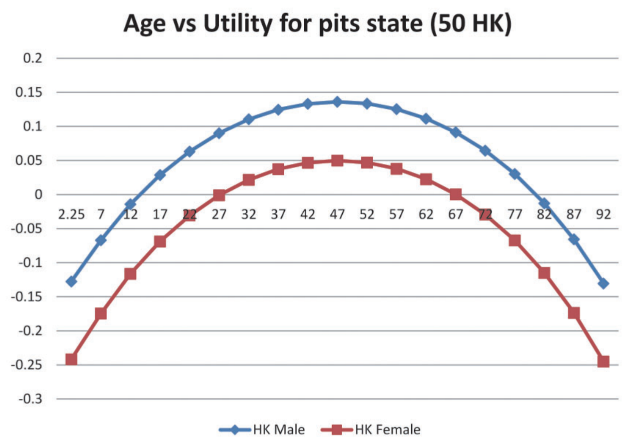

Figure 10. Mean SG utility values by age for pits state: HK/UK

3.3 100 HK health states

Finally, we look at 100 HK health states together with the 249 UK health states. The sample of 100 HK health states was chosen in the same way above. Table 3 shows the observed sample mean health state utility and the posterior mean and standard deviation for population mean utility of the 100 health states in the (HK/UK) together with the HK valuations (HK only). The predicted mean valuations for the health states ranged from 0.0478 (pits) to 1 (perfect) for the HK (HK/UK) population. Figure 12 shows the predicted mean health state valuations (green line) for the HK population (HK/UK) along with the predicted mean health state valuations (red line) for the HK (HK only) population and the observed sample mean health state utility of the 100 health states (blue line). The purple line represents the difference between the two HK valuations. Notice that both valuations are very similar for the majority of the health states, although both are underestimating the observed valuations.

Figure 13 shows the posterior distributions of the covariates (HK, Sex, Age and Age^2). As can be seen, these distributions are concentrated away from zero, so indicates important effects. In comparison with Figure 3, the sex effect is of opposite sign and about the same magnitude as the main effect for the HK (HK only). Figure 14 shows the mean SG utility values for the pits state for the (HK/UK). In comparison with Figure 3, we see that both valuations are very similar. Figure 15 show the posterior distributions of the underlying regression parameters γ and β_1 of the HK/UK. In comparison with Figure 5, we see that all of the 6 coefficients in both figures are almost negative, so the fitted parametric relationship for the both analysis satisfy monotonicity.

To this end, we compare the two approaches in terms of predicting the values for states that have not been used in the estimation. Note that there are 197 health states in the HK data from which 100 states were used for model fitting above and the remaining 97 states were used for model checking. Table 4 shows the true sample mean health state utility and the posterior mean and standard deviation for population mean utility of the 97 left out health states in the (HK/UK) together with the HK valuations (HK only). As can be seen, both valuations are very similar for the majority of the health states. The prediction errors are broadly consistent with the predictive standard deviations for the two approaches. The predictive performance for the combined analysis is slightly better though as the variance of the standardised prediction errors is 0.72 for HK/UK versus 0.883 for the HK only. Also the root mean square errors (RMSE) of predictions are marginally similar too, with 0.057 for the combined data and 0.074 for the HK only.

