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THE SUBJECTIVE WELLBEING SCALE: HOW REASONABLE IS THE CARDINALITY ASSUMPTION?

by

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DISCUSSION PAPER 11.15

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Abstract:

This paper empirically investigates the reasonability of assuming subjective wellbeing (SWB) data are cardinal. The inability or reluctance to assume cardinality implies limitations to use of data and methodology, which has been demonstrated to yield potentially biased results. This analysis uses the concept of transitivity to investigate the likely functional form of the SWB reporting function via a second alternative wellbeing measure. Here, data on mental health are used for this purpose. Results indicate that the SWB reporting function cannot deviate strongly from linearity, implying that the cardinality assumption is reasonable in most research contexts. An auxiliary analysis examines the bias that may result from possible nonlinearities in the SWB reporting function, which gives an indication of the potential cost of wrongfully imposing cardinality upon these data.

Key words: Subjective wellbeing, life satisfaction, cardinality, mental health

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Introduction

The use of survey-based data on SWB in economic analysis has become mainstream, though scholars differ in their assumptions about the nature of the SWB scale. While psychologists tend to assume cardinality, economists are often reluctant to do so.[1] Consequently, scholars differ in their use of analytical tools. This paper provides an empirical investigation into the reasonableness of imposing cardinality on subjective wellbeing (SWB) data.

Ferrer-i-Carbonell and Frijters (2004) represents an important contribution to the SWB literature by demonstrating the potential costs of rejecting cardinality without due justification. Comparing the results from methods which impose and avoids the assumption of cardinality they find that results of simple analyses are generally consistent, which in itself seems to provide some justification for the cardinality assumption. They argue that reluctance to assume cardinality has resulted in predominantly logit and probit based estimators and a lack of time-invariant fixed effects models in economic analysis, which can lead to biased results. This implies that SWB data users need to understand how reasonable the cardinality assumption is and can make informed judgements about whether or not to impose cardinality on these data.

This study uses Australian data on life satisfaction and mental health to examine the likely shape of the SWB reporting function, as this allows us to make inferences about the cardinality of the SWB scale. Results indicate that this shape is likely to lie somewhere in the range between ‘very weakly sigmoid’ and ‘very weakly inverse sigmoid’, with a reasonable possibility of linearity. This allows SWB data users to understand the likely risks involved in assuming these data are cardinal and the possible costs of wrongfully assuming cardinality. This will hopefully encourage data users to make more efficient use of the information contained in these data, and avoid the information waste that may result from treating the SWB scale as merely ordered.

The SWB Reporting Function

This study examines cardinality specifically of the eleven-point numeric SWB scale. The discrete numeric SWB scale, where respondents are asked to indicate their degree of

[1] Throughout this paper cardinality will refer to interval, and not ratio-scale quality. That is, it is the criterion of equidistance of the SWB scale that is examined. Interval quality is sufficient for the vast majority of analytical tools used in economic research. For a more detailed discussion on the issue of ratio-quality in wellbeing data, see Kristoffersen (2010). For good surveys of the development of wellbeing and utility measurement in economics, see for example Bruni and Sugden (2007), Colander (2007), and van Praag and Ferrer-i-Carbonell (2004).

happiness or satisfaction with life by choosing an integer on a scale between two extremes, conveys some intention of cardinality. Research into the perception of such scales have revealed that people interpret them as cardinal, and intend to provide responses that reflect this as accurately as possible (Van Praag 1991; Parducci 1995; Schwartz 1995). However, we don't know much about whether such intentions result in a scale that is indeed cardinally comparable across individuals. That is, we don't know whether people who score 9 and 10 on the SWB scale are equally different to people who score 5 and 6, in terms of true wellbeing.

Following the notation used in Blanchflower and Oswald (2004), the relationship between the true unobservable concept of wellbeing and the observed response can be modeled as follows:

$$r = h(u) + e \, . \qquad (1)$$

Here, r is the individual's reported wellbeing score, u is to be interpreted as the individual's true wellbeing or utility, h is the function that transforms true wellbeing into reported wellbeing, and e is an error term. Cardinality is a consequence of a linear function h (Blanchflower and Oswald 2004). Because u is unobservable, we cannot observe the shape of function h directly, though it is possible to investigate its shape indirectly.

Like other latent variables, there is a potentially limitless range of ways to capture wellbeing into some observable measure, including psychophysical measures (which can include anything from smiling frequency to brain activity) and survey instruments (generated by item response). Underlying every one of these measures is a reporting function which translates the same unobservable concept of true wellbeing into a particular indicator. That is, u translates into SWB via the function h, and also into another alternative wellbeing measure we can call w via another function we can call g. Since u is unobservable both h and g are also unobservable. However, using the rule of transitivity, certain features of h and g may be observed indirectly via a third function we can call k, which describes the relationship between r and w. Formally (ignoring the error terms):

$$r = h(u), \;\; w = g(u) \;\rightarrow\; r = h\left[g^{-1}(w) \right] = k(w) \qquad (2)$$

This means that the curvature of the observable function k is a result of the combination of h and the inverse of g. The observed form of k then implies a limited set of possibilities with respect to the shapes of functions h and g. In particular, if we know something about the shape of g, the range of possible shapes of h may be quite narrow.

