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Peter J. Hammond University of Warwick,
Federica Liberini Zurich, Switzerland and
Eugenio Proto, University of Warwick

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Do Happier Britons Have More Income? First-Order Stochastic Dominance Relations

Peter J. Hammond: p.j.hammond@warwick.ac.uk
Department of Economics, University of Warwick, Coventry CV4 7AL, UK
Federica Liberini: liberini@kof.ethz.ch
WEH D 4, Weinbergstrasse 35, 8092 Zürich, Switzerland
Eugenio Proto: e.proto@warwick.ac.uk
Department of Economics, University of Warwick, Coventry CV4 7AL, UK.

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Abstract

Using British Household Panel Survey data, for subjects not reporting the highest permitted satisfaction level, we show that the conditional income distribution given a higher reported level of life satisfaction first-order stochastically dominates the corresponding conditional distribution given any lower satisfaction level. Subjects reporting the highest satisfaction level, however, have an income distribution dominated by distributions for some less satisfied individuals. Interestingly, this "top anomaly" is undetectable by standard ordered probit analysis. An alternative binary probit model for reporting maximal satisfaction suggests a possible explanation: more educated subjects not only tend to have higher income, but are also less likely to report maximal satisfaction.

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1 Subjective Well-Being and Income

Psychologists since Watson (1930) and then Wilson (1967) have been regularly using survey data on self-reported happiness. Later, since Diener (1984), they have moved on to "subjective well being" (henceforth SWB). As far as we are aware, the first economists to use such data, and to link happiness or SWB to income, were Van Praag (1968, 1971), as well as Van Praag and Kapteyn (1973). Shortly thereafter Easterlin (1974) produced his well known "paradox". This used linear regression to show that rising standards of living in the US had failed to promote any trend increase in SWB over the quarter century from 1946 to 1970.

Since Easterlin's results were published, numerous studies have focused on later regression results suggesting that his negative conclusions may only hold in rather special circumstances. In particular, his results were further qualified by Oswald (1997), who found evidence in industrialized countries of only a small positive temporal correlation between "self-reported life satisfaction" and GDP; this result is consistent with Stevenson and Wolfers (2008) who find significant happiness gains in Japan, for instance, during the post-war period.[1]

Now true well-being (TWB) is a value-laden concept that is surely inherently unobservable. So statistical results of this kind acquire much of their normative significance from the implicit assumption that SWB is an observable proxy for TWB. Thus, following Ferrer-i-Carbonell and Frijters (2004), we regard each person's TWB as a latent variable or unobservable parameter which is correlated with observable variables like income, and so affects the conditional likelihood of reporting different possible SWB levels.

2 The Monotone Likelihood Ratio Property

The work by Easterlin (1974) and many successors uses linear regression, and so considers how the conditional expected value of SWB depends on income and other variables. By contrast, we treat observed SWB as having only *ordinal* rather than cardinal significance. We recognize that when people are more likely to report higher SWB levels, that does suggest a better economic state of affairs. This leads us to look for statistical results which are invariant

[1] Clark, Frijters and Shields (2008), along with Stevenson and Wolfers (2008), provide extensive surveys of the literature on regression results related to the Easterlin paradox.

under any strictly increasing transformation of the SWB variable. It also suggests using what Amemiya (1981) describes as an "ordered qualitative response model", of which prominent examples include the ordered logit or ordered probit models used by Blanchflower and Oswald (2004), amongst others.

Our focus, therefore, is on how SWB measured on an ordinal scale relates to personal income. Instead of positive correlation between SWB and income, which relies on a cardinal measure of SWB, we look for the *monotone likelihood ratio property* (or MRLP) requiring the relative likelihood of higher reports of SWB to increase with income.[2] As discussed in the appendix, MRLP implies that the relative conditional likelihood of higher income should increase with reported SWB. This implies in turn *first-order stochastic dominance* (henceforth FOSD) property requiring that, given any higher level of SWB, all quantiles of the conditional income distribution must be higher. So of course must the conditional expectation of any increasing function of individual income. The appendix also investigates when the MRLP property is implied by Amemiya's ordered qualitative response model; we show in particular that both the ordered logit and ordered probit models satisfy MRLP, and so have the FOSD property.