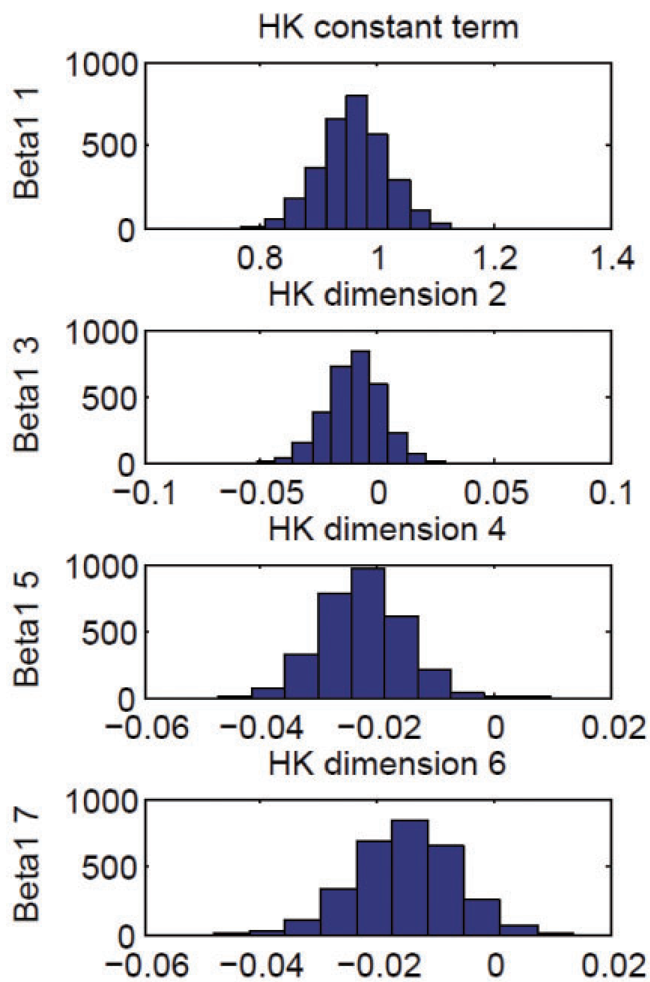

Figure 11. Posterior distribution of the underlying regression parameters γ and β (HK/UK)

4. Discussion

In this article, we have applied a nonparameteric Bayesian method to estimate a utility function applicable across HK and UK to show with a small sample of HK health states, but also drawing extra information from the UK data, we obtain the same accuracy we would get with the full HK sample. This will be hugely important in countries without the same capacity to run large evaluation exercises.

Table 3. Posterior estimates for the 100 sampled health states

Health States	Observed mean	HK data ONLY		100 HK & UK data		Difference
		Predicted mean	Predicted STD	Predicted mean	Predicted STD	
111111	1	1	0	1	0	0
113141	0.8022	0.7541	0.0303	0.7476	0.0383	0.0065
115211	0.7951	0.7632	0.0334	0.7547	0.0378	0.0085
232111	0.7796	0.7448	0.028	0.6869	0.0293	0.0579
131331	0.7638	0.6953	0.0306	0.6867	0.0381	0.0086
113352	0.7441	0.717	0.0275	0.6793	0.0346	0.0377
133132	0.7425	0.6949	0.0283	0.6435	0.0297	0.0514
341123	0.7389	0.6481	0.0299	0.6261	0.034	0.022
115131	0.7243	0.7068	0.0309	0.7185	0.0389	-0.0117
522321	0.7164	0.6689	0.0272	0.6068	0.031	0.0621
141215	0.7089	0.6765	0.032	0.6543	0.0441	0.0222
114631	0.7057	0.6239	0.0357	0.6043	0.0462	0.0196
122425	0.704	0.6611	0.0279	0.6408	0.0315	0.0203
414522	0.7007	0.6081	0.0314	0.5262	0.0356	0.0819
135312	0.7	0.6648	0.0281	0.6527	0.0346	0.0121
244353	0.6976	0.5668	0.0322	0.51	0.0429	0.0568
122233	0.6894	0.6726	0.0286	0.6682	0.029	0.0044
142154	0.6821	0.6313	0.0291	0.6052	0.0342	0.0261
115314	0.6788	0.6414	0.0328	0.6635	0.0401	-0.0221
113615	0.6685	0.6125	0.0346	0.5936	0.0457	0.0189
241531	0.6643	0.5999	0.0286	0.5843	0.0331	0.0156
434211	0.6601	0.6238	0.0315	0.6151	0.0385	0.0087
311654	0.6581	0.5192	0.0355	0.4542	0.0461	0.065
435335	0.6579	0.5733	0.0304	0.5135	0.0445	0.0598
135435	0.655	0.6004	0.0303	0.5924	0.0427	0.008
112153	0.6519	0.6519	0.0306	0.6343	0.0385	0.0176
235224	0.6506	0.613	0.0285	0.5737	0.0331	0.0393
111621	0.6492	0.6136	0.0316	0.6395	0.0302	-0.0259
432621	0.6423	0.5545	0.0307	0.5239	0.0423	0.0306
113634	0.64	0.5777	0.0317	0.5539	0.0427	0.0238
345411	0.6347	0.6118	0.0315	0.5385	0.0423	0.0733
343425	0.6307	0.578	0.0297	0.526	0.0395	0.052
641211	0.6294	0.5515	0.0369	0.5146	0.0465	0.0369
135155	0.6251	0.572	0.0342	0.5294	0.0458	0.0426
324155	0.6248	0.5301	0.0349	0.4653	0.0436	0.0648
615253	0.6248	0.5072	0.0365	0.4498	0.0507	0.0574
115251	0.6223	0.626	0.0304	0.6199	0.0396	0.0061
211615	0.6206	0.6275	0.0333	0.6125	0.0434	0.015
631333	0.6175	0.521	0.0329	0.4913	0.0427	0.0297
641114	0.6165	0.582	0.0319	0.5803	0.0428	0.0017
315235	0.6161	0.5675	0.0309	0.5769	0.0412	-0.0094
145621	0.6093	0.5814	0.0328	0.5579	0.0425	0.0235
412152	0.608	0.5585	0.0267	0.5347	0.0318	0.0238
315515	0.6064	0.5474	0.0314	0.5305	0.0367	0.0169
341251	0.6023	0.5882	0.0321	0.5583	0.0429	0.0299
645415	0.6023	0.4502	0.0381	0.4328	0.0521	0.0174
341651	0.6015	0.5161	0.0338	0.4947	0.0452	0.0214
512242	0.6013	0.5721	0.0265	0.5561	0.0331	0.016
645132	0.601	0.478	0.0358	0.4129	0.0482	0.0651

