Tariffs for the Euroqol health states based on modelling the individual VAS and TTO data of the York survey

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Introduction

This paper is a sequel to our paper on the grouped VAS and TTO data of the York survey. In the interest of brevity this paper assumes that readers have access to that first paper. The aim of this paper is to provide suitable models that describe the individual VAS and TTO adjusted scores in terms of the 5 health factors and the respondents' characteristics.

Statistical Method

Notation

1. Four link functions will be investigated:

(i) The identity link function:	$g_0(M) = M$
(i) The logit function:	$g_1(M) = \ln (M / (1-M))$
(ii)The complementary log-log function form 1:	$g_2(M) = \ln (-\ln (1-M))$
(iii)The complementary log-log function form 2:	$g_3(M) = \ln (-\ln(M))$.

2. The adjusted VAS and TTO scores lie between -1 and 1. The following transformation which maps the interval (-1, 1) onto the unit interval (0,1) has therefore been applied to the data before using the link functions g_1, g_2 and g_3:

   $$f(M) = (M+1) / 2$$

3. The set of covariates that will be considered to explain the variation in the adjusted scores are:

   (i) The main effects of the 5 health factors, redefined here as follows:

   Linear effects $F_i(k)$ = -1 if for state k factor i is at level 1
   = 0 if for state k factor i is at level 2
   = 1 if for state k factor i is at level 3

   Non linear effects $F_{i3}(k)$ = 1 if for state k factor i is at level 3
   = 0 if for state k factor i is not at level 3

(ii) The main effects of the 10 variables defining the 'extremity' of each state, ie all of the E_{1m} and E_{3m} (m=1,...,5) where:

$E_{1m}(k)$ = 1 if for state k the number of 1s is equal to m
= 0 if for state k the number of 1s is not equal to m.

$E_{3m}(k)$ = 1 if for state k the number of 3s is equal to m
= 0 if for state k the number of 3s is not equal to m.

(iii) Two dummy variables to indicate whether any of the dimensions is at level 1 or any of the dimensions is at level 3.

$ANY_1(k)$ = 1 if for state k there is one factor or more at level 1.
= 0 if for state k there is no factor at level 1.

$ANY_3(k)$ = 1 if for state k there is one factor or more at level 3.
= 0 if for state k there is no factor at level 3.

(iv) Covariates that describes the available demographic and social characteristics of each respondent, denoted here by C_{lr} (where r denotes the respondent number, ie r =1,2,...,2844 and l denotes the lth characteristics). Note that respondents with missing characteristics have been excluded from models that include respondent characteristics; hence the maximum of r is 2844 instead of 2997.

Strategy

Our strategy in the search of a suitable model can be summarised as follows:

1. Use one of the suggested link function g_L (L=0,1,2 or 3) to produce a set of transformed scores $Y_L(r,k)$ (r=1,2,...2844 or 2997 and k=1,2,..42). (Note that for each respondent information is available about only 12 states out of the total of 42).

2. For a given L, fit the following models:

Model 1: $Y_L(r,k) = \alpha + \alpha_1 ANY_1(k) + \alpha_2 ANY_3(k) + \varepsilon(r,k)$

Model 2: $Y_L(r,k) = \alpha + \Sigma_i \beta_i F_i(k) + \Sigma_i \beta_{i3} F_{i3}(k) + \varepsilon(r,k)$

Model 3: $Y_L(r,k) = \alpha + \alpha_2 ANY_3(k) + \Sigma_i \beta_i F_i(k) + \Sigma_i \beta_{i3} F_{i3}(k) + \varepsilon(r,k)$

Model 4: $Y_L(r,k) = \alpha + \alpha_1 ANY_1(k) + \alpha_2 ANY_3(k) + \Sigma_i \beta_i F_i(k) + \Sigma_i \beta_{i3} F_{i3}(k)$
$+ \varepsilon(r,k)$