Psychometric indicators tend to use responses to a specific set of questions to generate an observable measure of a latent psychological concept. For example, intelligence and extraversion can be measured in this way. The reporting functions for such indicators are expected to follow sigmoid form, as specified by the basic Rasch model (Rasch 1961). Specifically, indicators which include responses to multiple questions are close to linear across the middle section of the measurement scale, though score distances increase toward the very edges of the scale. In general, the more items are included in the indicators the less curved, and more close to linear, the aggregate reporting function is likely to be. The SWB indicator is different from other psychometric indicators, most significantly in that the definition, as well as the evaluation and translation, of psychological wellbeing rest entirely with the respondent. Hence, SWB reporting function may well also be sigmoid shaped, though this is less certain.

The literature provides conclusive evidence that the SWB reporting function is positive monotonic.[2] Beyond this, there is no common consensus on its specific shape. Hence, data users must either assume cardinality, which implies assuming a linear reporting function, or reject cardinality, which generally implies rejecting any information contained in SWB data beyond order.

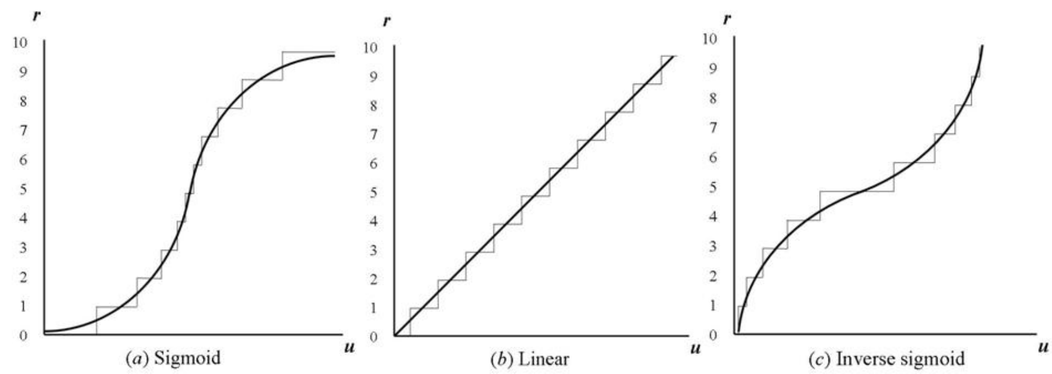
Ng (2008) argues that the SWB reporting function is likely to be sigmoid, suggesting that it takes more wellbeing to lift someone from a score of 9 to a score of 10 (or from 0 to 1) than it does to lift someone from a score of 5 to a score of 6, because of the bounded nature of the measured scale. Studies on attitudes toward selecting scores at the extremes of a scale have found that some people who feel very happy and satisfied avoid selecting the maximum score of 10, either due to modesty, the idea that the maximum score is not possible or because “it is always possible to be even happier” (Lau 2007). However, given that this only applies to some people, groups of people who score 9 and 10 may be *less* different, rather than more different, in terms of true wellbeing. If such effects dominate the reporting function when observed across individuals, its shape may be inverse sigmoid, rather than sigmoid.

Hence, to the extent that the reporting function h has some recognisable pattern, it is likely to lie somewhere in the spectrum between sigmoid and inverse sigmoid, including linearity, as illustrated in Figure 1.

[2] See for example Larsen and Fredrickson (1999), van Praag (1991), Sandvik, Diener, *et al*. (1993), and Diener, Suh, *et al.* (1999).

Figure 1

Hypothesized Reporting Functions



Note: The stepped lines in this diagram reflect discrete measurement scales. Panel (*a*) is adapted from Ng (2008). Panel (*b*) and the notation used is sourced from Blanchflower and Oswald (2004).

This set of possible reporting functions produces a limited set of possible shapes of the observable function *k*, which itself also must lie somewhere in the spectrum between sigmoid and inverse sigmoid, depending on the shape of function *g*. For example, a linear function *k* can only result from functions *g* and *h* taking exactly the same form (with the same strength in curvature). This is because function *k* is function *h* transformed by g^{-1}, so if *h* and *g* have the same shape and curvature function *k* will be linear. If *g* and *h* take opposite forms, then the form of *k* will be an exaggeration of *h*. Of course, many other possibilities exist, as summaries in Table 1.

Table 1

The possible shapes of function k, given the shapes of functions h and g

		Function *h*				
		S	*s*	*LIN*	*is*	*IS*
Function *g*	*S*	*LIN*	*is*	*IS*	*IS**	*IS***
	s	*s*	*LIN*	*is*	*IS*	*IS**
	LIN	*S*	*s*	*LIN*	*is*	*IS*
	is	*S**	*S*	*s*	*LIN*	*is*
	IS	*S***	*S**	*S*	*s*	*LIN*

Legend: *LIN* = linear; *s* = weakly sigmoid; *S* = strongly sigmoid; *S** = very strongly sigmoid (etc.);
is = weakly inverse sigmoid; *IS* = strongly inverse sigmoid; *IS** = very strongly inverse sigmoid (etc).

If function *k* is found to be irregular we could either conclude that no recognisable pattern exists, and that cardinality is not a reasonable assumption, or the range of possible functional forms could potentially be expanded in search for a recognisable pattern and a functional form that enables transformation of SWB data onto a linear scale.