(Table continued on page 11)

Table 3. (continued.)

Health States	Observed mean	HK data ONLY		100 HK & UK data		Difference
		Predicted mean	Predicted STD	Predicted mean	Predicted STD	
132524	0.5983	0.5742	0.0271	0.5518	0.033	0.0224
414355	0.5976	0.5418	0.0307	0.4868	0.0433	0.055
611154	0.5961	0.5321	0.0343	0.5403	0.0441	-0.0082
241135	0.5824	0.5784	0.031	0.5635	0.0406	0.0149
611621	0.5816	0.5301	0.0324	0.5125	0.0453	0.0176
145645	0.5814	0.5158	0.0334	0.5196	0.0468	-0.0038
631315	0.5806	0.5188	0.0334	0.4854	0.0453	0.0334
511633	0.5805	0.5385	0.0302	0.4941	0.0445	0.0444
115653	0.5728	0.4944	0.0322	0.4532	0.0406	0.0412
443215	0.5719	0.5798	0.0276	0.5523	0.0341	0.0275
615315	0.5634	0.4869	0.0354	0.4896	0.0456	-0.0027
614135	0.5587	0.4997	0.0355	0.4938	0.0446	0.0059
441331	0.557	0.5554	0.0294	0.5448	0.0363	0.0106
144341	0.5565	0.5665	0.0284	0.5787	0.0304	-0.0122
641154	0.545	0.4952	0.0344	0.4732	0.0478	0.022
445641	0.5364	0.4497	0.0345	0.415	0.0486	0.0347
415651	0.5347	0.4622	0.0353	0.4276	0.0506	0.0346
145652	0.5291	0.4513	0.0359	0.4371	0.0486	0.0142
611652	0.5207	0.4095	0.0361	0.4	0.0478	0.0095
541451	0.5194	0.502	0.0301	0.4735	0.0416	0.0285
545115	0.5171	0.5385	0.031	0.5262	0.0418	0.0123
622513	0.5108	0.5061	0.0274	0.4517	0.0372	0.0544
642453	0.5104	0.4143	0.0341	0.4092	0.0469	0.0051
545353	0.5103	0.4024	0.0341	0.3521	0.0482	0.0503
534113	0.5076	0.5044	0.0293	0.5161	0.0358	-0.0117
415313	0.5055	0.5463	0.0283	0.5838	0.0362	-0.0375
143654	0.5028	0.4905	0.0322	0.4641	0.0442	0.0264
344633	0.5002	0.468	0.0316	0.4478	0.0416	0.0202
633122	0.4986	0.4906	0.0291	0.4759	0.0331	0.0147
645154	0.4948	0.3667	0.0351	0.3453	0.0488	0.0214
635651	0.4884	0.3501	0.0397	0.3336	0.0549	0.0165
441615	0.4883	0.4979	0.0316	0.4459	0.0446	0.052
641654	0.4842	0.4086	0.0356	0.4013	0.0503	0.0073
641132	0.4794	0.4942	0.0327	0.4564	0.042	0.0378
345355	0.4751	0.4782	0.0302	0.4324	0.0445	0.0458
415655	0.4739	0.3966	0.0361	0.3472	0.053	0.0494
611645	0.4649	0.4465	0.032	0.4091	0.048	0.0374
623155	0.4501	0.4516	0.0341	0.4273	0.0459	0.0243
642612	0.4496	0.4718	0.0295	0.4078	0.0384	0.064
631355	0.4479	0.4507	0.0299	0.4239	0.0396	0.0268
615451	0.4431	0.4229	0.0339	0.4014	0.0476	0.0215
443652	0.4431	0.3972	0.0322	0.3873	0.0441	0.0099
323644	0.4377	0.4304	0.03	0.3614	0.0367	0.069
615614	0.4344	0.4654	0.0329	0.4904	0.0433	-0.025
644631	0.416	0.4152	0.0328	0.3821	0.0473	0.0331
615412	0.4129	0.4956	0.0301	0.4791	0.0395	0.0165
645441	0.4085	0.4032	0.0323	0.3545	0.0466	0.0487
421455	0.4016	0.4961	0.0283	0.4708	0.0379	0.0253
613625	0.3453	0.4022	0.0311	0.368	0.0442	0.0342
445145	0.3405	0.4656	0.0291	0.4369	0.0395	0.0287
633535	0.3343	0.3641	0.0309	0.3239	0.0451	0.0402
645655	0.067	0.0544	0.0232	0.0478	0.042	0.0066