Model 5: $Y_L(r,k) = \alpha + \Sigma_i \beta_i F_i(k) + \Sigma_i \beta_{i3} F_{i3}(k) + \Sigma_m \gamma_{1m} E_{1m}(k) + \Sigma_m \gamma_{3m} E_{3m}(k) + \varepsilon(r,k)$

Model 6: $Y_L(r,k) = \alpha + \Sigma_i \beta_i F_i(k) + \Sigma_i \beta_{i3} F_{i3}(k) + \Sigma_l \eta_l C_l(r) + \varepsilon(r,k)$

Model 7: $Y_L(r,k) = \alpha + \alpha_2 ANY_3(k) + \Sigma_i \beta_i F_i(k) + \Sigma_i \beta_{i3} F_{i3}(k) + \Sigma_l \eta_l C_l(r) + \varepsilon(r,k)$

Model 8: $Y_L(r,k) = \alpha + \alpha_1 ANY_1(k) + \alpha_2 ANY_3(k) + \Sigma_i \beta_i F_i(k) + \Sigma_i \beta_{i3} F_{i3}(k) + \Sigma_l \eta_l C_l(r) + \varepsilon(r,k)$

Model 9: $Y_L(r,k) = \alpha + \Sigma_i \beta_i F_i(k) + \Sigma_i \beta_{i3} F_{i3}(k) + \Sigma_m \gamma_{1m} E_{1m}(k) + \Sigma_m \gamma_{3m} E_{3m}(k) + \Sigma_l \eta_l C_l(r) + \varepsilon(r,k)$

where the α, βs, γs and ηs are unknown parameters to be estimated using least squares methods under the assumption that $\varepsilon(r,k)$ are independently Normally distributed random variables. This assumption is simplistic, since it implies that all respondents with the same characteristics have the same values, subject only to random error. A more realistic form of Model 1 would have been:

Model 1': $Y_L(r,k) = \alpha(r) + \alpha_1 ANY_1(k) + \alpha_2 ANY_3(k) + \varepsilon(r,k)$

where $\alpha(r)$ are the mean values for each respondent r. Since computationally this means estimating 2997 respondent-specific parameters, the simpler models 1 to 9 were pursued instead. Note that model 1 describes the data in terms of whether any of the factors is at level 1 and any at level 3; model 2 describes the data in terms of the main effects of the 5 health factors; and model 4 is a combination of models 1 and 2. Model 3 is a simplified version of model 4 that describes the data in terms of the main effects of the 5 health factors and whether any factor is at level 3. Model 5 describes the data in terms of the main effects of the 5 health factors and the extremity of the states. Models 6, 7, 8 and 9 are as models 2, 3, 4 and 5 with the addition of the respondent characteristics. Note also that the intercept parameter α in models 1, 2, 3, 4 and 5 represents the estimated $Y_L(16)$, where state 16 is the state '22222'.

3. When fitting the additional terms in models 6, 7, 8 and 9 over and above models 2, 3, 4 and 5, use stepwise linear regression with significance levels of 0.1% to enter a new variable and 1% to remove an existing variable. These stringent significance levels have been used to overcome the problem of multiple comparisons that is inherent in the stepwise procedure especially when using so many possible covariates. These significance levels will reduce the probability of including terms that are associated with the response variable just by chance.

4. Assess the goodness of fit for each model, firstly by R^2 and secondly by examining the residuals produced by the model, informally via residual plots and formally by testing for Normality by the Kolmogorov-Smirnov test, testing for the independence of the error terms by the Durbin Watson test, and testing for heteroscedasticity by regressing the square of the residuals on the predicted values (so that a significant F-test from this regression would mean significant heteroscedasticity).