The Shape of the Indirect Reporting Function *k*

The function *k* describes the relationship between reported wellbeing *r* and an alternative wellbeing measure *w*. Here, *r* is represented by self-assigned scores on life satisfaction (a measure of SWB). These are obtained by asking respondents to indicate their level of life satisfaction by choosing an integer on an eleven-point numeric scale where only the ends and midpoint of the scale are labeled (0 = very dissatisfied, 5 = neither satisfied nor dissatisfied, and 10 = very satisfied). The alternative wellbeing measure (*w*) used in this analysis is the specific mental health component of the SF-36 Health Survey instrument. The full SF-36 Health Survey instrument contains 36 questions on physical and broad mental health, the latter comprising social functioning, vitality and specific mental health. Both wellbeing measures are sourced from the Australian HILDA survey.[3]

The specific mental health index (hereafter referred to as the MH index) is generated by asking the question 'How much of the time during the past 4 weeks (a) have you been a nervous person, (b) have you felt so down in the dumps that nothing could cheer you up, (c) have you felt calm and peaceful, (d) have you felt down, and (e) have you been a happy person'. Responses are coded to a six-point scale of (1) all of the time, (2) most of the time, (3) a good bit of the time, (4) some of the time, (5) a little of the time, and (6) none of the time. The MH score is calculated by first reversing the scores where appropriate such that higher values indicate better mental health, then adding the score for each question, and finally standardising this sum to a 0-100 index, in accordance to the procedure outlined in Ware *et al.* (2000). The components of the SF-36 Health Survey instrument has specifically been found to fit a weakly sigmoid Rasch model (Raczek *et al.* 1998).

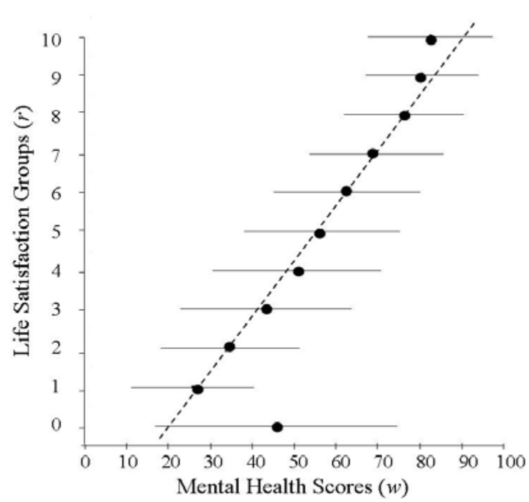
The analysis is performed as follows. First, the sample is sorted by SWB scores to produce eleven SWB groups for each score point. Each individual is assigned a MH score, such that each SWB group exhibits a frequency distribution of MH scores. The shape of the function *k* is revealed via the shifts in the distributions of MH scores as we move up the SWB scale. A

[3] The analysis was performed using cross-sectional data from several waves (1 through to 8) of the HILDA survey. Results were very similar for all waves. The results presented in this paper are from wave 6. All waves exhibit slight differences in wellbeing characteristics, and the characteristics of the wave 6 data were found to be very close to those of all waves combined. It was not practical to pool all the data due to computational limitations.

positive monotonic function *k* requires that the mean MH scores of each SWB group ($\overline{w}_j$) follow an ascending ordering. A linear function *k* requires that the distances between each adjacent pair of means (d_j) are equal. If these distances increase toward the extremes of the scale this implies a sigmoid shaped function *k*, and if they decrease toward the extremes of the scale this implies an inverse sigmoid shape.

The actual shifts in the MH distributions of each SWB group are illustrated in Figure 2. This figure displays mean MH scores of each group, with a line extending one standard deviation in each direction. Details are provided in Table 2. The figure shows that function *k* is remarkably close to linear. The last two SWB groups deviate slightly away from the straight line in a manner that is suggestive of a weakly inverse sigmoid shaped function *k*. The notable exception is the first SWB group, thought not much can be implied from this given the small size of this group (14 respondents). In general, the low number of respondents in the bottom half of the SWB scale suggests that what occurs at this end is less important than what occurs at the upper half of the scale.

Figure 2:
Mental Health Characteristics of Life Satisfaction Groups



The hypothesis that the function *k* is in fact linear is testable. This implies testing the hypothesis that the distances between the MH means are equal, which implies estimating the model

$$w_i = \beta_0(SWB_{0,i}) + \beta_1(SWB_{1,i}) + ... + \beta_9(SWB_{9,i}) + \beta_{10} + \varepsilon_i . \qquad (3)$$

Here, mental health scores (w) are regressed on a set of dummy variables indicating the life satisfaction group to which each sampled individual belongs. SWB_0 has the value 1 for individuals with a life satisfaction score of 0, and a value of 0 otherwise, and so forth. SWB_{10} is the control group. The intercept term β_{10} will then return the mean mental health value for SWB_{10}, and the other betas give the distance of the other group means from this value. The parameter ε is the error term.

Table 2

Descriptive Statistics of the Data

Mental Health (MH, w)		*Life Satisfaction (SWB, r)*				
N	11610	N	11610			
Mean	74.30	Mean	7.91			
Median	80	Median	8			
SD	17.15	SD	1.46			
Score Interval	Distribution	Score Groups	Distribution	Mean MH score ($\overline{w}_j$)	SD of MH scores	Difference in mean MH score (d_j)
		0	0.12%	45.71	29.00	-
0-9	0.23%	1	0.18%	25.71	14.62	-20.00 (d_1)
10-19	0.34%	2	0.30%	34.71	16.69	9.00 (d_2)
20-29	1.51%	3	0.59%	43.20	20.40	8.49 (d_3)
30-39	1.71%	4	1.11%	50.46	20.18	7.25 (d_4)
40-49	5.83%	5	4.28%	56.54	18.57	6.08 (d_5)
50-59	7.73%	6	5.57%	62.45	17.52	5.91 (d_6)
60-69	15.95%	7	19.99%	69.64	16.05	7.19 (d_7)
70-79	16.00%	8	33.47%	76.28	14.38	6.63 (d_8)
80-89	33.75%	9	21.86%	80.49	13.36	4.22 (d_9)
90-100	16.95%	10	12.52%	82.48	14.88	1.98 (d_{10})