Note. Abbreviation: STD, standard deviation.

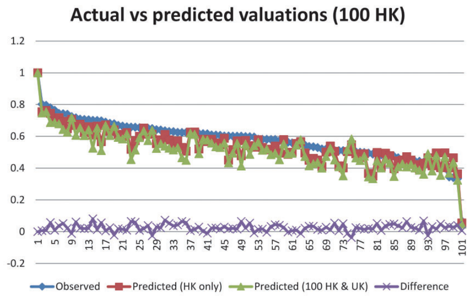

Figure 12. Actual and predicted mean health state valuations for the 100 sampled health states

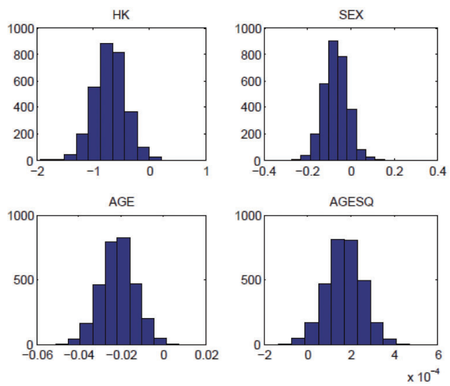

Figure 13. Posterior distribution of the covariates (HK/UK)

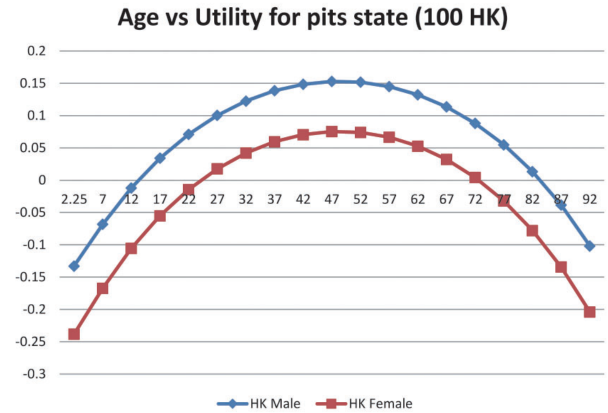

Figure 14. Posterior distribution of the covariates (HK/UK)

The work presented in this paper demonstrates that with 25, 50 and 100 states, the HK analysis gets the broad features as the full analysis with all states as far as predicted mean valuations, covariates and interactions are concerned. However, in terms of the dimension-specific parameters β_1, there is more uncertainty and possibility of larger effects with 25 and/or 50 health states, and with 100 states we get effects of about the right magnitude and mostly negative. This implies that reducing the numbers of states to 25 and/or 50 runs the risk of misestimating the dimension-specific effects.