Results

VAS DATA

Only some of the models examined need be summarised here. Table 1 summarises the R^2 of models 1, 2, 3, 4 and 5 when using the link functions g_0, g_1, g_2 and g_3. The goodness of fit produced by these models when using form 2 of the complementary log link function, g_3, were higher than when using the other link functions. Table 2 shows the summary statistics for models 2, 3, 4, 5 and 7 when using g_3 as the link function. To combine goodness of fit with simplicity, model 3 is chosen as the 'best buy' since it explains 52.3% of the variation in the data by using 11 explanatory variables; in comparison model 5 explains only an extra 1.5% with an extra six explanatory variables. For completeness, tables 3, 4 and 5 show the parameter estimates for models 2, 3 and 7. Table 5 shows the type of respondent characteristics that are associated with the VAS ratings in addition to the basic variables of model 3. All of these models seem to be 'mispecified', showing significant heteroscedasticity and non-normal errors. Nevertheless they all show non-significant Durbin Watson tests, suggesting that the errors are at least independent. Table 6 shows the predicted values for the 42 states using model 3 and their deviations from the observed means and medians.

TTO DATA

Again only some of the models examined need be summarised here. Table 7 summarises the R^2 of models 1, 2, 3, 4 and 5 when using the link functions g_0, g_1, g_2

and g_3. The goodness of fit produced by g_0 was in general the best. Table 8 shows the analysis of variance for models 2, 3, 4, 5 and 7 when using g_0 as the link function. As for the VAS data, to combine goodness of fit with simplicity model 3 is chosen as the 'best buy'. For completeness, tables 9, 10 and 11 show the parameter estimates for the models 2, 3 and 7. All of these models seem to be 'mispecified', showing significant heteroscedasticity and non-normal errors. Nevertheless they all show non-significant Durbin Watson tests, suggesting that the errors are at least independent. Table 12 shows the predicted values for the 42 states using model 3, and their deviations from the observed means and medians.

Discussion

In this paper two important aspects of model selection for the individual VAS and TTO data were investigated. The first was the choice of the scale of measurement. Among the investigated link functions, the complementary log provided the best fit for the VAS data. This suggests that for this method of rating the adjusted scores are not symmetric about zero ie death. This can be confirmed by examining the means of the VAS data for each state; table 6 shows that only one state (33333) had a mean value which is negative ie worse than death. Using this method of scaling the estimated adjusted score for each state is generally closer to the median than the mean adjusted score (table 6). This achievement of more robust estimates for the adjusted VAS scores is a positive reason for scaling the data by the complementary log link function.

For the TTO data, none of the link functions investigated provided a better fit than the identity link. This absence of any benefit from scaling the data means that the resulting estimates are closer to the mean than to the median adjusted score for each state (table 12). However, the skewness of the data as illustrated by the differences between the means and medians of table 12 and the asymmetry of the residual plot in figure 2, suggest that a successful scaling of the TTO data is still needed. The link functions g_1, g_2 and g_3 were chosen because they can map the data from the range (-1,1) to the range $(-\infty, \infty)$ via the range (0,1), no other link function was investigated. The failure of these link functions suggests that a better strategy would be to use the Box-Cox family of transformations to estimate the scaling parameter that achieves the best compromise between Normality, heteroscedasticity and independence of the transformed data.

The second aspect of model selection investigated in this paper was the choice of covariates that best explain the data. The covariates investigated were the main effects of the five health factors, ten variables defining the 'extremity' of each state, a range of respondent characteristics and finally two variables that summarise the extremity of the state (ANY_1 and ANY_3). For the VAS data, the main effects of the five health factors (model 2) explained 47.2% of the variation in the data, 4.2% more than model 1, which uses only the two summary variables ANY_1 and ANY_3. Adding ANY_3 to model 2 explained a further 5.1% of the variation. In contrast model 5 explained 1.5% more of the variation than model 2 by using 7 extra variables (the main effects of the extremity of each state). The simplicity and goodness of fit of model 3 were the main reasons for choosing it to summarise the VAS data. Similarly model 3 provides a good summary for the TTO data. Although nine respondent characteristics were significantly associated with the TTO method of rating, the resulting model 7 explained only 1.4% more of the variation in the data than model 3. This improvement in the fit was thought to be too costly since it would complicate the calculation of the tariff considerably. Nevertheless the parameter estimates of model 7 are provided so that the reader can study the effect of these characteristics on the rating of the states. In particular respondents with poor self care had considerably higher TTO estimates (table 11).