Testing for equidistance of MH means ($\overline{w}_j$) implies testing that the betas in Equation (3) are equidistant. This requires that a representative distance is chosen with which all other distances are compared. This may be determined by the slope of the best-fit linear equation between the two wellbeing measures, excluding the first and last SWB groups, which implies the representative difference is that between SWB_4 and SWB_5.[4] The hypothesis is therefore tested by imposing the following restrictions on the model:

[4] This slope is calculated at 5.43 for the entire sample, 6.06 when excluding the SWB_{10} group, or 6.18 excluding both the SWB_0 and the SWB_{10} groups. The distance between SWB_4 and SWB_5 is closest (6.08) to the latter slopes.

$$H_0:\ (\beta_1-\beta_0)-(\beta_5-\beta_4)=0,...,(\beta_8-\beta_7)-(\beta_5-\beta_4)=0,(-\beta_9)-(\beta_5-\beta_4)=0 \quad (4)$$

When the model is estimated with these restrictions, the nested hypothesis is rejected by the data (F = 17.78, p-value < 0.0000). The first and the last two distances (i.e. d_1, d_9 and d_{10}) have to be excluded from the nested hypothesis in order for the F-test to fail (F = 0.49, p-value = 0.8154), and equidistance to be accepted.[5] Hence, statistical tests reject linearity of the function k in favour of a weakly inverse sigmoid shape. It should be noted that this hypothesis test is naturally much more sensitive to deviations from linearity in the upper end of the SWB scale, as this is where the majority of respondents belong. Hence, larger deviations away from linearity further down the SWB scale may not cause the hypothesis to be rejected, but even small deviations in the upper half will.

Given that g is found to be weakly sigmoid, a weakly inverse sigmoid shape of k implies that the shape of h must be close to linear.

Implications

The analysis above demonstrates that the SWB reporting function must be very close to linear. However, it is possible that h is very weakly sigmoid (if g is more strongly sigmoid than k is inverse sigmoid), and it is also possible that h is very weakly inverse sigmoid (if g is less strongly sigmoid than k is inverse sigmoid). This means it is possible to examine the consequences of imposing cardinality upon SWB data if the SWB-reporting function is in fact very weakly sigmoid or inverse sigmoid.

An illustrative example is provided below, where three sets of estimates of the same parameters are produced, using raw SWB data and two different transformations. The transformations will represent the correction required to linearise very weakly curved SWB reporting functions. The strength of curvature of these functions may be described by the ratio of the distance between adjacent scores at the end of the SWB scale and the distance between adjacent scores at the middle of the scale. This score interval ratio is about one-third for function k, which gives the definition of a weak curvature used here. The curvature of a 'very weakly' sigmoid function is defined here as being two-thirds (half-way between one-third and one). The linearisation of a 'very weakly' sigmoid reporting function requires transformation by a similarly 'very weakly' inverse sigmoid function, and vice versa. Details of these transformations are provided in Appendix A.

[5] Other nearby distances were also used as benchmark representative differences, with the same main statistical results. Regression output for key models are provided in Appendix B.

Consider then a linear regression model where SWB is expressed as a function of financial satisfaction, demographic characteristics, employment status, physical health and personal characteristics.[6] Model estimates are provided in Table 3 (standard errors are provided in brackets).

Table 3
Effects of Data Transformation

Explanatory Variables	*SWB reporting function* *Very weakly inverse sigmoid*		*Linear (raw data)*		*Very weakly sigmoid*	
Intercept	3.84***	(0.1293)	3.97***	(0.1135)	4.08***	(0.1009)
Financial satisfaction	0.258***	(0.0097)	0.247***	(0.0092)	0.236***	(0.0089)
Female	0.133***	(0.0439)	0.114***	(0.0383)	0.096***	(0.0338)
Partnered	0.267***	(0.0547)	0.239***	(0.0478)	0.212***	(0.0421)
Children in household	-0.058	(0.0446)	-0.044	(0.0389)	-0.031	(0.0342)
Unemployed	0.257*	(0.1463)	0.165	(0.1274)	0.098	(0.1122)
Not in labour force	0.361***	(0.0642)	0.278***	(0.0560)	0.210***	(0.0493)
Health	0.016***	(0.0012)	0.014***	(0.0010)	0.013***	(0.0009)
Personal characteristics (‘trust’)	0.185***	(0.0227)	0.168***	(0.0198)	0.152***	(0.0174)
$\bar{R}^2$	0.262		0.271		0.276	
F-statistic	195.98 (p<0.000)		204.76 (p<0.000)		210.70 (p<0.000)	
Number of observations	4395		4395		4395	

Statistical significance at the 90, 95 and 99 per cent levels of confidence is indicated by *, **, and ***.