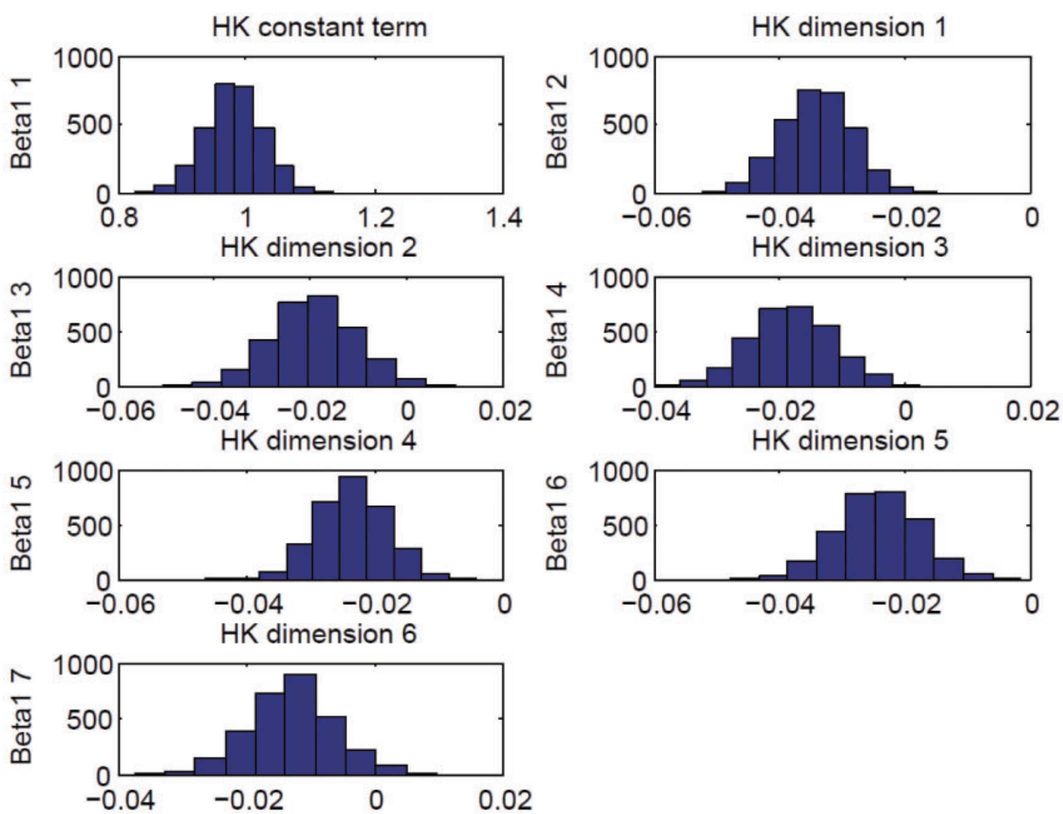

Figure 15. Posterior distribution of the underlying regression parameters γ and β (HK/UK)