Despite the R^2 achieved by the models studied none of them passed the tests for Normality or heteroscedasticity of the residual errors. This is not surprising since the power of these tests is very high with such a large number of observations (35964). Nevertheless, it is clear from the residual plot of the TTO data (Figure 2) that there is a systematic pattern in the residuals. A better scaling of the TTO data may overcome this effect.

In summary the two models (model 3 with a complementary log link function form 2 and model 3 with an identity link function) chosen to summarise the individual VAS and TTO adjusted score both combine simplicity and goodness of fit to the data. Nevertheless neither is ideal. With such simple models this seems inevitable. Fortunately we can identify three analytical procedures with the potential to improve these models in future. First, in analysing visual analogue scales, it is preferable to begin with raw data rather than adjusted scores. Secondly the Box-Cox family of transformations is more flexible than the three specific transformations that we investigated. Finally in the short time available to us we could not access any software with the power to estimate parameters for each of the 3000 or so respondents.

Conclusion

Thus we believe that further investment in statistical analysis would lead to even better models and hence better tariffs. Nevertheless the fact that one simple model explains 52% of the variation in individual VAS scores (table 2) and another simple model explains 46% of the variation in individual TTO scores (table 8) represents a major achievement for the MVH team at York. More important it represents a sound basis on which to recommend tariffs for the EuroQol health states. Our tariff for the VAS data can be derived directly from table 4 and that of the TTO data from table 10. The performance of these tariffs is summarised in table 6 and table 12 respectively. That table 12 is virtually identical to the corresponding table of the MVH team's own analysis (table 8 of Dolan, 1994) represents a satisfactory validation of their tariff for the TTO data.

Table 1 Goodness of fit (R^2) for the VAS data using the 4 different link functions

	g_0	g_1	g_2	g_3
Model 1 (2 df[1])	41.1	36.4	25.8	43.0
Model 2 (10 df)	46.9	40.5	29.5	47.2
Model 3 (11 df)	49.0	44.1	31.1	52.3
Model 4 (12 df)	49.4	44.4	31.2	52.8
Model 5 (17 df)	49.5	44.9	31.4	53.6

1 df = degrees of freedom

Table 2 Summary statistics for the VAS data using the complementary log link function form 2

	Sum of squares	DF	Mean square	F-test	Significance of goodness of fit tests (K-S, F for H , D-W)[1]
Model 2 (R^2=47.2%)					
Due to model 2	17620.0	10	1762.0	3215.9	(0.001, 0.001, 0.10)
Residual	19698.7	35953	0.55		
Model 3 (R^2=52.3%)					
Due to model 2	17620.0	10	1762.0	3595.9	(0.001, 0.001, 0.08)
model 3 - model 2	1907.3	1	1907.3	3892.4	
Residual	17791.4	35952	0.49		
Model 4 (R^2=52.8%)					
Due to model 3	19527.3	11	1775.2	3622.9	(0.001, 0.001, 0.08)
model 4 - model 3	190.0	1	190.0	387.8	
Residual	17601.4	35951	0.49		
Model 5 (R^2=53.8%)					
Due to model 3	19527.3	11	1775.2	3622.9	(0.001, 0.001, 0.08)
model 5 - model 3	459.9	6	76.6	156.3	
Residual	17331.5	35946	0.49		
Model 7 (R^2=53.0%)					
Due to model 2	16757.1	10	1675.7	3419.8	(0.001, 0.001, 0.08)
model 3 - model 2	1788.5	1	1788.5	3650.0	
respondent's characteristics	224.2	10	22.4	45.7	
Residual	16641.3	34106	0.49		

1 The goodness of fit tests summarised are the Kolmogorov-Smirnov test for Normality (K-S), the F test for heteroscedasticity (F for H) and the Durbin Watson test for independence (D-W).