Our earlier note (Hammond, Liberini, and Proto, 2011) confirmed the FOSD property for a data set taken from the World Values Survey, with its four levels of possible SWB reports. This paper investigates whether FOSD also holds for data drawn from the British Household Panel Survey (BHPS), another widely used dataset which is briefly described in Section 3. The empirical analysis reported in Section 4 verifies a consistent pattern of stochastic dominance between different conditional income distributions, with one notable and fairly consistent anomaly. What we call the "top anomaly" involves those "maximally satisfied" individuals who report an SWB level right at the top of the allowable scale. The conditional income distribution of these exceptional individuals consistently fails to exhibit stochastic dominance when compared to the conditional income distributions of individuals who report some lower SWB levels.

To investigate the top anomaly further, for each decile in the income distribution, we find the conditional probability of reporting different satisfaction levels; this reveals the top anomaly in a different way. We also

[2]The general concept of MRLP, along with some of its statistical properties, are discussed in Milgrom (1981).

emphasize that the top anomaly cannot be inferred from the ordered probit regression results reported in Section 5, since these consistently attach a significantly positive coefficient to income. The same section reports the income elasticities of the probability of reporting each of the seven satisfaction levels in the BHPS data, and shows that these are also positive at the top satisfaction level.

In Section 6 we use a probit estimator to show that the probability of declaring the highest SWB level is significantly negatively associated with income. Interestingly, this negative relationship disappears when controls for education are added. This seems to suggest that aspiration may be important in helping to explain the top anomaly.

Section 7 contains some brief concluding remarks. The appendix presents some familiar sufficient conditions for a discrete choice model to yield results satisfying the first-order stochastic dominance property that is the main theme of this paper.

3 Data Source

Our data source is the British Household Panel Survey (BHPS) covering the years 1996–2008, ever since the question on life satisfaction was first introduced in 1996. This panel provides longitudinal data, with the same individuals interviewed every year. We now provide a brief description of the main variables we use.

Life Satisfaction. The relevant question is *"How dissatisfied or satisfied are you with your life overall?"* Each subject's answer is coded on a scale running from 1 (not satisfied at all) to 7 (completely satisfied).

Household income. We have followed World Bank-World Development indicators for converting the BHPS data for annual household income into US dollars measured at 2005 constant prices.

Control variables. In some regressions we control for demographic variables such as age and gender, marital status, and number of children in the household. Other regressions introduce measures of educational attainment as additional control variables.