The model estimates essentially provide the range of what is possible within the boundaries suggested by the main analysis. That is, the true model estimates are likely to lie somewhere in the range bounded by the estimates provided in the table. Model fit is very similar for all three sets of estimates, though slightly better for the very weakly sigmoid reporting function. This may be interpreted as support for this type of nonlinearity. Variable coefficients all have the expected signs and relative magnitudes, except for the unemployment dummy variable. Unemployment is commonly found to have a strong negative effect on SWB, however this effect is mediated here by the financial satisfaction variable, which absorbed the negative

[6] These data are drawn from Wave 6 of the HILDA data set, and are limited to people between age 36 and 55 (inclusive). Because this age-bracket is quite narrow, age is not included as an explanatory variable. Financial satisfaction is used instead of income and wealth, to indicate utility of income and wealth. This is convenient because the coefficient for income is highly sensitive to the inclusion of wealth and also physical health into the model, which makes it difficult to interpret the income slope coefficient. Financial satisfaction is measured by asking respondents “How satisfied are you with your financial situation?”, and responses are provided on a 0-10 scale, as for life satisfaction. This reporting function is therefore assumed to exhibit the same shape as the life satisfaction reporting function, and these scores are therefore transformed using the corresponding methods. The other explanatory variables are chosen because they are identified in the literature as important determinants of SWB. Health is represented by the Physical Health component of the SF-36 Survey Instrument, which aggregates responses to a set of questions probing physical health into an index number between 0 and 100 (where 100 is best possible physical health). Personal characteristics are found to be captured in psychometric variable such as optimism, neuroticism, self-esteem and trust. Here, a variable for trust is used, which aggregates responses to six questions probing trust into an index between 1 and 7.

effects of unemployment and leaves the coefficient positive, though with low statistical significance.

A sigmoid transformation of SWB scores effectively stretches the SWB scale at its edges. Because the majority of respondents score in the upper half of the scale, the transformation causes the intercept term to fall and the slope coefficients to increase (along with the standard errors), as seen in the first column of Table 3. Conversely, an inverse sigmoid transformation compresses the SWB scale at its edges, hence the intercept increases and the slope coefficients fall (as do the standard errors), as seen in the last column of Table 3. Variables may differ in terms of where on the SWB scale they have the greatest impact. That is, some variables may affect SWB by 'shifting' individuals from high scores to even higher scores, while other variables may shift individuals from low scores to moderate scores. Coefficients for the former type of variable will be most affected by data transformation, while coefficients for the latter type are unlikely to be affected. Coefficients will only be moderately affected for variables that have a similar effect across all types of individuals. Note that the coefficient for financial satisfaction is only affected through interactions with other included variables, since this scale is transformed in the same way as the life satisfaction scores.

The statistical significance for independent variables are unaffected by SWB data transformations, with the exception of the unemployment variable, which is only significant in determining SWB when the reporting function is assumed to be very weakly inverse sigmoid (though, as mentioned, this coefficient has the wrong sign and cannot be interpreted in isolation). Ignoring unemployment, the variable that is most effected by data transformations is the dummy variable for people who are not in the labour force. This variable increases by 30 per cent when the reporting function is assumed very weakly inverse sigmoid, and falls by 25 per cent when assumed very weakly sigmoid. Therefore, employment variables seem to be most sensitive to the functional form of the reporting function. The intercept term is least affected by data transformation in relative terms (intercepts change by about 3 per cent). Among the variables, health and personal characteristics are least affected, where coefficients change by about 11 per cent after data transformation.

In sum, possible nonlinearities in the SWB reporting function do not affect the significance of intercepts or slope coefficients in this example. Relative magnitudes are also not notably affected, though absolute magnitudes are somewhat affected. This illustrative analysis indicates that slope coefficients can be affected by as much as 30 per cent. SWB data users who wish to assume cardinality but also consider the possibility of nonlinearities in the reporting function can use this information to place an extra error margin around their model estimates.

Conclusion

The choice of whether or not to accept cardinality must in general be made on the basis of the trade-off between known rewards and unknown costs. If rewards are considerable data users are probably more likely to indulge in such a leap of faith, but if they are not it may seem safest to assume at most that SWB data are monotonically ordered. Conservative data users may still feel uneasy about accepting cardinality so long as we can never truly know this to be true.

The main premise of this paper is to employ the basic rule of transitivity to provide information about the SWB reporting function, even though it is unobservable directly. The analysis presented here shows specifically that the SWB reporting function may well be linear, and if it is not strictly linear it is likely to be very close to linear. In conclusion, the assumption of linearity appears eminently reasonable, though SWB data users ought to acknowledge the possibility that some bias may result from the possibility of a weak curvature. While cardinality is not categorically proved or rejected, this paper transforms the cardinality assumption from being a leap of faith to being an informed decision based on observed metrics and logical deduction.

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Appendix A: Transforming SWB Scores

If the SWB reporting function is sigmoid, then the linearisation of SWB requires these data to be transformed by an inverse sigmoid function of the same strength of curvature. The standard logit function is inverse sigmoid, and is specified

$$y = \ln\left(\frac{x}{1-x}\right).$$

Here, the input variable x is bounded by (0,1). Hence, SWB must first be scaled such that it falls within this domain. The closer the end-points are allowed to get to 0 and 1, the stronger the curvature of the function. The curvature of a ‘very weakly’ inverse sigmoid function, as defined here, is consistent with a domain of [0.18, 0.82], which gives the output range [-1.5,1.5].

Similarly, an inverse sigmoid SWB reporting function is linearised by transforming SWB data using a sigmoid function with the same strength curvature. The standard logistic function is sigmoid, and is specified

$$y = \frac{1}{1+e^{-x}}.$$

Because this is the inverse of the standard logit function, the domain for x consistent with a ‘very weakly’ sigmoid function is [-1.5, 1.5], with the output range of [0.18, 0.82].

Raw transformed values can be scaled according to the requirements of the researcher. In this case, it is deemed appropriate to keep the distances between score points intact around the middle of the scale the same for both the raw data and the transformed data. Thus, the scores of 4, 5 and 6 are the same across all scales.

Appendix B: Regression output

Note: Model estimates for this paper was calculated using Limdep econometric software. Mental health scores are labelled “MMH” in the regression output.