Table 3 Parameter estimates for the VAS data using the complementary log link function form 2 and model 2

Parameter	Estimate	SE	T-value
Constant	-1.107	.011	-99.3
F1	0.245	.010	24.9
F2	0.310	.010	29.9
F3	0.333	.011	29.9
F4	0.213	.011	21.7
F5	0.283	.010	27.6
F13	-.085	.018	-4.8
F23	-.183	.018	-10.3
F33	-.088	.019	-4.8
F43	0.174	.017	10.0
F53	-.025	.018	-1.4

Table 4 Parameter estimates for the VAS data using the complementary log link function form 2 and model 3

Parameter	Estimate	SE	T-value
Constant	-1.397	0.012	-120.6
F1	0.235	0.009	25.1
F2	0.375	0.100	37.8
F3	0.079	0.011	7.0
F4	0.308	0.010	32.6
F5	0.266	0.010	27.3
F13	-.128	0.017	-7.6
F23	-.359	0.017	-20.9
F33	0.019	0.018	1.1
F43	-.224	0.017	-12.7
F53	-.249	0.018	-14.0
ANY3	0.813	0.013	62.1

Table 5 Parameter estimates for the VAS data using the complementary log link function form 2 and model 7

Parameter	Estimate	SE	T-value
Constant	-1.442	0.018	-80.1
F1	0.236	0.010	24.7
F2	0.379	0.010	37.5
F3	0.078	0.012	6.7
F4	0.308	0.010	32.0
F5	0.268	0.010	26.9
F13	-.125	0.017	-7.4
F23	-.365	0.017	-24.7
F33	-.020	0.019	-1.1
F43	-.225	0.018	-12.5
F53	-.250	0.018	-13.8
ANY3	0.808	0.013	60.5
The respondent has a degree (including nurses & teachers)	0.106	0.013	8.1
The respondent mobility is mediocre[1]	-.056	0.012	-4.5
The respondent has experienced illness in others	0.061	0.008	7.2
The respondent social class is 4 or 5 (semi or unskilled)	-.109	0.012	-9.1
The respondent social class is 3 (skilled but not managerial)	-.073	0.010	-7.3
The respondent is separated, divorced or widowed	0.052	0.010	5.4
The respondent is a smoker	0.048	0.008	5.8
The respondent has passed school leaving examination	0.049	0.009	5.1
The respondent is older than 60	0.038	0.010	3.9
The respondent usual activity level is mediocre[1]	-0.051	0.013	-3.9

1 Mediocre means the second level of this variable

Table 6 Predicted adjusted VAS scores for an average respondent using the complementary log link function form 2 and model 3, compared with the observed median and mean scores

State	code	Predicted	Median	Mean	Predicted - Median	Predicted - Mean
1	21111	0.83	0.85	0.79	-0.02	0.04
2	11211	0.85	0.85	0.80	0	0.05
3	11121	0.82	0.85	0.81	-0.03	0.01
4	12111	0.81	0.84	0.79	-0.03	0.02
5	11112	0.83	0.87	0.81	-0.04	0.02
6	12211	0.79	0.73	0.69	0.06	0.10
7	12121	0.74	0.70	0.66	-0.04	0.08
8	11122	0.77	0.72	0.67	0.05	0.10
9	22121	0.68	0.68	0.58	0	0.10
10	22112	0.69	0.615	0.59	0.07	0.10
11	11312	0.56	0.54	0.51	0.02	0.05
12	21222	0.69	0.56	0.53	0.13	0.16
13	12222	0.64	0.55	0.53	0.09	0.11
14	21312	0.47	0.50	0.45	-0.03	0.02
15	22122	0.59	0.53	0.51	0.06	0.08
16	22222	0.56	0.50	0.46	0.06	0.10
17	11113	0.62	0.51	0.49	0.11	0.13
18	13212	0.44	0.45	0.42	-0.01	0.02
19	13311	0.51	0.40	0.38	0.11	0.13
20	11131	0.58	0.45	0.40	0.13	0.18
21	12223	0.28	0.37	0.34	-0.09	-0.06
22	21323	0.30	0.30	0.26	0	0.04
23	23321	0.24	0.27	0.25	-0.03	-0.01
24	32211	0.41	0.30	0.29	0.11	0.12
25	21232	0.32	0.33	0.31	-0.01	0.01
26	22323	0.07	0.25	0.20	-0.18	-0.13
27	33212	0.26	0.21	0.18	0.05	0.08
28	23313	0.25	0.20	0.16	0.05	0.09
29	22331	0.20	0.25	0.21	-0.05	-0.01
30	11133	0.47	0.34	0.27	0.13	0.20
31	21133	0.35	0.25	0.23	0.10	0.12
32	23232	0.08	0.21	0.20	-0.13	-0.12
33	33321	0.17	0.15	0.11	0.02	0.06
34	32313	0.20	0.16	0.13	0.04	0.07
35	22233	0.08	0.17	0.16	-0.09	-0.08
36	32223	0.06	0.16	0.13	-0.10	-0.07
37	13332	0.17	0.16	0.14	0.01	0.03
38	32232	0.02	0.17	0.12	-0.15	-0.10
39	32331	0.13	0.13	0.09	0	0.04
40	33232	0.01	0.10	0.06	-0.09	-0.05
41	33323	-.01	0.07	0.02	-0.08	-0.03
42	33333	-0.07	0.00	-0.07	-0.07	0

