The Relative Importance of Health, Income and Social Relations for Subjective Well-being: An Integrative Analysis

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Abstract*:*

There is much evidence that health, income and social relationships are important for our well-being, but little evidence on their relative importance. This study makes an integrative analysis of the relative influence of health related quality of life (HRQoL), household income and social relationships for subjective well-being (SWB), where SWB is measured by the first three of the five items on the satisfaction with life scale (SWLS). In a comprehensive 2012 survey from six countries, seven disease groups and representative healthy samples (N=7933) reported their health along several measures of HRQoL. A Shapley value decomposition method measures the relative importance of health, income and social relationships, while a quantile regression model tests how the effects of each of the three predictors vary across different points of SWB distributions. Results are compared with the standard regression. The respective marginal contribution of social relationships, health and income to SWB (as a share of goodness-of-fit) is 50.2, 19.3 and 7.3% when EQ-5D-5L is used as a measure of health. These findings are consistent across models based on five alternative measures of HRQoL. The influence of the key determinants varied significantly between low and high levels of the SWB distribution, with health and income having stronger influence among those with relatively lower SWB. Consistent with several studies, income has a significantly positive association with SWB, but with diminishing importance.

Keywords – HRQoL; Subjective well-being; Social relationships; Shapley value; Quantile regression; Six OECD-countries

Introduction

In recent years, measures of subjective well-being (SWB) has gained importance as an indicator of economic and social progress (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004; Stiglitz, 2009). This is largely because, in addition to material thing, human well-being is determined by many aspects of people's life circumstances such as health, social networks, quality of institutions, or leisure activities. As argued by Diener (1984), SWB is best understood as encompassing three separate aspects, such as life satisfaction, positive affect, and the absence of negative affect. Here we consider the satisfaction with life scale (SWLS), which is a widely used measure of SWB (Stiglitz et al., 2009; Blanchflower, 2009). It involves an *evaluative judgment* of how one's quality of life is doing in general (Diener et al., 1985), which requires making an effort and remembering past experiences. It is the most stable dimension of SWB over an individual's life course (Diener, 1984) and robust to the effects of social desirability bias and stable across countries (Pacek & Radcliff, 2008).

SWB is also a population outcome measure beyond morbidity, mortality, and economic status that tells how people perceive the circumstances of their life from their own perspective (Diener & Seligman, 2004). A variety of evidence points to a robust correlation between SWB and alternative measures of personal well-being, such as independently ascertained friends' reports and with health and sleep quality (Diener, Lucas, & Scollon, 2006; Kahneman & Krueger, 2006). SWB-measures provide valid and reliable information on how well people - and the wider societies - are doing, thereby assessing quality of life in addition to economic and social indicators (Diener & Suh, 1997). Thus, SWB data can be used to shape and appraise policy.

Several studies have concluded that health is positively associated with subjective well-being (Binder & Coad, 2011; Cubí-Mollá, de Vries, & Devlin, 2014; Deaton, 2008; Graham, 2008; Okun & George, 1984). In a seminal study by Campbell, Converse, and Rodgers (1976), health was rated by respondents as the most important factor in happiness. The degree of the association between

health and SWB varies as a function of whether health is rated by experts or by self-assessment. Objective measures of health, such as a physician's observations and diagnoses, are less correlated with SWB than subjective measures of health, such as a self-report of overall health status (Diener, Suh, Lucas, & Smith, 1999; Larson, 1978; Okun & George, 1984). However, regardless of how health is measured, health and SWB are significantly associated.

Similarly, numerous studies have been conducted on the effect of income on SWB (Diener & Seligman, 2004; Easterlin, 1995; Ferrer-i-Carbonell, 2005; Rojas, 2011), concluding that the relationship is generally positive but diminishing. In his seminal paper, Easterlin (1995) suggested: "raising the incomes of all, does not increase the happiness of all, because the positive effect of higher income on subjective well-being is offset by the negative effect of higher living level norms brought about by the growth in incomes generally" (p. 36). People either adapt to their circumstances (Diener et al., 1999; Menzel, Dolan, Richardson, & Olsen, 2002), and hence end up no more satisfied than they were before, or they raise their financial aspirations (Easterlin, 1995), which will make them feel *less* satisfied with their increase in income.

There is growing evidence that social relationships are crucial for people's health and well-being (Binder & Coad, 2011; Diener & Biswas-Diener, 2011; Lin, 1999). Individual-level social capital can be defined as the social skills and networks that enable an individual to access and/or mobilize resources embodied in social structure in purposive actions (Lin, 1999), which, of course enhance individuals' SWB. It has been argued that social relationships have the power to influence identity and recognition that are essential for the maintenance of mental health and entitlement to social resources (Lin, 1999), which in turn are associated with well-being. Furthermore, research in this area suggest that close supportive relationships are considered a *necessary condition* for SWB (Diener & Biswas-Diener, 2011; Helliwell & Putnam, 2004). Although social context and individual level effects

play a role, studies suggest strong and stable effect of social relationships on SWB (Gleibs, Morton, Rabinovich, Haslam, & Helliwell, 2013; Helliwell & Putnam, 2004).

Research questions and contributions

Despite an increasing interest into the partial effects of health, income and social relationships on SWB, empirical studies on the associations between these integrated factors on SWB are sparse. Most studies examined the link between individuals' subjective health ratings and SWB and found this link to be positive and strong (Dolan, Peasgood, & White, 2008; Graham, 2008). Few studies extend to more detailed health measures such as provided by using health state utility (HSU) instruments. For example, Graham, Higuera, and Lora (2011) conducted a cross-sectional study for a number of Latin American countries, where EQ-5D measure of health problems was related to health satisfaction and life satisfaction. The present study utilizes several measures of health including *objective* diagnosis indicators in alternative models to test for the stability of results on the relative importance of health on SWB. Moreover, the measure of social relationships used in this paper is unique in that it provides a composite score, which combines the extent and quality of both primary ties (close friends and families) and secondary ties with the public (social inclusion and isolation).

We apply the Shapley value regression based techniques to determine the relative importance of each variable for SWB. While variance decomposition techniques are common in research related to poverty and income inequalities, few applications exist in SWB studies. Graham and Nikolova (2015) discussed the relative importance of objective vs. subjective perceived opportunities for different SWB dimensions using variance decomposition techniques. Sundmacher, Scheller-Kreinsen, and Busse (2011) applied similar approach to assess the contribution of material, cultural-behavioural, capability and psychosocial factors to variations in health. They both used a variance decomposition technique proposed by Fields (2003) that allows for a negative value, which creates difficulty in interpretation. The Shapley value regression applied in this paper is calculated across all possible

combinations of predictors, and is always positive unlike other net effect measures (Conklin, Powaga, & Lipovetsky, 2004).