Model 1: Here, equation 3 is estimated with the full set of restrictions expressed in equation 4.

```
--> REGRESS;Lhs=MMH;Rhs=ONE,SWB0,SWB1,SWB2,SWB3,SWB4,SWB5,SWB6,SWB7,SWB8,SWB9
    ;Cls:B(3)-B(2)-B(7)+B(6)=0,B(4)-B(3)-B(7)+B(6)=0,B(5)-B(4)-B(7)+B(6)=0
    ,2B(6)-B(5)-B(7)=0,B(8)-2B(7)+B(6)=0,B(9)-B(8)-B(7)+B(6)=0
    ,B(10)-B(9)-B(7)+B(6)=0,B(11)-B(10)-B(7)+B(6)=0,-B(11)-B(7)+B(6)=0$

+-----------------------------------------------------+
| Ordinary    least squares regression                |
| Model was estimated Aug 03, 2011 at 11:04:10AM      |
| LHS=MMH      Mean                 =   74.29638      |
|              Standard deviation   =   17.14765      |
| WTS=none     Number of observs.   =      11610      |
| Model size   Parameters           =         11      |
|              Degrees of freedom   =      11599      |
| Residuals    Sum of squares       =   2650102.      |
|              Standard error of e  =   15.11545      |
| Fit          R-squared            =   .2236480      |
|              Adjusted R-squared   =   .2229786      |
| Model test   F[ 10, 11599] (prob) = 334.14 (.0000)  |
| Diagnostic   Log likelihood       =  -47997.85      |
|              Restricted(b=0)      =  -49467.38      |
|              Chi-sq [ 10]  (prob) =2939.06 (.0000)  |
| Info criter. LogAmemiya Prd. Crt. =   5.432381      |
|              Akaike Info. Criter. =   5.432381      |
| Autocorrel   Durbin-Watson Stat.  =  1.9248284      |
|              Rho = cor[e,e(-1)]   =   .0375858      |
+-----------------------------------------------------+
+--------+--------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 Constant|    82.4762560       .39654110   207.989   .0000
 SWB0    |   -36.7619703      4.05918871    -9.056   .0000    .00120586
 SWB1    |   -56.7619703      3.32221165   -17.086   .0000    .00180879
 SWB2    |   -47.7619703      2.58556610   -18.473   .0000    .00301464
 SWB3    |   -39.2733575      1.86239151   -21.088   .0000    .00594315
 SWB4    |   -32.0188917      1.38866211   -23.057   .0000    .01111111
 SWB5    |   -25.9350085       .78546586   -33.019   .0000    .04280792
 SWB6    |   -20.0218511       .71440701   -28.026   .0000    .05572782
 SWB7    |   -12.8312754       .50565183   -25.376   .0000    .19991387
 SWB8    |   -6.20039395       .46480069   -13.340   .0000    .33471146
 SWB9    |   -1.98177218       .49725969    -3.985   .0001    .21860465
```

```
+--------------------------------------------------+
| Linearly restricted regression                   |
| Ordinary    least squares regression             |
| Model was estimated Aug 03, 2011 at 11:04:11AM   |
| LHS=MMH      Mean                 =   74.29638   |
|              Standard deviation   =   17.14765   |
| WTS=none     Number of observs.   =      11610   |
| Model size   Parameters           =          2   |
|              Degrees of freedom   =      11608   |
| Residuals    Sum of squares       =   2686667.   |
|              Standard error of e  =   15.21347   |
| Fit          R-squared            =   .2129360   |
|              Adjusted R-squared   =   .2128682   |
| Model test   F[  1, 11608] (prob) =3140.48 (.0000)|
| Diagnostic   Log likelihood       =  -48077.40   |
|              Restricted(b=0)      =  -49467.38   |
|              Chi-sq [  1]  (prob) =2779.97 (.0000)|
| Info criter. LogAmemiya Prd. Crt. =   5.444535   |
|              Akaike Info. Criter. =   5.444535   |
| Autocorrel   Durbin-Watson Stat.  =  1.9156571   |
|              Rho = cor[e,e(-1)]   =   .0421714   |
| Restrictns.  F[  9, 11599] (prob) =  17.78 (.0000)|
| Not using OLS or no constant. Rsqd & F may be < 0.|
| Note, with restrictions imposed,  Rsqd may be < 0.|
+--------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	85.6274287	.24661394	347.212	.0000	
SWB0	-54.3339862	.96955687	-56.040	.0000	.00120586
SWB1	-48.9005876	.87260118	-56.040	.0000	.00180879
SWB2	-43.4671890	.77564549	-56.040	.0000	.00301464
SWB3	-38.0337904	.67868981	-56.040	.0000	.00594315
SWB4	-32.6003917	.58173412	-56.040	.0000	.01111111
SWB5	-27.1669931	.48477843	-56.040	.0000	.04280792
SWB6	-21.7335945	.38782275	-56.040	.0000	.05572782
SWB7	-16.3001959	.29086706	-56.040	.0000	.19991387
SWB8	-10.8667972	.19391137	-56.040	.0000	.33471146
SWB9	-5.43339862	.09695569	-56.040	.0000	.21860465

Model 2: Here, equation 3 is estimated with a limited set of restrictions, with the first distance and last two distances removed.