Table 4. Predictions for 97 left out health states

Health States	Observed mean	HK data ONLY		100 HK & UK data		Difference
		Predicted mean	Predicted STD	Predicted mean	Predicted STD	
111645	0.5055	0.6273	0.0715	0.5573	0.074	0.07
112455	0.6777	0.6265	0.0713	0.5367	0.0703	0.0898
112613	0.7305	0.7045	0.0638	0.7144	0.0673	-0.0099
112651	0.6288	0.6758	0.0686	0.6173	0.0698	0.0585
113411	0.7324	0.7979	0.0637	0.7084	0.0513	0.0895
115355	0.5346	0.5684	0.0753	0.4918	0.0736	0.0766
115432	0.6201	0.6126	0.0714	0.5925	0.0766	0.0201
121212	0.8253	0.8356	0.0631	0.7905	0.0533	0.0451
124125	0.612	0.6983	0.0658	0.6893	0.0612	0.009
125143	0.6505	0.5835	0.0748	0.5365	0.0751	0.047
125625	0.5478	0.6113	0.0664	0.5835	0.0714	0.0278
131151	0.7621	0.6964	0.073	0.6924	0.0799	0.004
131542	0.7067	0.6521	0.0579	0.5937	0.0483	0.0584
131555	0.5327	0.5549	0.0737	0.496	0.0709	0.0589
135633	0.5085	0.5565	0.068	0.5279	0.0739	0.0286
142113	0.6585	0.716	0.0694	0.6392	0.0703	0.0768
142335	0.6654	0.6343	0.0611	0.5983	0.0651	0.036
143641	0.5733	0.56	0.0662	0.5387	0.0673	0.0213
144455	0.5676	0.5704	0.0659	0.5339	0.0717	0.0365
144613	0.6916	0.6428	0.0677	0.6306	0.0708	0.0122
145515	0.5903	0.6118	0.0738	0.6116	0.0798	0.0002
211111	0.8584	0.9575	0.0447	0.9036	0.0453	0.0539
211251	0.6738	0.685	0.0714	0.6365	0.0751	0.0485
211633	0.7051	0.6666	0.0578	0.6791	0.0593	-0.0125
212145	0.6188	0.618	0.0711	0.6037	0.0603	0.0143
213323	0.6571	0.6867	0.0612	0.6875	0.0464	-0.0008
214435	0.5943	0.535	0.0695	0.4488	0.0653	0.0862
221452	0.6627	0.6167	0.0685	0.523	0.0644	0.0937
224612	0.6385	0.6335	0.0672	0.5417	0.0554	0.0918
243433	0.5053	0.4704	0.0706	0.4919	0.0625	-0.0215
243615	0.5913	0.5428	0.0684	0.5502	0.0721	-0.0074
312332	0.701	0.6856	0.0614	0.6578	0.0497	0.0278
315123	0.5582	0.6687	0.0627	0.7099	0.0648	-0.0412
315341	0.6486	0.6633	0.0611	0.6654	0.0635	-0.0021
321122	0.7987	0.7816	0.0547	0.7578	0.0428	0.0238
325433	0.5685	0.5467	0.0678	0.5302	0.0645	0.0165
331115	0.6584	0.6751	0.069	0.6607	0.0704	0.0144
332411	0.6152	0.6261	0.0666	0.6045	0.0559	0.0216
333135	0.631	0.5055	0.0731	0.4745	0.0634	0.031
333455	0.6131	0.4976	0.0662	0.4373	0.0643	0.0603
334251	0.5031	0.535	0.0694	0.504	0.0684	0.031
341414	0.7513	0.6491	0.0593	0.6625	0.0621	-0.0134
341634	0.5209	0.3929	0.0791	0.379	0.0693	0.0139
342613	0.6672	0.5917	0.0611	0.5751	0.0628	0.0166
345153	0.4966	0.5408	0.0677	0.4768	0.0713	0.064
345535	0.6564	0.5834	0.0579	0.5936	0.0606	-0.0102
345553	0.4538	0.4327	0.0656	0.4238	0.0687	0.0089
411612	0.6595	0.6199	0.0658	0.601	0.0699	0.0189
413212	0.6879	0.6641	0.0748	0.5846	0.0716	0.0795

(Table continued on page 14)

Table 4. (continued.)