Table 7 Goodness of fit (R^2) for the TTO data using the 4 different link functions

	g_0	g_1	g_2	g_3
Model 1 (2 df)	37.8	36.8	32.3	37.7
Model 2 (10 df)	44.6	42.0	39.2	41.3
Model 3 (11 df)	45.9	44.0	39.9	44.5
Model 4 (12 df)	46.0	44.2	40.0	44.8
Model 5 (17 df)	46.2	44.3	40.0	44.9

Table 8 Summary statistics for the TTO data using the identity link function

	Sum of squares	DF	Mean square	F-test	Significance of goodness of fit tests (K-S, F for H, D-W)[1]
Model 2 (R^2=44.6%)					
Due to model 2	7034.8	10	703.5	2931.3	(0.001, 0.001, 0.07)
Residual	8752.9	35953	0.24		
Model 3 (R^2=45.9%)					
Due to model 2	7034.8	10	703.5	2931.3	(0.001, 0.001, 0.06)
model 3 - model 2	214.3	1	214.3	892.9	
Residual	8538.6	35952	.24		
Model 4 (R^2=46.0%)					
Due to model 3	7249.1	11	629.0	2745.9	(0.001, 0.001, 0.06)
model 4 - model 3	16.4	1	16.4	68.3	
Residual	8522.2	35951	.24		
Model 5 (R^2=46.2%)					
Due to model 3	7249.1	11	659.0	2745.8	(0.001, 0.001, 0.06)
model 5 - model 3	38.7	6	6.5	27.1	
Residual	8499.9	35946	.24		
Model 7 (R^2=47.3%)					
Due to model 2	6715.0	10	671.5	2919.5	(0.001, 0.001, 0.06)
model 3 - model 2	197.5	1	197.5	858.7	
respondent's characteristics	181.0	9	20.1	87.4	
Residual	7906.5	34107	.23		

1 The goodness of fit tests summarised are the Kolmogorov-Smirnov test for Normality (K-S), the F test for heteroscedasticity (F for H) and the Durbin Watson test for independence (D-W).