We used quantile regression model (QRM) to test whether our predictors are more important for individuals with lower SWB than higher SWB. QRM was introduced in a SWB study by Hohl (2009) using the relationship between income and life satisfaction as an example. Binder and Coad (2011) extended this method to a wider investigation of happiness using health, income and social factors. They used an aggregated health measure (self-reported health and objective health) although objective health might be sufficiently captured by subjective health measures. Yuan and Golpelwar (2013) used a similar approach in testing SWB from the perspective of social quality. More recently, Binder and Coad (2015) examined the relationship between unemployment and SWB, and Graham and Nikolova (2015) assessed the capability-SWB relationship using QRM. The current paper further investigates the wider interrelationships by considering several measures of health and using a composite measure of social relationships.

Based on a comprehensive cross-sectional data set (N=7933) from six developed countries that combine a *healthy group* and seven *disease groups*, this paper aims to answer the following two questions: i) What is the relative importance of health, income and social relationships for SWB?, and; ii) Will the (relative) importance of these three key predictors differ depending on the level of the SWB distributions?

Data and Methodology

Data

Data was obtained from the multi-instrument comparison (MIC) study, which is based on a 2012 online survey carried out in Australia, Canada, Germany, Norway, UK and the US by a global panel company, CINT Pty Ltd (Richardson, Iezzi, & Maxwell, 2012). The data include a representative

'healthy group' (N=1760) and seven major disease groups (N=6173), which give a total sample size of 7933. The survey was approved by the Monash University Human Research Ethics Committee (MUHREC), Melbourne, Australia, reference number CF11/3192 – 2011001748.

Respondents were initially asked to indicate if they had a chronic disease and to rate their overall health on a visual analogue scale (VAS). Quotas on age, gender and education were used to obtain a demographically representative sample of a *healthy group*, defined by the absence of chronic disease and a VAS score of at least 70 on overall health. Quotas were also applied to obtain a target number of respondents in each disease group (arthritis, asthma, cancer, depression, diabetes, hearing loss, heart diseases). See Table 1.

[Insert Table 1 about here]

Responses were subject to several stringent edit procedures based upon a comparison of duplicated or similar questions as well as a minimum completion time, which excluded 17% of the observations (Richardson et al., 2012).

The measure of subjective well-being (SWB)

As compared to a single item life satisfaction, a multiple-item SWB measure is considered superior since it is more comprehensive in terms of the coverage of well-being, and more reliable (Van Praag, Frijters, & Ferrer-i-Carbonell, 2003). In preliminary analysis, the single global life satisfaction item from the personal well-being index (PWI) was used as an alternative, but performed less in explaining variation in SWB. Thus, we apply the multiple-item satisfaction with life scale (SWLS), which is designed to measure global cognitive judgments of satisfaction with one's life, proposed by Diener, Emmons, Larsen, and Griffin (1985). Following Zou, Schimmack, and Gere (2013), we use the first three of its five-items (*In most ways my life is close to my ideal; The condition of my life is excellent,*

and; *I am satisfied with my life*) each with 7-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Cronbach's alpha value is 93.5%, which is above minimum standard of 70% (DeVellis, 2012) showing a good internal consistency. The two excluded items are sensitive to age as they emphasizes on past experience of life satisfaction (Hultell & Petter Gustavsson, 2008), and hence they create some noise and produce a poorer Cronbach alpha. Further, they have been shown to have poorer psychometric properties than the first three items of the scale (Oishi, 2006). The total sum of score is linearly transformed on a [0 – 1] scale; i.e., first, item scores are set equal to the rank order of the response and then summed to obtain a score, X_i. Then, X_i is constrained to the range (0-1) using a unity based normalization equation as follows:

$X_{i,0to1} = \frac{(X_i - X_{\min})}{(X_{\max} - X_{\min})}$, where X_{min} and X_{max} are the scores obtained when the response to every item of the instrument is at its minimum (worst) and maximum (best) level respectively. See Table 2 for variable descriptions.

[Table-2 about here]

Predictors

Health related quality of life (HRQoL) is measured in five alternative regression models, based on four health state utility (HSU) instruments (EQ-5D-5L, SF-6D, HUI3, 15D) and one direct health valuation measure (visual analogue scale, VAS). We focus on the two most widely used HSU instruments (EQ-5D-5L, SF-6D) and VAS, leaving results for HUI3 and 15D in the Appendix. The EQ-5D-5L (hereafter EQ-5D) defines health in terms of five-dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression), each with five response categories ranging from no problems to unable to/extreme problems. An EQ-5D 'health state' is defined by selecting one level from each dimension, giving a total of 3125 health states. We apply the new preference-based value

set for England, which is anchored on a [-0.208 – 1] scale, with 1 indicating 'full-health' and 0 representing dead (Devlin & van Hout, 2014).

The SF-6D has six-dimensions (physical functioning, social functioning, role limitations, pain, mental health and vitality), each with four to six levels (Brazier, Roberts, & Deverill, 2002). It defines a total of 18,000 health states. The most inferior health state has a value of 0.30 on the preference-based scale; i.e. the scale length is shorter that for EQ-5D which has a lower end at -0.208.

The direct assessment of health (VAS) is based on answers to the question*: "Think about a scale of 0 to 100, with zero being the least desirable state of health that you could imagine and 100 being perfect health (physical, mental and social). What rating from 0 to 100 would you give to the state of your health?"* These values are then normalized to a [0 – 1] scale. Hereafter HRQoL refers to both the indirect (HSU) and direct (VAS) measures of health unless otherwise stated.

Since *household income* is measured as categorical variable with different income brackets in each country, we chose the mid-point of the household income brackets, and treated it as a continuous variable. However, for an open-ended top category a more rigorous approach was used that involves extrapolating from the next-to-last category's midpoint using the frequencies of both the last (open-ended) and the next-to-last categories, and impute the median from this distribution. This is in line with Parker and Fenwick (1983) who suggested that the median of the open-ended category is a more appropriate choice. Each respondent has been assigned with the mid-point income value of the corresponding income range. Then, income measure for each country was converted to a common currency expressed in US dollars using purchasing power parity (PPP) for actual individual consumption conversion factor in the year 2012. Eventually, income measures were transformed into natural logarithm to allow a non-linear relationship between income and SWB in accordance with recent consensus in the literature (Binder & Coad, 2011; Easterlin, 2001).