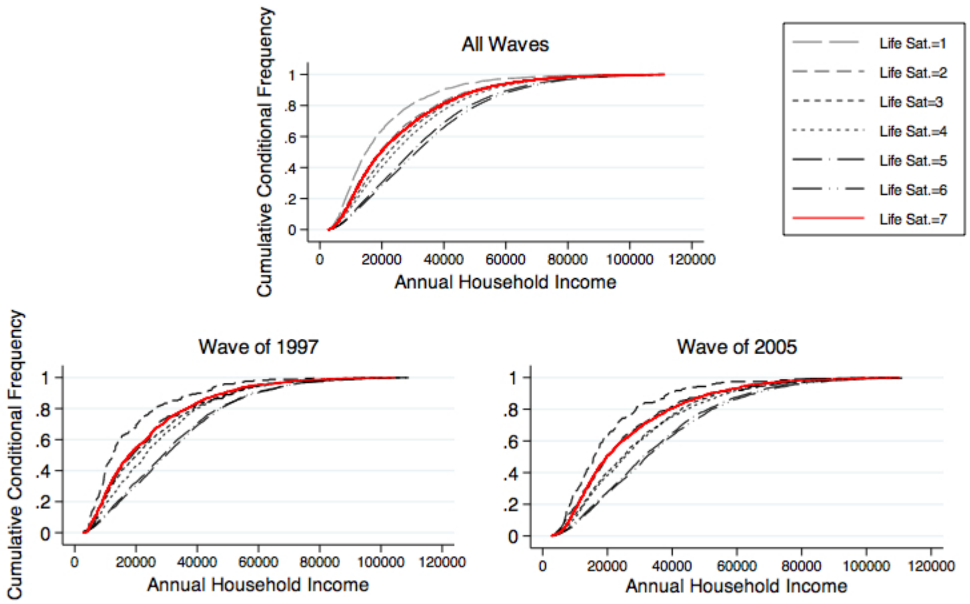

Figure 1: **Household Income Distribution Conditioned on SWB**

4 Stochastic Dominance and a Top Anomaly

Based on combined data from all the waves of the BHPS that we can use, the top part of Figure 1 presents graphs of all seven conditional income distributions, one for each possible level of SWB in the range $K := \{1, \ldots, 7\}$. For each pair of levels $k, k' \in K$ with $k > k'$, we observe that the income distribution corresponding to level k strictly stochastically dominates the income distribution corresponding to level k' — that is, the respective conditional distribution functions $y \mapsto F_k(y)$ and $y \mapsto F_{k'}(y)$ satisfy $F_k(y) > F_{k'}(y)$ for all $y \geq 0$, implying that the proportion of level k households whose income is at or below any income level $\bar{y}$ exceeds the corresponding proportion of level k' households. But this relationship fails for fully satisfied individuals who report the top level 7; in fact, the level 7 income distribution dominates only those for the two lowest levels — namely, 1 and 2. The same pattern of dominance relations emerges in all single waves. For example, the lower two parts of Figure 1 presents similar graphs for data from year 1997, when the question on life satisfaction was included for the first time, and from year 2005.

To obtain a formal test of these first-order stochastic dominance relations, we used the Stata® package in order to compute the Kolmogorov–Smirnov test statistics when: (i) the null hypothesis is that the two unknown conditional distributions being compared are identical; (ii) the one-sided alternative hypothesis is that the first named unknown conditional distribution does indeed stochastically dominate the second. The resulting p-values for the 5 tests that F_{k+1} dominates F_k for $k = 1, 2, \ldots, 5$, and for the 2 tests that F_7 dominates both F_1 and F_2, are all equal to 0.0000 to four decimal places. The same p-values apply to the 4 further tests that F_k dominates F_7, for $k = 3, 4, 5, 6$.

A similar inference can be drawn from Figure 2 which, for each decile in the household income distribution, shows the estimated conditional probability of reporting the satisfaction levels 5, 6 and 7 respectively, along with the relevant confidence interval in each case. Here the top anomaly manifests itself in the fact that these probabilities increase with income for satisfaction levels 5 and 6, but *decrease* with income for satisfaction level 7. Indeed, there are roughly equal proportions of individuals in the lowest income decile who report the top three levels of SWB — namely, 5, 6, or 7. These proportions steadily increase for levels 5 and 6, and faster for level 6 than for level 5; yet they steadily decrease for level 7.

To summarise, in all these cases we have verified that first-order stochastic dominance does indeed hold for all pairs of conditional income distributions except those involving "maximally satisfied" individuals who, by definition, report the topmost level of life satisfaction. Indeed, in all cases one observes this "top anomaly".

5 An Ordered Probit Analysis

Table 1 reports the results of an ordered probit regression with reported life satisfaction as the dependent variable. In line with previously known results, there is a significantly positive coefficient for the logarithm of household income.

Table 2 presents income elasticities for the probability of reporting each separate level of satisfaction. Note that the income elasticity for the top level is positive and significant. So the top anomaly that emerges from our non-parametric analysis does not show up at all in an ordered probit regression.