```
--> REGRESS;Lhs=MMH;Rhs=ONE,SWB0,SWB1,SWB2,SWB3,SWB4,SWB5,SWB6,SWB7,SWB8,SWB9
    ;Cls:B(4)-B(3)-B(7)+B(6)=0,B(5)-B(4)-B(7)+B(6)=0,2B(6)-B(5)-B(7)=0
    ,B(8)-2B(7)+B(6)=0,B(9)-B(8)-B(7)+B(6)=0,B(10)-B(9)-B(7)+B(6)=0$
```

```
+--------------------------------------------------+
| Ordinary    least squares regression             |
| Model was estimated Aug 03, 2011 at 11:08:03AM   |
| LHS=MMH      Mean                 =   74.29638   |
|              Standard deviation   =   17.14765   |
| WTS=none     Number of observs.   =      11610   |
| Model size   Parameters           =         11   |
|              Degrees of freedom   =      11599   |
| Residuals    Sum of squares       =   2650102.   |
|              Standard error of e  =   15.11545   |
| Fit          R-squared            =   .2236480   |
|              Adjusted R-squared   =   .2229786   |
| Model test   F[ 10, 11599] (prob) = 334.14 (.0000)|
| Diagnostic   Log likelihood       =  -47997.85   |
|              Restricted(b=0)      =  -49467.38   |
|              Chi-sq [ 10]  (prob) =2939.06 (.0000)|
| Info criter. LogAmemiya Prd. Crt. =   5.432381   |
|              Akaike Info. Criter. =   5.432381   |
| Autocorrel   Durbin-Watson Stat.  =  1.9248284   |
|              Rho = cor[e,e(-1)]   =   .0375858   |
+--------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	82.4762560	.39654110	207.989	.0000	
SWB0	-36.7619703	4.05918871	-9.056	.0000	.00120586
SWB1	-56.7619703	3.32221165	-17.086	.0000	.00180879
SWB2	-47.7619703	2.58556610	-18.473	.0000	.00301464
SWB3	-39.2733575	1.86239151	-21.088	.0000	.00594315
SWB4	-32.0188917	1.38866211	-23.057	.0000	.01111111
SWB5	-25.9350085	.78546586	-33.019	.0000	.04280792
SWB6	-20.0218511	.71440701	-28.026	.0000	.05572782
SWB7	-12.8312754	.50565183	-25.376	.0000	.19991387
SWB8	-6.20039395	.46480069	-13.340	.0000	.33471146
SWB9	-1.98177218	.49725969	-3.985	.0001	.21860465

```
+----------------------------------------------------+
| Linearly restricted regression                     |
| Ordinary    least squares regression               |
| Model was estimated Aug 03, 2011 at 11:08:03AM     |
| LHS=MMH      Mean                 =   74.29638     |
|              Standard deviation   =   17.14765     |
| WTS=none     Number of observs.   =      11610     |
| Model size   Parameters           =          5     |
|              Degrees of freedom   =      11605     |
| Residuals    Sum of squares       =   2650775.     |
|              Standard error of e  =   15.11346     |
| Fit          R-squared            =   .2234507     |
|              Adjusted R-squared   =   .2231830     |
| Model test   F[  4, 11605] (prob) = 834.83 (.0000) |
| Diagnostic   Log likelihood       =  -47999.33     |
|              Restricted(b=0)      =  -49467.38     |
|              Chi-sq [  4]  (prob) =2936.11 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   5.431602     |
|              Akaike Info. Criter. =   5.431602     |
| Autocorrel   Durbin-Watson Stat.  =  1.9252943     |
|              Rho = cor[e,e(-1)]   =   .0373529     |
| Restrictns.  F[  6, 11599] (prob) =    .49 (.8154) |
| Not using OLS or no constant. Rsqd & F may be < 0. |
| Note, with restrictions imposed,  Rsqd may be < 0. |
+----------------------------------------------------+
+--------+--------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 Constant|    82.4762560       .39648894   208.017   .0000
 SWB0    |   -36.7619703      4.05865483    -9.058   .0000    .00120586
 SWB1    |   -53.1442301      1.01941775   -52.132   .0000    .00180879
 SWB2    |   -46.4349734       .88620950   -52.397   .0000    .00301464
 SWB3    |   -39.7257166       .75914702   -52.329   .0000    .00594315
 SWB4    |   -33.0164599       .64189042   -51.436   .0000    .01111111
 SWB5    |   -26.3072032       .54085545   -48.640   .0000    .04280792
 SWB6    |   -19.5979464       .46669919   -41.993   .0000    .05572782
 SWB7    |   -12.8886897       .43344416   -29.736   .0000    .19991387
 SWB8    |   -6.17943293       .45024631   -13.725   .0000    .33471146
 SWB9    |   -1.98177218       .49719429    -3.986   .0001    .21860465
```