Social relationship (SR) is measured by a composite score based on four questions from the Assessment of Quality of Life instrument (Richardson, Iezzi, Khan, & Maxwell, 2014). Two questions consider the extent of enjoyment and satisfaction with ones close relationships [*How much do you enjoy your close relationships (family and friends)?; Your close relationships (family and friends) are:…*] and two questions evaluate ones feelings with respect to isolation and exclusion (*How often do you feel socially isolated?; How often do you feel socially excluded or left out?*). A *social relationship* measure is constructed by calculating the total score of the five/six-point scale response levels to these four questions (reverse-coded, 1=immensely/very satisfied/never to 5/6= I hate it/Very unpleasant/always). The reliability coefficient (as measured by Cronbach's alpha) is 0.843, showing good internal consistency. The total score is linearly transformed to a [0 – 1] scale.

Missing information: Despite high overall response rates in this study, 11.4 % have missing value on household income. Missing values can bias the estimates of the parameters and reduce the power of the model when these are not random. Therefore, we employed multiple imputation (MI) by a chained equation, which is the most appropriate and flexible approach for specifying an imputation model per variable (White, Royston, & Wood, 2011). For example, when data is skewed, predictive mean matching (PMM) is the most relevant model instead of standard linear regression, which restricts the imputed values of a variable to be within the range of observed values, and is less sensitive to model misspecification (Little, 1988). Another important topic in MI is the number of data imputations. A rule of thumb is that the number of imputations must be greater than or equal to the fraction of missing information in the data (White et al., 2011). In our case, the fraction of missing information is about 0.13, and hence we generate 15 imputed datasets. In this study, the estimates with multiple imputation are quite similar to those obtained from the complete case analysis, but the standard errors are relatively smaller implying that imputation has led to more precision.

Control variables

In addition to the socio-demographic factors (age, gender, marital status, education, employment status), we controlled for chronic diseases as well as country dummies. Age-squared (divided by 100) is included to control the curvilinear effect of age on SWB. Gender (0 = male; 1 = female) is used to control sex differences. Education level is accounted for by dummies (0=high school; 1=diploma or certificate; 2=university). Employment status is dichotomized (*unemployed* vs. *all others*) to reflect the evidence that being unemployed has a particularly strong negative effect on SWB (Dolan et al., 2008). Marital status (0 = no partner/spouse, 1 = partner/spouse) has also proven to be an important determinant of SWB (Diener et al., 1999). Disease groups are included since they may signal health variations not captured by the HRQoL measures used, and country dummies to capture country specific heterogeneity. All explanatory variables were tested for multi-collinearity and were found to be satisfactory as the Variance Inflation Factors (VIFs) of all independent variables were below 2.0, which is much less than the generally accepted maximum threshold value of 10 (O'brien, 2007).

Regression Models

Standard ordinary least square (OLS) regression is chosen to test the stability of our results against the main model used; the quantile regression model (QRM). It also produces an overall measure of goodness-of-fit (R^2), which can be decomposed to provide the relative importance of predictors.

To detect which main predictors are relatively more important for SWB, we use *standardized coefficient* estimates and *variance decomposition* method. In practice, the relative importance of predictors (in a regression model) is frequently measured by the size of the standardized coefficients, which would be a good estimate only if the predictor variables are uncorrelated. However, in health research with inherently imprecise measures of complex concepts such as life satisfaction, perceived

health, etc., correlation among predictors is often the norm. Therefore, the Shapley value regression (Shapley, 1953) is the reliable and stable method to the estimation of predictor importance, even in the presence of high multi-collinearity. The Shapley value decomposition is a desirable candidate as it is the only rule that satisfies efficiency, symmetry and monotonicity (Huettner & Sunder, 2012; Shorrocks, 2013). The efficiency property guarantees that the marginal contribution of each predictor sums to R^2, and hence no value is lost. It is also symmetric, meaning that two predictors that create the same additional value receive the same share of the total value, i.e. the property of equal treatment. Monotonicity property ensures that if all of the marginal contributions of a given predictor increases, its share will also increase.

The Shapley value measures the marginal contribution to the R^2 from adding a given independent variable to the model, weighted by the number of permutations represented by this sub model (Shorrocks, 2013). Based on this definition, the Shapley value of a single attribute X_j with a simplified notation can be given by:

$$SV_j = \sum_k \sum_i \gamma_k \left[\nu\left(M_{i|j}\right) - \nu\left(M_{i|j(-j)}\right) \right] \qquad (1)$$

where

SV_j is Shapely value for predictor j; $\nu(M_{i|j})$ is the R^2 of a model *i* containing predictor *j*;

$\nu(M_{i|j(-j)})$ is the R^2 of the same model *i* without *j*; and

$\gamma_k = \frac{k!(p-k-1)!}{p!}$ is a weight based on the number of predictors in total (p) and the number of predictors in this model (k).

Quantile regression models (QRM) were applied to analyse the extent to which the relative importance of HRQoL, income and social relationships vary depending on the level of SWB

distribution. Unlike the OLS, the QRM does not depend on distributional assumptions of error terms, which allows for individual heterogeneity as the slope parameters differ along the quantiles (Koenker & Bassett, 1978). Furthermore, QRM permits us to explore the entire conditional distribution by analysing the effects of predictors at different levels of the SWB distribution, while OLS regressions describe the conditional mean alone. Thus, following Koenker and Bassett (1978), the QRM is expressed as:

$$SWB_i = \beta_0^{(q)} + \beta_1^{(q)} HRQoL_i + \beta_2^{(q)} \ln(I_i) + \beta_3^{(q)} SR_i + \gamma^{(q)} C_i + \varepsilon_i \qquad (2)$$

where SWB_i is an outcome variable; *HRQoL* refers to the chosen health related quality of life measures; *I* is household income (in natural logarithm); *SR* is social relationships; C_i is a vector of control variables; $\beta^{(q)}$ and $\gamma^{(q)}$ are the vector of parameters to be estimated for each quantile under consideration; ε_i is error term, and; 0 < q < 1 indicates the proportion of the population having scores below the quantile specified. Formulation of QRM requires that the q^{th} quantile of the error term be zero, and hence $Quant^{(q)}(SWB_i \left| X_i = \beta^{(q)} X_i \right.)$. Thus, the quantile regression estimator for the q^{th} quantile, 0< q <1, minimizes the objective function:

$$\min_{\beta \in \Re} \left[\sum_{i:SWB_i > \beta X_i} q \mid SWB_i - \beta^{(q)} X_i \mid + \sum_{i:SWB_i < \beta X_i} (1-q) \mid SWBi - \beta^{(q)} X_i \mid \right] \qquad (3)$$

where X_i is a vector of all regressors given in equation (2), and β is a vector of parameters to be estimated.