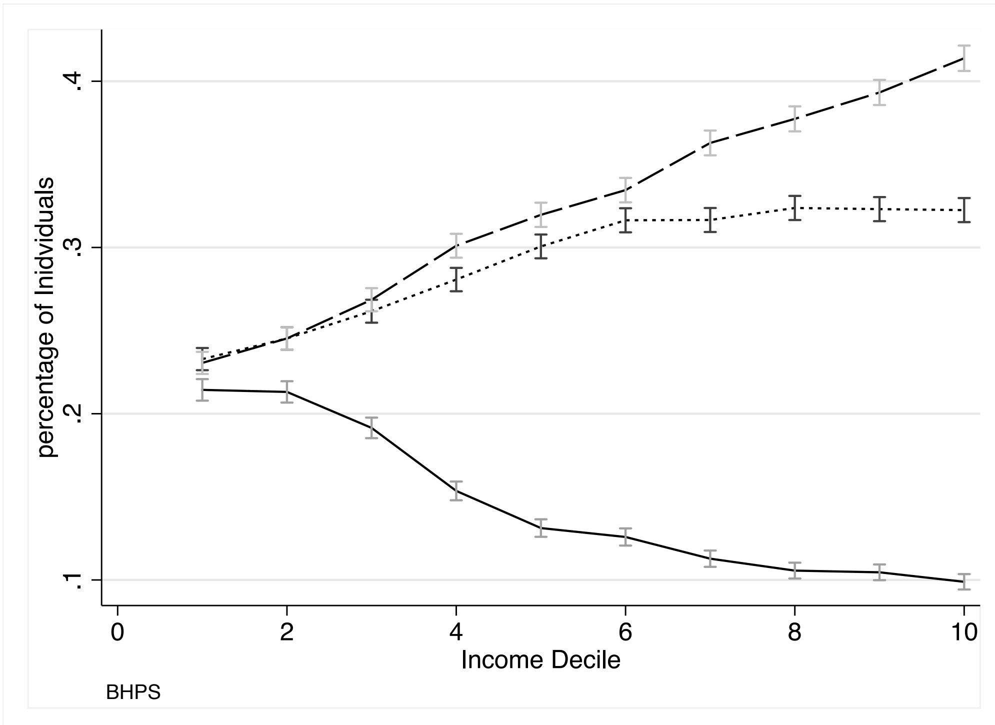

Figure 2: **Proportions Reporting the Top Three Life Satisfaction Levels Conditional on Household Income Decile** Continuous Line: $s = 7$; Dashed Line: $s = 6$; Dotted Line: $s = 5$. The bars represent the 95% confidence intervals for each decile.

6 Happiness, Income, and Education

The above results suggest that it may be worth investigating separately what factors other than income could explain the propensity to report maximal satisfaction.

After controlling for age, age squared, and gender, a simple probit regression (based on 119,366 observations) with log income as the only other right-hand side variable yields a regression coefficient of -0.0607 with a standard error of 0.0140, thus implying a p-value below 0.01. This confirms a negative association between income and the probability of reporting maximal satisfaction, which is consistent with our earlier non-parametric analysis.

One possible explanation might be that higher income involves longer hours of work, which is associated with somewhat less than perfect life sat-

Table 1: Ordered Probit Estimates

	Full Sample	1997	2002
Ln(Income)	0.113***	0.117***	0.0829***
	(0.0046)	(0.0172)	(0.0145)
Female	0.0395***	0.0525**	0.0368**
	(0.0057)	(0.0215)	(0.0182)
Age	-0.0368***	-0.0389***	-0.0359***
	(0.0009)	(0.0036)	(0.0031)
Age Squared	0.0004***	0.0005***	0.0004***
	(9.28e-06)	(3.58e-05)	(3.06e-05)
Any Children	-0.1130***	-0.1600***	-0.1020***
	(0.0069)	(0.0266)	(0.0221)
Married	0.2760***	0.2240***	0.3140***
	(0.0067)	(0.0258)	(0.0216)
Observations	140,153	9,617	13,467
χ^2	6308.10	447.15	687.37
Pseudo R^2	0.0141	0.0143	0.0160

Standard errors in parentheses

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

isfaction. A second possible explanation might be that higher income is less effective for a person who lives in a location where regional GDP per capita is higher. The regression results shown in the first and second columns of Table 6 suggest that work hours and regional GDP per head do have the expected effect on the proportion of maximally satisfied people. But adding these variables as controls even strengthens the negative effect of higher income on this proportion, since the regression coefficient changes from -0.0607 to -0.0844 — though this may be a result of adding other additional control variables, as indicated in the table.