Model 3: The standard SWB model estimates:

```
--> REGRESS;Lhs=SWB;Rhs=ONE,FINSAT,FEMALE,PARTNERE,CHILDREN,UNEMPLOY,NIL
    ,PHEALTH,TRUST$

 ************************************************************************
 * NOTE: Deleted    517 observations with missing data. N is now   4395 *
 ************************************************************************

+----------------------------------------------------+
| Ordinary    least squares regression               |
| Model was estimated Jul 13, 2011 at 04:14:41PM     |
| LHS=SWB      Mean                 =   7.694198     |
|              Standard deviation   =   1.439969     |
| WTS=none     Number of observs.   =       4395     |
| Model size   Parameters           =          9     |
|              Degrees of freedom   =       4386     |
| Residuals    Sum of squares       =   6633.551     |
|              Standard error of e  =   1.229812     |
| Fit          R-squared            =   .2719186     |
|              Adjusted R-squared   =   .2705906     |
| Model test   F[  8,  4386] (prob) = 204.76 (.0000) |
| Diagnostic   Log likelihood       =  -7140.886     |
|              Restricted(b=0)      =  -7838.246     |
|              Chi-sq [  8]  (prob) =1394.72 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =   .4157684     |
|              Akaike Info. Criter. =   .4157684     |
| Autocorrel   Durbin-Watson Stat.  =  1.8831152     |
|              Rho = cor[e,e(-1)]   =   .0584424     |
+----------------------------------------------------+
+--------+--------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 Constant|    3.96765545       .11349951    34.957   .0000
 FINSAT  |     .24696210       .00922966    26.757   .0000   6.26985210
 FEMALE  |     .11353679       .03829951     2.964   .0030    .53424346
 PARTNERE|     .23920238       .04775994     5.008   .0000    .77952218
 CHILDREN|    -.04352588       .03886943    -1.120   .2628    .49442548
 UNEMPLOY|     .16530846       .12735980     1.298   .1943    .02252560
 NIL     |     .27757828       .05596557     4.960   .0000    .15017065
 PHEALTH |     .01435809       .00104166    13.784   .0000   78.3768108
 TRUST   |     .16816260       .01979690     8.494   .0000   4.64893981
```

Model 4: SWB model estimates where the SWB reporting function is assumed to be very weakly sigmoid, and SWB is transformed by a very weakly inverse sigmoid function:

```
--> REGRESS;Lhs=sigSWB;Rhs=ONE,sigfs,FEMALE,PARTNERE,CHILDREN,UNEMPLOY,NIL,PH...

 ************************************************************************
 * NOTE: Deleted    517 observations with missing data. N is now   4395 *
 ************************************************************************


+-----------------------------------------------------+
| Ordinary    least squares regression                |
| Model was estimated Jul 13, 2011 at 04:15:25PM      |
| LHS=SIGSWB   Mean                 =   7.503407      |
|              Standard deviation   =   1.272942      |
| WTS=none     Number of observs.   =       4395      |
| Model size   Parameters           =          9      |
|              Degrees of freedom   =       4386      |
| Residuals    Sum of squares       =   5151.552      |
|              Standard error of e  =   1.083764      |
| Fit          R-squared            =   .2764631      |
|              Adjusted R-squared   =   .2751434      |
| Model test   F[  8,  4386] (prob) = 209.49 (.0000)  |
| Diagnostic   Log likelihood       =  -6585.265      |
|              Restricted(b=0)      =  -7296.384      |
|              Chi-sq [   8]  (prob) =1422.24 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =    .1629261     |
|              Akaike Info. Criter. =    .1629261     |
| Autocorrel   Durbin-Watson Stat.  =  1.8851208      |
|              Rho = cor[e,e(-1)]   =    .0574396     |
+-----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	4.08309242	.10089646	40.468	.0000	
SIGFS	.23636988	.00885747	26.686	.0000	6.19332028
FEMALE	.09583369	.03375141	2.839	.0045	.53424346
PARTNERE	.21211739	.04210899	5.037	.0000	.77952218
CHILDREN	-.03108326	.03424967	-.908	.3641	.49442548
UNEMPLOY	.09752744	.11227171	.869	.3850	.02252560
NIL	.21018944	.04933013	4.261	.0000	.15017065
PHEALTH	.01294924	.00091827	14.102	.0000	78.3768108
TRUST	.15197847	.01744107	8.714	.0000	4.64893981

Model 5: SWB model estimates where the SWB reporting function is assumed to be very weakly inverse sigmoid, and SWB is transformed by a very weakly sigmoid function:

```
--> REGRESS;Lhs=logSWB;Rhs=ONE,logfs,FEMALE,PARTNERE,CHILDREN,UNEMPLOY,NIL,PH...

 ************************************************************************
 * NOTE: Deleted    517 observations with missing data. N is now   4395 *
 ************************************************************************


+-----------------------------------------------------+
| Ordinary    least squares regression                |
| Model was estimated Jul 13, 2011 at 04:15:42PM      |
| LHS=LOGSWB   Mean                 =   7.893795      |
|              Standard deviation   =   1.641960      |
| WTS=none     Number of observs.   =       4395      |
| Model size   Parameters           =          9      |
|              Degrees of freedom   =       4386      |
| Residuals    Sum of squares       =   8726.863      |
|              Standard error of e  =   1.410570      |
| Fit          R-squared            =   .2633300      |
|              Adjusted R-squared   =   .2619863      |
| Model test   F[  8,  4386] (prob) = 195.98 (.0000)  |
| Diagnostic   Log likelihood       =  -7743.585      |
|              Restricted(b=0)      =  -8415.174      |
|              Chi-sq [   8]  (prob) =1343.18 (.0000) |
| Info criter. LogAmemiya Prd. Crt. =    .6900340     |
|              Akaike Info. Criter. =    .6900341     |
| Autocorrel   Durbin-Watson Stat.  =  1.8817540      |
|              Rho = cor[e,e(-1)]   =    .0591230     |
+-----------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	3.84398794	.12926523	29.737	.0000	
LOGFS	.25765779	.00967570	26.629	.0000	6.34862438
FEMALE	.13300939	.04392848	3.028	.0025	.53424346
PARTNERE	.26684858	.05474237	4.875	.0000	.77952218
CHILDREN	-.05770592	.04458472	-1.294	.1956	.49442548
UNEMPLOY	.24617719	.14602275	1.686	.0918	.02252560
NIL	.36098092	.06417535	5.625	.0000	.15017065
PHEALTH	.01586935	.00119417	13.289	.0000	78.3768108
TRUST	.18497742	.02271044	8.145	.0000	4.64893981

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