A significant departure of the QRM estimator from the OLS estimator is that in the QRM, the residuals are measured using a weighted sum of vertical distances (without squaring), where the weight is (*1 – q)* for points below the fitted line and *q* for points above the line. The unique feature of QRM is its ability to estimate parameters appropriate for the chosen quantiles other than the median. For instance, it may be important to evaluate the extreme distributions to understand whether a particular policy intervention is equally important for individuals with lower and higher SWB. All statistical analyses are conducted using Stata® ver. 14.0 (StataCorp LP, College Station, Texas, USA).

Results

Table 3 reports the regression results of unstandardized and standardized coefficients for each of the three HRQoL-measures. Results from OLS1 includes measures for the three key variables (HRQoL, income, social relationships), but adjusting for variables that are standard to include in this literature: gender, age, unemployment, education, marital status. Results from OLS2 in addition includes dummies for diagnosis and countries. The larger the difference across the three HRQoL-measures after adjusting for diagnostic groups (and hence the larger the disease dummies), the weaker is the HRQoL measure to capture the diagnosis-specific variations. In general, the two HSU instruments perform worse in picking up diagnosis caused variations than does the direct VAS-measure. All country dummies except US suggest higher SWB than the reference UK. Interestingly, the increased R^2 of the disease and country variables are very small. However, there is no fundamental difference between the two models, i.e. social relationships, HRQoL and household income remain significant determinants of SWB in that order. Thus, hereafter our analysis focuses on the full model, OLS2 of Table 3, unless otherwise specified.

The standardized coefficient reveal that the relative importance of HRQoL on SWB is *higher* when using VAS as compared to the HSU-instruments. For instance, a 1 standard deviation increase in VAS

leads to an increase of 0.318 standard deviations in SWB (*ceteris paribus*), which is more than twice as strong as EQ-5D (Table 3).

[Insert Tables 3 and 4 about here]

Among the main independent variables, *social relationship* shows the strongest effect on SWB followed by HRQoL. Household income shows a significantly positive association with SWB, but its effect size (the coefficient magnitude) is small. If we had *not* controlled for education, the influence of income would increase slightly (e.g. from 0.031 to 0.035 in Table 3, Model A). Appendix Table A1 depicts both the OLS and QRM results of the full model when HRQoL is measured by 15D and HUI3.

Consistent with previous studies, age shows a significant U-shaped impact on SWB with lowest SWB at 45 years of age when HRQoL is measured by SF-6D (Table 3). Women enjoy a 2-percentage point higher life satisfaction than male; and living with partner or spouse increases SWB with at least 4 percentage point over those living alone. More education is associated with increased SWB, e.g. a university degree involves 3.3 percentage point higher SWB than high-school (Model A in Table 3). Being unemployed reduces SWB by about 7.5 percentage points, which is consistent across all HRQoL measures.

Table 4 provides an alternative measure of relative importance of a variable. The share of HRQoL in the explained overall variance of SWB ranges from 19.3% (for EQ-5D) to 31.6% (for VAS). Social relationship alone explains nearly half of this overall variation in SWB explained by all predictors in the model, when EQ-5D is used as a measure of HRQoL. The marginal contribution of household income is small, around 7%, across all models reported in Table 4.

Table 5 summarizes quantile regression results at three different distributions of SWB: 25th, 50th, and 75th percentiles. For almost all variables, the coefficients vary across the three quantiles, implying that the impact of health, income and social relationships on SWB depends on the *level* of well-being.

[Insert Table 5 about here]

HRQoL and income are much more important the lower is your SWB. For example, the coefficient of SF-6D at lower quantile is twice (b=0.45) that of the third quantile (b=0.22). The importance of social relationship is more stable across the SWB distributions, though its effect is slightly stronger at lower level. The pseudo R^2 is much lower at the upper quantile compared to the median or lower quantile, implying that the variables included explain less of the variations in the upper level of SWB distributions (Table 5).

In general, social relationship is the most important determinant of SWB followed by HRQoL measures in both OLS regression model and QRM. However, OLS regression underestimates the effect of predictors at lower quantile and overestimates at the upper quantile (Table 5). Figure 1 is a graphical depiction of quantile regression coefficients for these predictors at different levels of SWB.

[Insert Fig. 1 about here]

Although the overall effect of age on life satisfaction is small, its influence is stronger in the groups with lower level of SWB. Marital status and education have similar patterns (Table 5), i.e. they are more important at lower quantiles than upper quantiles. Being unemployed, however, appears to have similar importance across the whole SWB distributions.

Discussion

This study examines the relative importance of health, income and social relationship as determinants of SWB. The standardized coefficients and variance decomposition results suggest that measure of health, particularly self-rated measure, have the strongest associations with SWB. For instance, the Shapley value decomposition reveal that the proportion of variation in SWB associated uniquely with VAS is 15.8% after controlling for all other variables including disease and country dummies. However, this variation in SWB is around 8.7% and 10.8% with EQ-5D and SF-6D, respectively. Previous studies also documented that health accounts for 4% to 16% of the variance in SWB, and self-rated health would be more strongly related to SWB indicators than health ratings by others (Larson, 1978). This is mainly because, self-ratings of health would reflect both an *objective* component related to health and a *subjective* element pertaining to general living conditions (Suchman, Phillips, & Streib, 1958). In addition, self-rated health measures reflect individual's actual physical condition as well as level of emotional adjustment (Hooker & Siegler, 1991), and the relative importance of self-rated health for SWB is escalated by this emotional element. In similar vein, Richardson, Chen, Khan, and Iezzi (2015) also argued that HSU instruments with a limited coverage of mental health are least able to account for variation in SWB.

Another reason why VAS performs better than the HSU instruments (measured by both EQ-5D and SF-6D) in predicting SWB might be the wording of the VAS question used in this survey, which explicitly includes a reference to the social dimension ('physical, mental and social'), something which appears to give a correspondingly lower relative importance of social relationship under VAS as compared to the indirect measures of HRQoL.