Table 2: Income Elasticity of Self-Reported Life Satisfaction from Ordered Probit Model Estimates

Income Elasticity	BHPS		
	Full Sample	1997	2002
Life Satisfaction = 1	-0.004***	-0.005***	-0.003***
	(0.0002)	(0.0008)	(0.0006)
Life Satisfaction = 2	-0.005***	-0.005***	-0.003***
	(0.0002)	(0.0008)	(0.0006)
Life Satisfaction = 3	-0.010***	-0.010***	-0.007***
	(0.0004)	(0.0016)	(0.0013)
Life Satisfaction = 4	-0.015***	-0.015***	-0.0109***
	(0.0006)	(0.0023)	(0.0019)
Life Satisfaction = 5	-0.010***	-0.009***	-0.007***
	(0.0004)	(0.001)	(0.0013)
Life Satisfaction = 6	0.019***	0.018***	0.013***
	(0.0008)	(0.0026)	(0.0023)
Life Satisfaction = 7	0.025***	0.028***	0.019***
	(0.0010)	(0.0041)	(0.0033)
Observations	140,153	9,617	13,467

Standard errors in parentheses

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

A better possible explanation of the anomaly emerges from the regression results displayed in the third and fourth columns, where various controls for different educational attainment levels or professional/commercial qualifications have been introduced. Now the negative effect of income on the proportion of maximally satisfied has become insignificant. Instead, the proportion of maximally satisfied is significantly negatively correlated with most of the indicators of educational attainment included in the BHPS data. These indicators range from: (i) passing with a grade between 2 and 5 in more than one subject in the Certificate of Secondary Education (or CSE) examinations taken by most 16-year old children in British schools;[3] to (ii) having a postgraduate or higher degree. The significantly negative coefficients may be because the maximally satisfied have lower aspirations, so a lower tendency to seek formal educational qualifications.

Table 3: **Probit Estimates for Reporting Maximal Satisfaction**

BHPS data for the whole period 1996–2008
All regressions include controls for age, age squared, gender, wave effects, number of children, as well as marital, employment and health status

Log income	−0.0844***	(0.0180)	−0.0063	(0.0186)
Log regional GDP	−0.3112***	(0.0663)	−0.2433***	(0.0676)
Hours worked	−0.0023**	(0.0009)	−0.0026***	(0.0009)
Higher degree			−0.5954***	(0.0749)
First degree			−0.6227***	(0.0435)
Teaching qualif.			−0.3822***	(0.0775)
Other higher qualif.			−0.3942***	(0.0329)
Nursing qualif.			−0.4183***	(0.0880)
Advanced level GCE			−0.4499***	(0.0374)
Ordinary level GCE			−0.3011***	(0.0329)
Commercial qualif.			−0.2542***	(0.0722)
CSE grade 2–5			−0.1566***	(0.0511)
Apprenticeship			−0.1956**	(0.0796)
Other qualif.			0.0145	(0.1129)
Num. Observations	95,691		94,020	

Standard errors in parentheses
*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

[3]Passing at grade 1 is deemed equivalent to an Ordinary level GCE (General Certificate of Education) qualification.

7 Conclusion

Our main empirical finding is that, when tested using BHPS data, the FOSD hypothesis set out in Section 2 and the Appendix holds for all levels of life satisfaction except the highest, but consistently fails for the highest level. This "top anomaly" is consistent with Oishi, Diener, and Lucas (2010), who use several datasets to show that the conditional average wage of individuals declaring the highest level of satisfaction is less than that of individuals declaring the level immediately below. They infer that an individual's economic performance is optimised when they experience some internal level of happiness, bounded away from both the top and bottom extremes. The top anomaly we have identified also accords with a finding due to Benjamin *et al.* (2012) who asked individuals to predict the effect of various hypothetical scenarios on their life satisfaction. Typically, they found that the scenarios in which their wealth would be highest are not always those that maximize their SWB level.

Indeed, the data seem consistent with the hypothesis that the top anomaly arises because a high aspiration level negatively affects SWB, while positively affecting income. Testing this properly would require new data closely related to aspiration levels.

Meanwhile, the top anomaly may be reason for caution in using any measure of aggregate SWB as an objective of economic policy. After all, policies which increase individuals' aspiration levels may well be socially desirable, even though they may make individuals less likely to report that they are experiencing maximal life satisfaction.