Health States	Observed mean	HK data ONLY		100 HK & UK data		Difference
		Predicted mean	Predicted STD	Predicted mean	Predicted STD	
415115	0.6264	0.6169	0.0686	0.618	0.0714	-0.0011
415453	0.5826	0.5256	0.0642	0.546	0.0675	-0.0204
421314	0.6607	0.6322	0.0667	0.583	0.0554	0.0492
421641	0.6118	0.6027	0.0613	0.5944	0.0631	0.0083
423435	0.6172	0.5866	0.0591	0.5547	0.0592	0.0319
423615	0.6373	0.5683	0.0622	0.5417	0.064	0.0266
425131	0.5312	0.5509	0.0778	0.4981	0.074	0.0528
431443	0.5838	0.5202	0.0638	0.5026	0.0543	0.0176
441255	0.5133	0.5395	0.0671	0.5056	0.0675	0.0339
442655	0.353	0.3039	0.0777	0.2824	0.0777	0.0215
444611	0.6854	0.5756	0.064	0.5313	0.0688	0.0443
445233	0.4914	0.4717	0.0693	0.4309	0.0677	0.0408
445615	0.4775	0.4955	0.0724	0.4659	0.0744	0.0296
511114	0.6239	0.672	0.0792	0.6098	0.0583	0.0622
511435	0.6804	0.5411	0.0684	0.5601	0.0677	-0.019
511615	0.5991	0.5136	0.0712	0.4842	0.077	0.0294
513654	0.4584	0.4403	0.0679	0.4286	0.0694	0.0117
515155	0.6677	0.5897	0.0619	0.5842	0.0645	0.0055
523551	0.6141	0.5495	0.0616	0.5384	0.058	0.0111
531635	0.5015	0.4516	0.0656	0.3993	0.0571	0.0523
533415	0.5342	0.5309	0.0622	0.4858	0.0663	0.0451
543533	0.4771	0.4381	0.0628	0.4964	0.0581	-0.0583
545151	0.5136	0.4451	0.077	0.3824	0.0806	0.0627
545422	0.6088	0.4837	0.061	0.4749	0.0497	0.0088
611221	0.681	0.74	0.0618	0.6524	0.0593	0.0876
611432	0.4712	0.4963	0.071	0.4485	0.0714	0.0478
611454	0.3346	0.4306	0.0704	0.4209	0.0749	0.0097
612415	0.4566	0.4789	0.0726	0.4221	0.0782	0.0568
614434	0.4449	0.4812	0.0645	0.4868	0.056	-0.0056
615455	0.4993	0.4006	0.0706	0.4056	0.0749	-0.005
615631	0.5056	0.5136	0.0683	0.4403	0.0734	0.0733
615653	0.381	0.3951	0.073	0.4135	0.0775	-0.0184
621135	0.4934	0.5357	0.0731	0.5399	0.074	-0.0042
623353	0.4256	0.4701	0.0687	0.4	0.0662	0.0701
624431	0.5694	0.5654	0.0653	0.4795	0.0604	0.0859
624633	0.3082	0.2823	0.0791	0.26	0.0739	0.0223
625141	0.5605	0.5282	0.0704	0.4287	0.0611	0.0995
631632	0.4974	0.4633	0.0702	0.4186	0.0709	0.0447
632615	0.5484	0.4196	0.0681	0.3918	0.073	0.0278
633653	0.4335	0.371	0.0683	0.4049	0.069	-0.0339
635611	0.4001	0.4323	0.0791	0.3649	0.0815	0.0674
642151	0.5356	0.4967	0.0719	0.4531	0.0774	0.0436
642313	0.5499	0.5602	0.0624	0.5992	0.0655	-0.039
642651	0.3731	0.3614	0.0716	0.332	0.0788	0.0294
643125	0.5007	0.5278	0.0661	0.5429	0.0681	-0.0151
643143	0.463	0.4929	0.066	0.4857	0.0676	0.0072
644614	0.4387	0.4697	0.0687	0.4594	0.0702	0.0103
645235	0.3724	0.3304	0.0729	0.3397	0.0765	-0.0093

Note. Abbreviation: STD, standard deviation.

A key point worth mentioning is that the choice of HK samples does not have a big effect on how well we can estimate the parameters. Although the results presented here are based on health states selected randomly in terms of UK posterior mean utilities, we have obtained (results not shown) similar results when 1) health states are chosen to be well spread over the space of states and 2) health states selected randomly in terms of UK posterior standard deviation values.

The nonparametric model brings two potential advantages. Firstly, where there is sufficient data in one country to estimate a model but few data on another, the pooled analysis produces better estimation of the second country's population utility function than analyzing its data separately. Understanding this will be hugely important in terms of reducing the need for large surveys being undertaken using expensive and often time consuming face to face interviews with techniques such as SG and TTO in every country. Secondly, a Bayesian approach offers the potential for using the results in one country to inform the design in another country by using the results in one country as informative priors. We believe this type of analysis may also allow us to produce better estimation to the second country's population utility function than analyzing its data separately. Work in progress on demonstrating this idea.

The model is applicable to other generic health state descriptive systems such as EQ-5D and HUI-II, as well as to more specialised, disease-specific systems. Work is in progress on application to EQ-5D system. Matlab code for implementing the nonparametric model is available on request.

ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by the author.

CONFLICTS OF INTEREST DISCLOSURE

The author declares that he has no conflict of interest.

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