The results from the quantile regression model demonstrate that *health* is more important for individuals with lower level of SWB than those with higher level of SWB. This can be explained by the fact that *health* is considered as a *necessity* for individuals' at the bottom of SWB distribution since

they could be a deprived group in terms of both health and financial conditions. We find similar conclusions in the literature that the coefficient of health decreases across the quantiles (Binder & Coad, 2011; Graham & Nikolova, 2015). In general, our study contributes to the evidence that SWB is positively correlated with HRQoL. The degree of this association between HRQoL and SWB varies depending on whether HRQoL is valued indirectly through a generic descriptive system (e.g. EQ-5D and SF-6D) or directly on a rating scale (VAS).

With regard to the income-SWB association, household income has the lowest relative importance among the three main predictors. This result is consistent with findings from previous research (Easterlin, 1995; Ferrer-i-Carbonell, 2005; Rojas, 2011), which show that income has a statistically significant but weak association with SWB in cross-section studies. The association is weak in the sense that the coefficient is relatively small, and incomes contribution to goodness of model fit of the regression (R^2) is also low, which indicates that income alone explains 7.3% of the *explained* variability in SWB (Table 4, Model A). This weak association between income and SWB might partly be attributable to the nature of our sample; that is, subjects with chronic conditions might prioritize other domains of life than material well-being.

Further, a number of explanations have been given in the literature for the weak relative importance of income for SWB. Easterlin (1995) suggested a social comparison model, whereby an individual's relative income is more important that his absolute income. Another explanation could be habituation or adaptation (Diener et al., 1999; Menzel et al., 2002), where external circumstances and events (e.g. change in income) will only influence SWB temporarily, after which happiness will gradually move back towards the set point. Moreover, since the material aspirations increase with a rise in income, raising income may not necessarily increase SWB (Easterlin, 1995). Our findings also support the positive-coefficient hypothesis that SWB rises with income (Graham, 2011), but rejects the close-relationship hypothesis that income is a good predictor of SWB (Rojas, 2011). The

significant positive effect, though small, exists even after controlling for socio-demographic factors including education and unemployment. As shown in Appendix Fig.1, although the effect of income is strongest at low levels of income, it remains substantial even at higher income levels suggesting that importance of income diminishes as people get richer, but does not satiate once a certain income level is reached. This result corroborates earlier findings that SWB increases with income but with diminishing return (Diener & Biswas-Diener, 2002; Frey & Stutzer, 2010). Our quantile regression analysis also supports the finding that income is more important for the less fortune than the already well-off individuals.

Our summary measure of social relationships revealed a strong association with SWB. Life-satisfaction is more consistently related to the presence and quality of social relationship than are other predictors. It contributes half of the overall *explained* variation in SWB when health is measured by EQ-5D. Several studies provide strong support for the significant importance of social relationship for SWB (Binder & Coad, 2011; Dolan et al., 2008) although few studies considered an aggregate measure of social relationship as did the present study. Research also shows that the relative importance of predictors depend mainly on the units covered in the analysis, where the share of social variables appears to be higher in the studies with restricted international coverage of the data like the present one (Diener, Kahneman, & Helliwell, 2010). These could be reasons why social relationship is strongly related to SWB.

Furthermore, social interactions provide the opportunity in which self-realization and fulfilment take place through shared identities such as families and communities (Lin, 1999), which enhances well-being. It is less controversial to argue that people with enhanced social relationships are expected to have better psychological well-being as well as physical health (Cohen, 2004), as it entails several positive properties such as increased coping ability, feeling respected and recognized. In addition, enhanced social relationships obviously promote trust and reduce transaction costs, and hence help

as a source of information and motivation that serve as a potential force for enhancing SWB. Further important explanation for higher relative importance of social relationship is that it is a self-reported measure with a multi-item scale just like our SWB, which would possibly strengthen their association. In general, the better social inclusion and close relationship with family and friends, the higher will be the SWB.

With regard to control variables, this study confirms previous findings from the literature on SWB. SWB is U-shaped in age, and women have higher SWB than men. Our results are similar to the general finding that unemployment has a significant negative effect on SWB (Dolan et al., 2008) whereas SWB significantly increases with being married (Richards, 2015). There is contradicting findings with respect to education. Education has a positive effect on SWB in this study and the study by Gerdtham and Johannesson (2001), a negative effect in the study by Clark and Oswald (1994), and no significant effect in the study by Helliwell (2003).

Our OLS results depicted that the independent variables, all together, explain 45 - 50% of the variation in SWB. Other studies reveal similar results (Richardson et al., 2015). This result implies the presence of other determinants of well-being than considered here. For instance, personality traits exhibit some of the strongest associations with SWB, and it appears that genes may be partly responsible for this (Diener et al., 1999).

This study has several strengths: It contains both direct and indirect measure of health, including diagnosis types that enables us to confirm the consistency of health effects on SWB. Second, the social relationship variable is an aggregate measure that reflects broader importance of social factors on life satisfaction. Third, this study considers various individual, household and national-level control variables, minimizing potential model misspecification. Finally, the variance decomposition analysis has many desirable properties, which leaves no room for ambiguity as to which

decomposition method should be used, and the quantile regression model enables us to estimate the importance of each predictor at different quantiles (which the standard regression cannot do) with less distributional assumptions for the error terms, so the results are more robust.

As for the study limitations, cross-sectional data generally makes causal inferences problematic. Second, the study used absolute household income, which is derived from different income brackets for each observation in the survey. Though this approach is a common practice, it might have some impact on the reported results. The income variable is also given in local currencies of the six countries in the survey, and hence the purchasing power parity adjustment problems may influence our result, which is, of course, common to any cross-country studies. Finally, self-selection bias may have occurred, as individuals are volunteered to participate in the online survey.

Conclusions

Subjective well-being (SWB) is more than having a good financial standing and the absence of disease. It is an asset that allows people to realize their aspirations, and enhance their social ties. This study provides empirical evidence that health, income and social relationships are positively associated with SWB even after controlling for individual, household and national-level control variables. The study reveals that the aggregate measure of social relationship is the most important variable for SWB followed by HRQoL. Income, though significant, is less important for SWB. As a matter of necessities, health, income, education, marital status are more important for individuals at the lower end of the SWB distribution, whilst individual variations ('set-points') may explain more at the upper end. Further research is needed to identify what exactly determines life satisfaction at higher level of SWB distributions. However, this study acknowledges the integrated relative importance of health, income and social relations for SWB, particularly so for individuals' with poor level of SWB.