Appendix: Sufficient Conditions for Dominance

The Monotone Likelihood Ratio Property

This appendix investigates several different sufficient conditions for the first-order stochastic dominance property to hold. There are two random variables $s \in S$ and $y \in \mathbb{R}_+$, where (i) s denotes reported life satisfaction measured on a finite scale that runs from a minimum of $\underline{s}$ to $\bar{s}$; (ii) $y \geq 0$ denotes household income. We assume there is a joint absolutely continuous distribution on $S \times \mathbb{R}_+$, for which the joint density function $S \times \mathbb{R}_+ \ni (s, y) \mapsto f(s, y) \in \mathbb{R}$

is positive for all $(s, y) \in S \times \mathbb{R}_+$. Define the two marginal density functions

$$\mathbb{R}_+ \ni y \mapsto g(y) := \sum_{s \in S} f(s, y) \quad \text{and} \quad S \ni s \mapsto h(s) := \int_0^\infty f(s, y) dy$$

which are both positive valued throughout their domains. Then there exist well defined conditional density functions $S \ni s \mapsto p(s, y)$ for each $y \geq 0$, and $\mathbb{R}_+ \ni y \mapsto q(y|s)$ for each $s \in S$, such that

$$f(s, y) = p(s|y)g(y) = h(s)q(y|s) \quad \text{for all } (s, y) \in S \times \mathbb{R}_+. \tag{1}$$

The key hypothesis is that, whenever $s, s' \in S$ with $s' > s$, the conditional likelihood ratio $p(s'|y)/p(s|y)$ given y satisfies the *monotone likelihood ratio property* (or MRLP) of being an increasing function of y. That is, suppose higher SWB levels become relatively more likely as income increases. Given any pair $y, y' \in \mathbb{R}_+$ with $y' > y$, this hypothesis can be expressed in the form

$$\frac{p(s|y)}{p(s'|y)} > \frac{p(s|y')}{p(s'|y')}, \quad \text{or equivalently} \quad \begin{vmatrix} p(s|y) & p(s|y') \\ p(s'|y) & p(s'|y') \end{vmatrix} > 0 \tag{2}$$

using determinant notation. Equivalently, for each $s' > s$, the log likelihood ratio $\ln p(s'|y) - \ln p(s|y)$ should increase with y.[4]

Now, the double equalities of (1) imply that inequality (2) holds iff

$$\frac{1}{g(y)g(y')} \begin{vmatrix} f(s, y) & f(s, y') \\ f(s', y) & f(s', y') \end{vmatrix} = \frac{h(s)h(s')}{g(y)g(y')} \begin{vmatrix} q(y|s) & q(y'|s) \\ q(y|s') & q(y'|s') \end{vmatrix} > 0 \tag{3}$$

and so iff

$$q(y|s)q(y'|s') > q(y|s')q(y'|s) \tag{4}$$

Next we replace (y, y') by (η, η'), then take the double integral of both left and right hand sides of (4) over the rectangle $(\eta, \eta') \in [0, y] \times [y, \infty)$, throughout

[4]Formally, our MRLP condition is that the conditional likelihood ratios satisfy the logically equivalent condition that the determinant expression $f(s, y)f(s', y') - f(s, y')f(s', y)$ is positive strengthens the assumption that the random variables s and y are "affiliated", as defined by Milgrom and Weber (1982). Indeed, their definition of affiliation requires only that the determinant is nonnegative, which does not exclude the case when s and y are independent. Perhaps more appropriately, they are also said to have a log supermodular density function.

which $\eta < \eta'$ except on the set of measure zero in $\mathbb{R}^2$ where $\eta = y = \eta'$. Then, whenever $s < s'$, the result is the inequality

$$\int_0^y \int_y^\infty q(\eta|s)q(\eta'|s')d\eta d\eta' > \int_0^y \int_y^\infty q(\eta|s')q(\eta'|s)d\eta d\eta' \tag{5}$$

Next, because $\int_0^\infty q(\eta'|s')d\eta' = \int_0^\infty q(\eta'|s)d\eta d\eta' = 1$, it follows from (5) that

$$\int_0^y q(\eta|s)d\eta \left[1 - \int_0^y q(\eta'|s')d\eta'\right] > \int_0^y q(\eta|s')d\eta \left[1 - \int_0^y q(\eta'|s)d\eta'\right] \tag{6}$$

At this point we recall the standard notation $F(y|s)$ for the conditional cumulative distribution function

$$\mathbb{R}_+ \ni y \mapsto F(y|s) := \int_0^y q(\eta|s)d\eta$$

which is defined for all $s \in S$. Then the inequality (6) can be rewritten as

$$F(y|s)[1 - F(y|s')] > F(y|s')[1 - F(y|s)] \tag{7}$$

Cancelling the common term $-F(y|s)F(y|s')$ that appears on both sides of (7) obviously yields the first-order stochastic dominance property that, whenever $s, s' \in S$ satisfy $s < s'$, then $F(y|s) > F(y|s')$ for all $y > 0$.