Table 9 Parameter estimates for the TTO data using the identity link function and model 2

Parameter	Estimate	SE	T-value
Constant	0.424	0.007	57.0
F1	-.071	0.007	-10.7
F2	-.084	0.007	-12.1
F3	-.118	0.007	-15.9
F4	-.088	0.007	-13.4
F5	-.078	0.007	-11.4
F13	-.191	0.012	-16.4
F23	-.066	0.012	-5.6
F33	0.014	0.012	1.2
F43	-.277	0.012	-23.9
F53	-.160	0.012	-13.9

Table 10 Parameter estimates for the TTO data using the identify link function and model 3

Parameter	Estimate	SE	T-value
Constant	0.521	0.009	59.9
F1	-.067	0.007	-10.3
F2	-.105	0.007	-15.4
F3	-.033	0.008	-4.2
F4	-.119	0.007	-18.3
F5	-.072	0.007	-10.7
F13	-.177	.012	-15.3
F23	-.007	.012	-.62
F33	-.022	0.013	-1.8
F43	-.143	0.012	-11.7
F53	-.094	0.012	-7.6
ANY3	-.273	0.010	-30.0

Table 11 Parameter estimates for the TTO data using the identity link function and model 7

Parameter	Estimate	SE	T-value
Constant	0.568	0.009	59.9
F1	-.066	0.007	-10.0
F2	-.105	0.007	-15.1
F3	-.036	0.007	-4.5
F4	-.119	0.007	-17.9
F5	-0.070	0.007	-10.3
F13	-.176	0.012	-15.0
F23	-.010	0.012	-.79
F33	0.018	0.013	1.4
F43	-.145	0.012	-11.6
F53	-.103	0.013	-8.2
ANY3	-.269	0.010	-29.2
The respondent is older than 60	-.123	0.006	-19.4
The respondent is a male	0.043	0.005	7.9
The respondent is single	-.076	0.007	-10.5
The respondent is separated, divorced or widowed	-.063	0.007	-9.2
The respondent's mobility is mediocre[1]	0.045	0.008	5.7
The respondent's self care is poor[2]	0.374	0.070	5.4
The respondent's self care is mediocre[1]	0.066	0.014	4.5
The respondent's social class is 3	-.020	0.005	-3.8
The respondent's job cares for ill people	-.026	0.008	-3.5

1 Mediocre means the second level of this variable

2 Poor means the third level of this variable

Table 12 Predicted adjusted TTO scores for an average respondent using the identity link function and model 3, compared with the observed median and mean scores

State	code	Predicted	Median	Mean	Predicted - Median	Predicted - Mean
1	21111	0.85	0.95	0.88	-0.10	-0.03
2	11211	0.88	0.95	0.87	-0.07	0.01
3	11121	0.80	0.93	0.85	-0.13	-0.05
4	12111	0.81	0.93	0.83	-0.12	-0.02
5	11112	0.85	0.93	0.83	-0.08	0.02
6	12211	0.78	0.90	0.77	-0.12	0.01
7	12121	0.69	0.85	0.74	-0.16	-0.05
8	11122	0.73	0.83	0.72	-0.10	0.01
9	22121	0.63	0.78	0.64	-0.15	-0.01
10	22112	0.67	0.75	0.66	-0.08	0.01
11	11312	0.48	0.68	0.55	-0.20	-0.07
12	21222	0.63	0.65	0.55	-0.02	0.08
13	12222	0.59	0.65	0.55	-0.06	0.04
14	21312	0.42	0.65	0.54	-0.23	-0.12
15	22122	0.55	0.65	0.54	-0.10	0.01
16	22222	0.52	0.63	0.50	-0.11	0.02
17	11113	0.41	0.50	0.39	-0.09	0.02
18	13212	0.32	0.50	0.39	-0.18	-0.07
19	13311	0.34	0.50	0.35	-0.16	-0.01
20	11131	0.26	0.38	0.20	-0.12	0.06
21	12223	0.15	0.38	0.22	-0.23	-0.07
22	21323	0.13	0.38	0.16	-0.25	-0.03
23	23321	0.15	0.30	0.15	-0.15	0
24	32211	0.19	0.28	0.15	-0.09	0.04
25	21232	0.09	0.14	0.06	-0.05	0.03
26	22323	0.03	0.03	0.04	0	-0.01
27	33212	0.01	0.0	-0.02	0.01	0.03
28	23313	0.03	0.0	-0.07	0.03	0.10
29	22331	0	0.0	-0.01	0	0.01
30	11133	0.03	0.0	-0.05	0.03	0.08
31	21133	-0.04	-0.03	-0.06	-0.01	0.02
32	23232	-0.13	-0.03	-0.08	-0.10	-0.05
33	33321	-0.09	-0.18	-0.12	0.09	0.03
34	32313	-0.10	-0.23	-0.15	0.13	0.05
35	22233	-0.18	-0.23	-0.14	0.05	-0.04
36	32223	-0.16	-0.28	-0.17	0.12	0.01
37	13332	-0.11	-0.38	-0.23	0.27	0.12
38	32232	-0.26	-0.38	-0.22	0.12	-0.04
39	32331	-0.24	-0.38	-0.28	0.14	0.04
40	33232	-0.37	-0.43	-0.33	0.06	-0.04
41	33323	-0.33	-0.48	-0.39	0.15	0.06
42	33333	-0.59	-0.63	-0.54	0.04	-0.05