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Table 1 Respondents by disease groups and countries

	Country						
	Australia	Canada	Germany	Norway	UK	USA	Total
Healthy group	265	328	260	288	298	321	1760
Disease groups							
Arthritis	163	139	159	130	159	179	929
Asthma	141	138	147	130	150	150	856
Cancer	154	138	115	80	137	148	772
Depression	146	145	160	140	158	168	917
Diabetes	168	144	140	143	161	168	924
Hearing problems	155	144	136	115	126	156	832
Heart diseases	149	154	152	151	167	170	943
Total	1341	1330	1269	1177	1356	1460	7933

Table 2 Descriptive statistics

				Range	
Variables	Mean	SD	Median	Min	Max
Dependent variable					
Subjective well-being (SWB)	0.58	0.23	0.67	0.00	1.00
Independent variables					
Health					
EQ-5D-5L	0.82	0.19	0.87	-0.21	1.00
SF-6D	0.71	0.14	0.70	0.30	1.00
VAS	0.67	0.22	0.75	0.00	1.00
15D	0.85	0.13	0.88	0.25	1.00
HUI3	0.71	0.27	0.79	-0.34	1.00
Log income	3.54	0.84	3.62	1.80	5.98
Social relationships	0.74	0.19	0.77	0.00	1.00
Control variables					
Age	51.5	15.4	54.0	18.0	93.0
Gender					
Female	0.52	0.50	1.00	0.00	1.00
Education (Ref. High school)					
Diploma	0.40	0.49	0.00	0.00	1.00
University	0.28	0.45	0.00	0.00	1.00
Employment status (Ref. all others)					
Unemployed	0.08	0.27	0.00	0.00	1.00
Marital status (Ref. No partner/spouse)					
Partner/spouse	0.64	0.48	1.00	0.00	1.00

Note: See Table 1 for summary information of country and disease group dummies. For categorical variables (Gender, Education, Employment status and Marital status), the mean value indicates percentage share of the indicated group in the sample.

Table 3 OLS regression results on subjective well-being (SWB) (N = 7933)

	OLS1						OLS2					
	Model A		Model B		Model C		Model A		Model B		Model C	
Variables	b	β	b	β	b	β	b	β	b	β	b	β
HRQoL	0.225**	0.166**	0.375**	0.199**	0.376**	0.314**	0.194**	0.144**	0.330**	0.175**	0.381**	0.318**
Log Income	0.031**	0.101**	0.030**	0.099**	0.027**	0.087**	0.031**	0.100**	0.030**	0.098**	0.028**	0.089**
Social relationships	0.623**	0.468**	0.585**	0.440**	0.536**	0.403**	0.608**	0.457**	0.577**	0.434**	0.522**	0.392**
Gender												
Female	0.021**	0.040**	0.024**	0.047**	0.011**	0.022**	0.021**	0.041**	0.024**	0.047**	0.015**	0.028**
Age	-0.008**	-0.492**	-0.009**	-0.546**	-0.007**	-0.429**	-0.008**	-0.504**	-0.009**	-0.552**	-0.008**	-0.450**
Age-squared/100	0.009**	0.511**	0.009**	0.554**	0.008**	0.455**	0.009**	0.533**	0.010**	0.569**	0.008**	0.471**
Marital status												
Partner/Spouse	0.043**	0.081**	0.044**	0.083**	0.041**	0.076**	0.044**	0.082**	0.045**	0.083**	0.040**	0.074**
Education												
Diploma/Certificate	0.015**	0.029**	0.017**	0.032**	0.017**	0.032**	0.012*	0.023*	0.014*	0.026*	0.011*	0.020*
University	0.030**	0.053**	0.032**	0.055**	0.027**	0.047**	0.033**	0.057**	0.033**	0.058**	0.026**	0.045**
Employment status												
Unemployed	-0.081**	-0.084**	-0.080**	-0.082**	-0.080**	-0.082**	-0.075**	-0.077**	-0.074**	-0.076**	-0.074**	-0.076**
Disease dummies												
Arthritis							-0.014	-0.018	-0.009	-0.011	0.019*	0.024*
Asthma							-0.021**	-0.025**	-0.012	-0.015	0.016*	0.019*
Cancer							-0.057**	-0.065**	-0.046**	-0.053**	0.001	0.001
Depression							-0.056**	-0.070**	-0.047**	-0.058**	-0.016	-0.020
Diabetes							-0.041**	-0.051**	-0.033**	-0.041**	0.009	0.011
Hearing problems							-0.000	-0.000	0.005	0.006	0.025**	0.030**
Heart problems							-0.037**	-0.046**	-0.028**	-0.035**	0.018*	0.023*
Country dummies												
Australia							0.031**	0.046**	0.035**	0.050**	0.031**	0.045**
Canada							0.039***	0.056**	0.039**	0.056**	0.029**	0.042**
Germany							0.037**	0.053**	0.036**	0.051**	0.038**	0.054**
Norway							0.021**	0.029**	0.023**	0.032**	0.025**	0.034**
USA							0.007	0.010	0.008	0.012	-0.007	-0.010
Constant	-0.055*	-0.001	-0.082**	-0.001	-0.066**	-0.005	-0.014	-0.001	-0.050	-0.001	-0.075**	-0.005
R-squared	0.44		0.45		0.49		0.45		0.46		0.50	

Note: Dependent variable is SWB (measured by the first 3 items of satisfaction with life scale); *b,* unstandardized coefficient; *β,* standardized coefficient. HRQoL (health related quality of life) is measured by EQ-5D in Model A, SF-6D in Model B, and VAS in Model C.