An Ordered Discrete Choice Model

We consider a basic stochastic model of the form

$$\alpha(s) = u(y) + \epsilon \tag{8}$$

where:

1. $y \mapsto u(y)$ is a strictly increasing *utility function* of income;
2. $S \ni s \mapsto \alpha(s) \in \mathbb{R}$ is a strictly increasing transformation of the possible SWB levels;
3. ϵ is a *random disturbance* of mean zero.

Moreover, in the basic model, we assume that the random disturbances are independently and identically distributed, with a common probability density function $\mathbb{R} \ni \epsilon \mapsto \phi(\epsilon) \in \mathbb{R}_+$. The requirement that ϵ has mean zero implies, of course, that $u(y)$ equals the conditional mean of $\alpha(s)$ given y.

One special case of this model is a simplification of the regression equation used by Layard, Mayraz, and Nickell (2008) where: (i) $s \mapsto \alpha(s)$ is an affine function of the form $\alpha(s) = \beta + \gamma s$ for arbitrary constants β and γ with $\gamma > 0$; (ii) the utility function $y \mapsto u(y)$ gives rise to a marginal utility function $y \mapsto u'(y) = y^{-\eta}$ for a constant elasticity $\eta > 0$, which is a parameter to be estimated. Following Atkinson (1970), one could interpret η as the constant rate of inequality aversion.

A second special case is Amemiya's (1985) discrete choice or quantal model where the conditional probability $p(s|y)$ that a person with income level y reports an SWB level equal to s can be expressed as

$$p(s|y) = \phi(\alpha(s) - u(y)) \tag{9}$$

for a suitable density function $\mathbb{R} \ni \xi \mapsto \phi(\xi) \in \mathbb{R}_+$. Two special subcases are:

- the ordered probit model, with the probability density function

  $$\phi(\xi) = (1/\sqrt{2\pi}) \exp(-\tfrac{1}{2}\xi^2) \tag{10}$$

  of a standard normal random variable;

- the ordered logit model, where the cumulative distribution function is the transformed logistic function

  $$\mathbb{R} \ni \xi \mapsto \Lambda(\xi) = 1/(1 + e^{-\xi}) \in (0, 1)$$

  implying that the density function is

  $$\phi(\xi) = e^{-\xi}(1 + e^{-\xi})^{-2} \tag{11}$$

Strict Log Concavity as a Sufficient Condition

Let us transform variables by putting $\psi := \ln \phi$ in the discrete choice model (9). Note that when $s' > s$, one has

$$\ln \left[\frac{p(s'|y)}{p(s|y)} \right] = \psi(\alpha(s') - u(y)) - \psi(\alpha(s) - u(y))$$

Differentiating each side w.r.t. y implies that

$$\begin{aligned}\frac{d}{dy}\ln\left[\frac{p(s'|y)}{p(s|y)}\right] &= -u'(y)[\psi'(\alpha(s')-u(y))-\psi'(\alpha(s)-u(y))] \\ &= -u'(y)\int_{\alpha(s)-u(y)}^{\alpha(s')-u(y)}\psi''(\xi)d\xi\end{aligned}$$

Under the obvious assumption that $u'(y) > 0$ for all $y \geq 0$, a sufficient condition for MRLP to hold, and so for stochastic dominance, is that $\psi''(\xi) < 0$ for all real ξ. In this case one says that the function ϕ is *strictly log concave.*

We note that strict log concavity is obviously satisfied in the ordered probit model (10), when $\psi(\xi) = -\frac{1}{2}\ln(2\pi) - \frac{1}{2}\xi^2$.

The ordered logit model (11) has $\psi(\xi) = -\xi - 2\ln(1+e^{-\xi})$, implying that

$$\psi'(\xi) = -1 + 2\frac{e^{-\xi}}{1+e^{-\xi}} = -1 + \frac{2}{e^{\xi}+1} \quad \text{and so} \quad \psi''(\xi) = -\frac{2e^{\xi}}{(e^{\xi}+1)^2} < 0$$

Hence the ordered probit model also satisfies strict log concavity.