Figure 1 Plot of studentised residuals against predicted values for the VAS data using the complementary log function form 2 and model 3

```
           ++----+----+----+----+----+----+----+----++
S       10+                                           +
t         |                                           |
u         |                                           |
d         |                                           |
e         |          2631                             |
n        5+           1 11233587                      +
t         |           243 12 1 5FFAKDFB               |
i         |        24DEC83 2247A761359G******J        |
z         |        1E*******V*****NQSKP***PPR*R       |
e         |        5**************************E       |
d        0+        2***************************4      +
          |        4***************************2      |
R         |         7*****UGGTM***RY*V***Z**8         |
e         |        22NL**P824C4CDB89447887A622        |
s         |         22AC4438454BA 1 2  342  1         |
i       -5+               1 1    446474  1            +
d         |                             47222         |
u         |                                           |
a         |                                           |
l         |                                           |
       -10+                                           +
           ++----+----+----+----+----+----+----+----++
        -3.5       -2.5       -1.5        -.5        .5

                        Predicted Value
```

Symbols used:

1	1	11	B	21	L	31	V
2	2	12	C	22	M	32	W
3	3	13	D	23	N	33	X
4	4	14	E	24	O	34	Y
5	5	15	F	25	P	35	Z
6	6	16	G	26	Q	36 or more	*
7	7	17	H	27	R		
8	8	18	I	28	S		
9	9	19	J	29	T		
10	A	20	K	30	U		

Figure 2 Plot of studentised residuals against predicted values for the TTO data using the identity link function and model 3

```
         ++----+----+----+----+----+----+----+----++
S        4+                                        +
t         |                                        |
u         |Y                                       |
d         |A     F9                                |
e         |R     HB*Z*W**                          |
n        2+*     LJ*ISP******                      +
t         |*     *************** *                 |
i         |*     V************** **** *            |
z         |*     **Y************ **** ******       |
e         |*     Z************** **** ***********  |
d        0+*     ************U** **** ***********  +
          |*     ***********W*** *PV* ***********  |
R         |*     **************Q I*** *LRW*******  |
e         |      *************** *QWT B*****DLT*P  |
s         |        ************* **** MHFBCKKH**G  |
i       -2+             ******** *OK* GZJNLH71368  +
d         |                  N** *P** EK9E*C38771  |
u         |                       CHZ HAIFQ374742  |
a         |                            9B7OC41351  |
l         |                                26489   |
        -4+                                     2  +
         ++----+----+----+----+----+----+----+----++
        -.6       -.2         .2        .6         1
```

Predicted Value

Symbols Used:

1 - 1	11 - B	21 - L	31 - V
2 - 2	12 - C	22 - M	32 - W
3 - 3	13 - D	23 - N	33 - X
4 - 4	14 - E	24 - O	34 - Y
5 - 5	15 - F	25 - P	35 - Z
6 - 6	16 - G	26 - Q	36 or more - *
7 - 7	17 - H	27 - R	
8 - 8	18 - I	28 - S	
9 - 9	19 - J	29 - T	
10 - A	20 - K	30 - U	