** / * denotes statistical significance at 1% and 5% level, based on the heteroscedasticity-robust covariance matrix.

Table 4 Relative importance of predictors for subjective well-being (SWB)

	Model A			Model B			Model C		
Variable	SV	%R^2	(95% CI)	SV	%R^2	(95% CI)	SV	%R^2	95% CI
HRQoL	0.087	19.3	(17.23, 21.32)	0.108	23.8	(21.88, 25.43)	0.158	31.6	(29.43, 33.65)
Log income	0.033	7.3	(6.02, 8.60)	0.032	7.0	(5.81, 8.35)	0.033	6.6	(5.60, 7.75)
Social relationships	0.227	50.2	(47.4, 52.57)	0.214	46.8	(44.17, 49.09)	0.210	42.0	(39.45, 44.00)
Gender	0.001	0.2	(0.12, 0.44)	0.001	0.3	(0.18, 0.56)	0.001	0.1	(0.08, 0.25)
Age (and Age^2)	0.015	3.4	(2.61, 4.40)	0.015	3.3	(2.53, 4.14)	0.015	2.9	(2.21, 3.74)
Marital status	0.020	4.5	(3.43, 5.63)	0.020	4.4	(3.35, 5.48)	0.019	3.8	(2.87, 4.75)
Education (Diploma & University)	0.005	1.1	(0.66, 1.67)	0.005	1.1	(0.66, 1.68)	0.005	0.9	(0.54, 1.48)
Employment status	0.016	3.6	(2.65, 4.68)	0.016	3.5	(2.52, 4.66)	0.016	3.2	(2.29, 4.18)
Disease dummies†	0.039	8.6	(7.46, 10.14)	0.037	8.0	(6.84, 9.27)	0.036	7.1	(6.18, 8.34)
Country dummies†	0.008	1.8	(1.28, 2.56)	0.008	1.8	(1.30, 2.55)	0.009	1.8	(1.38, 2.54)
Total R^2	0.45	100		0.46	100		0.50	100	

Note: SV, Shapley value, sums to R^2 (the total amount of variance in SWB explained by all independent variables); % R^2 , relative importance values (sums to 100%), representing the proportional contribution of each variable to R^2; CI, 95% confidence interval for %R^2. Dependent variable is SWB (measured by the first 3 items of satisfaction with life scale). HRQoL (health related quality of life) is measured by EQ-5D in Model A, SF-6D in Model B, and VAS in Model C.

Table 5 Estimates of the quantile regression model on subjective well-being (SWB) (N = 7933)

	Model A			Model B			Model C		
Variables	q25	q50	q75	q25	q50	q75	q25	q50	q75
HRQoL	0.239**	0.234**	0.168**	0.453**	0.332**	0.223**	0.436**	0.455**	0.356**
Log Income	0.039**	0.033**	0.020**	0.038**	0.034**	0.021**	0.038**	0.028**	0.020**
Social relationships	0.690**	0.664**	0.581**	0.626**	0.639**	0.574**	0.577**	0.528**	0.507**
Gender									
Female	0.025**	0.028**	0.024**	0.028**	0.033**	0.025**	0.016*	0.020**	0.019**
Age	-0.010**	-0.009**	-0.007**	-0.011**	-0.010**	-0.008**	-0.009**	-0.008**	-0.006**
Age-squared/100	0.011**	0.009**	0.007**	0.012**	0.010**	0.008**	0.010**	0.008**	0.006**
Marital status									
Partner/Spouse	0.057**	0.053**	0.037**	0.055**	0.053**	0.039**	0.052**	0.047**	0.032**
Education									
Diploma/Certificate	0.030**	0.011	0.008	0.028**	0.011	0.009	0.018*	0.017**	0.005
University	0.055**	0.035**	0.024**	0.046**	0.035**	0.025**	0.036**	0.032**	0.020**
Employment status									
Unemployed	-0.080**	-0.088**	-0.087**	-0.080**	-0.083**	-0.087**	-0.073**	-0.086**	-0.082**
Disease dummies									
Asthma	-0.018	-0.021*	-0.017*	-0.006	-0.019*	-0.018	0.028**	0.012	0.011
Arthritis	-0.020	-0.003	-0.008	-0.006	-0.007	-0.013	0.018	0.016	0.022*
Cancer	-0.073**	-0.051**	-0.037**	-0.053**	-0.042**	-0.036**	0.003	0.005	0.005
Depression	-0.065**	-0.054**	-0.046**	-0.044**	-0.058**	-0.046**	-0.025	-0.018	-0.016
Diabetes	-0.059**	-0.036**	-0.018*	-0.048**	-0.030**	-0.023**	0.016	0.017	0.012
Hearing problems	-0.001	0.002	0.002	0.011	0.006	0.001	0.037**	0.022*	0.021**
Heart problems	-0.045**	-0.033**	-0.027**	-0.034**	-0.028**	-0.026**	0.019	0.020*	0.016
Country dummies									
Australia	0.036**	0.035**	0.034**	0.038**	0.040**	0.034**	0.041**	0.030**	0.032**
Canada	0.041**	0.037**	0.046**	0.042**	0.041**	0.044**	0.030*	0.029**	0.035**
Germany	0.043**	0.031**	0.018*	0.046**	0.032**	0.013	0.059**	0.023**	0.018*
Norway	0.022	0.012	0.013	0.030**	0.018	0.016	0.037**	0.009	0.013
USA	-0.012	-0.000	0.021*	-0.007	0.005	0.023**	-0.007	-0.009	0.009
Constant	-0.252**	-0.090**	0.179**	-0.308**	-0.100**	0.173**	-0.303**	-0.116**	0.097**
Pseudo R^2	0.32	0.30	0.22	0.32	0.30	0.22	0.35	0.34	0.25

Note: Dependent variable is SWB (measured by the first 3 items of satisfaction with life scale). HRQoL (health related quality of life) is measured by EQ-5D in Model A, SF-6D in Model B, and VAS in Model C.

** / * denotes statistical significance at 1% and 5% level, based on 200 bootstrap samples.

Appendix Table A1 OLS and QRM results on subjective well-being (SWB) when HRQoL is measured by 15D and HUI-3