References

[1] Amemiya, T. (1985) *Advanced Econometrics* (Oxford: Basil Blackwell)

[2] Atkinson, A.B. (1970) “Measuring Inequality” *Journal of Economic Theory* 2, 244–263.

[3] Benjamin, D.J., Heffetz, O., Kimball, M.S., and Rees-Jones, A. (2012) “What Do You Think Would Make You Happier? What Do You Think You Would Choose?” *American Economic Review*, 102(5), 2083–2110.

[4] Blanchflower, D.G. and Oswald, A.J. (2004). Well-Being over Time in Britain and the USA. *Journal of Public Economics*, 88, 1359–1386.

[5] Clark, A.E., Frijters, P. and Shields, M.A. (2008). Relative Income, Happiness, and Utility: An Explanation for the Easterlin Paradox and Other Puzzles. *Journal of Economic Literature*, 46, 1, 95–144.

[6] Diener, E. (1984) “Subjective Well Being” *Psychological Bulletin*, 95, 542–575.

[7] Easterlin, R.A. (1974) "Does Economic Growth Improve the Human Lot? Some Empirical Evidence" in Paul A. David and Melvin W. Reder (eds.) *Nations and Households in Economic Growth: Essays in Honor of Moses Abramovitz* (New York: Academic Press).

[8] Ferrer-i-Carbonell, A. (2005). Income and Well-being: An Empirical Analysis of the Comparison Income Effect. *Journal of Public Economics*, 89(5-6): 997–1019.

[9] Ferrer-i-Carbonell, A., and Frijters. P. (2004), "How Important Is Methodology for the Estimates of the Determinants of Happiness?" *Economic Journal*, 114: 641–659.

[10] Hammond, P.J., Liberini, F. and Proto, E. (2011) "Individual Welfare and Subjective Well-Being: Commentary Inspired by Sacks, Stevenson and Wolfers" World Bank ABCDE 2010; http://www2.warwick.ac.uk/fac/soc/economics/research/workingpapers/2011/twerp_957.pdf.

[11] Layard, R., Mayraz, G. and Nickell, S. (2008) "The Marginal Utility of Income" *Journal of Public Economics*, 92, 1846-1857.

[12] Milgrom, P.R. (1981) "Good News and Bad News: Representation Theorems and Applications" *Bell Journal of Economics* 12: 380–91.

[13] Milgrom, P.R. and Weber, R.J. (1982) "A Theory of Auctions and Competitive Bidding" *Econometrica* 50: 1089–1122.

[14] Oishi, S., Diener, E., and Lucas, R.E. (2007). The optimum level of well-being: Can people be too happy? *Perspectives on Psychological Science* 2, 346–360.

[15] Oswald, A. (1997). Happiness and Economic Performance. *Economic Journal*, 107, 1815-1831.

[16] Sacks, D.W., Stevenson, B. and Wolfers, J. (2010) "Subjective Well-Being, Income, Economic Development and Growth" paper presented to World Bank ABCDE 2010; http://siteresources.worldbank.org/DEC/Resources/84797-1251813753820/6415739-1251815804823/Justin_Wolfers_paper.pdf.

[17] Stevenson, B., and Wolfers, J. (2008) "Economic Growth and Subjective Well-Being: Reassessing the Easterlin Paradox" *Brookings Papers on Economic Activity* Spring, 1–87.

[18] Van Praag, B.M.S. (1968) *Individual Welfare Functions and Consumer Behavior* (Amsterdam: North-Holland).

[19] Van Praag, B.M.S. (1971) "The Welfare Function of Income in Belgium: An Empirical Investigation" *European Economic Review* 2: 337–369.

[20] Van Praag, B.M.S. and Kapteyn, A. (1973) "Further evidence on the individual welfare function of income: An empirical investigation in the Netherlands" *European Economic Review* 4: 33–62.

[21] Watson, G. (1930) "Happiness Among Adult Students of Education" *Journal of Educational Psychology* 21: 79–109.

[22] Wilson, W.R. (1967) "Correlates of Avowed Happiness" *Psychological Bulletin* 67: 294–306