	OLS				QRM					
	Model D		Model E		Model D			Model E		
Variables	b	β	b	β	q25	q50	q75	q25	q50	q75
HRQoL	0.400**	0.196**	0.195**	0.200**	0.513**	0.481**	0.346**	0.244**	0.247**	0.160**
Log Income	0.029**	0.095**	0.028**	0.092**	0.038**	0.031**	0.020**	0.033**	0.030**	0.020**
Social relationships	0.559**	0.420**	0.555**	0.417**	0.619**	0.603**	0.541**	0.612**	0.595**	0.537**
Gender										
Female	0.022**	0.043**	0.019**	0.036**	0.023**	0.032**	0.024**	0.018*	0.027**	0.022**
Age	-0.008**	-0.506**	-0.008**	-0.507**	-0.010**	-0.008**	-0.007**	-0.010**	-0.008**	-0.008**
Age-squared/100	0.009**	0.539**	0.009**	0.544**	0.011**	0.009**	0.008**	0.011**	0.009**	0.008**
Marital status										
Partner/Spouse	0.047**	0.086**	0.044**	0.082**	0.062**	0.056**	0.039**	0.062**	0.054**	0.038**
Education										
Diploma/Certificate	0.011*	0.020*	0.010	0.020	0.027**	0.011	0.004	0.027**	0.012	0.005
University	0.029**	0.051**	0.028**	0.049**	0.047**	0.032**	0.021**	0.052**	0.034**	0.017*
Employment status										
Unemployed	-0.076**	-0.078**	-0.074**	-0.076**	-0.081**	-0.089**	-0.088**	-0.082**	-0.080**	-0.093**
Disease dummies										
Arthritis	-0.006	-0.007	-0.005	-0.006	-0.001	-0.008	-0.011	-0.015	-0.020*	-0.017
Asthma	-0.005	-0.006	-0.018*	-0.021*	-0.008	0.000	-0.003	-0.010	0.005	-0.001
Cancer	-0.039**	-0.045**	-0.050**	-0.057**	-0.046**	-0.030**	-0.026**	-0.059**	-0.041**	-0.039**
Depression	-0.042**	-0.052**	-0.048**	-0.060**	-0.047**	-0.040**	-0.036**	-0.063**	-0.053**	-0.046**
Diabetes	-0.029**	-0.036**	-0.033**	-0.041**	-0.040**	-0.022*	-0.015*	-0.048**	-0.027**	-0.021*
Hearing problems	0.010	0.012	0.019*	0.023*	0.016	0.010	0.009	0.019	0.022**	0.016
Heart problems	-0.021**	-0.026**	-0.031**	-0.039**	-0.019	-0.015	-0.021**	-0.040**	-0.026**	-0.030**
Country dummies										
Australia	0.031**	0.045**	0.031**	0.046**	0.039**	0.027**	0.028**	0.041**	0.030**	0.032**
Canada	0.039**	0.056**	0.038**	0.055**	0.039**	0.033**	0.038**	0.048**	0.032**	0.040**
Germany	0.035**	0.049**	0.036**	0.051**	0.048**	0.019	0.014	0.052**	0.026**	0.014
Norway	0.019*	0.027*	0.018*	0.025*	0.022	0.007	0.007	0.027*	0.003	0.009
USA	0.007	0.011	0.006	0.010	-0.006	-0.004	0.022**	-0.001	-0.007	0.018
Constant	-0.166**	-0.001	0.048*	-0.001	-0.447**	-0.282**	0.049	-0.156**	-0.027	0.241**
R^2/Pseudo R^2	0.46		0.46		0.32	0.31	0.22	0.32	0.31	0.22

Note: Dependent variable is SWB (measured by the first 3 items of satisfaction with life scale); *b,* unstandardized coefficient; *β,* standardized coefficient. HRQoL (health related quality of life) is measured by 15D in Model D, and HUI-3 in Model E.

** / * denotes statistical significance at 1% and 5% level, based on the heteroscedasticity- robust covariance matrix for OLS and 200 bootstrap samples for QRM.

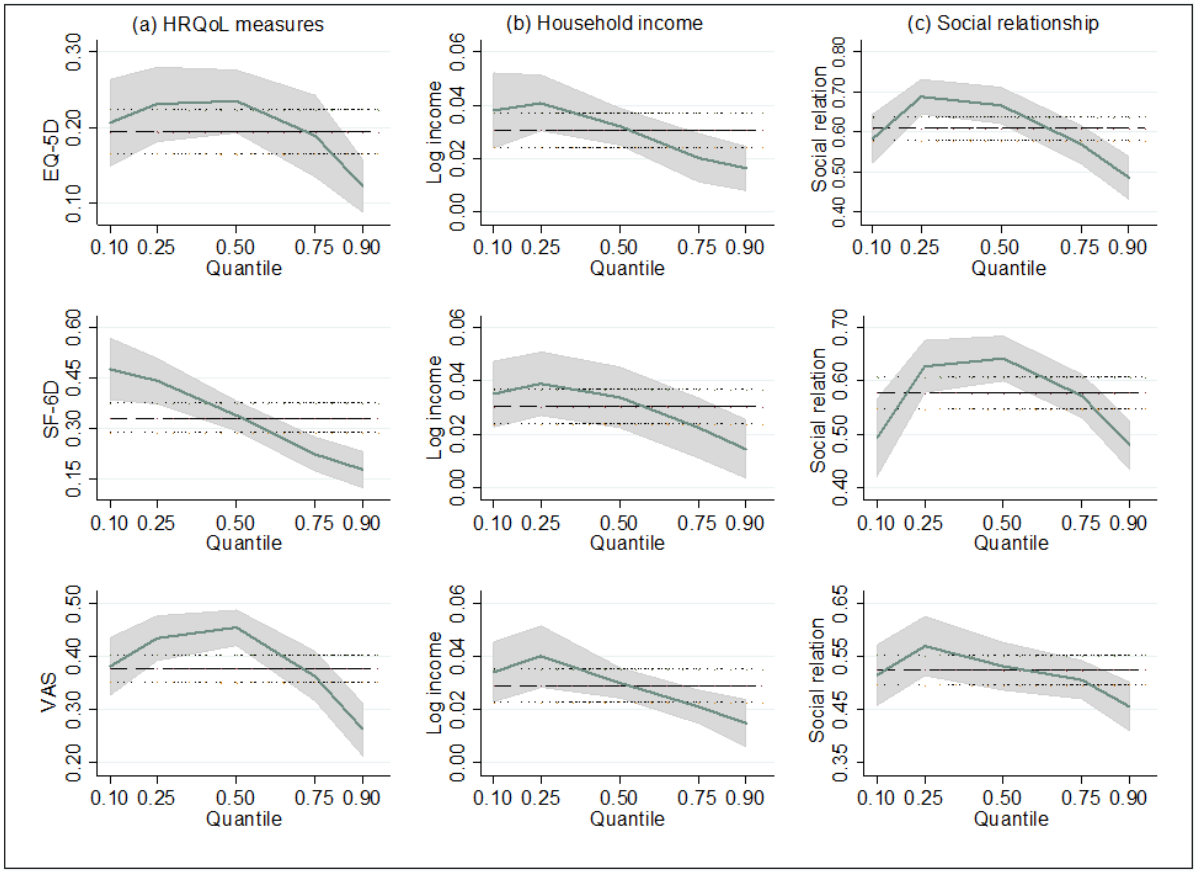
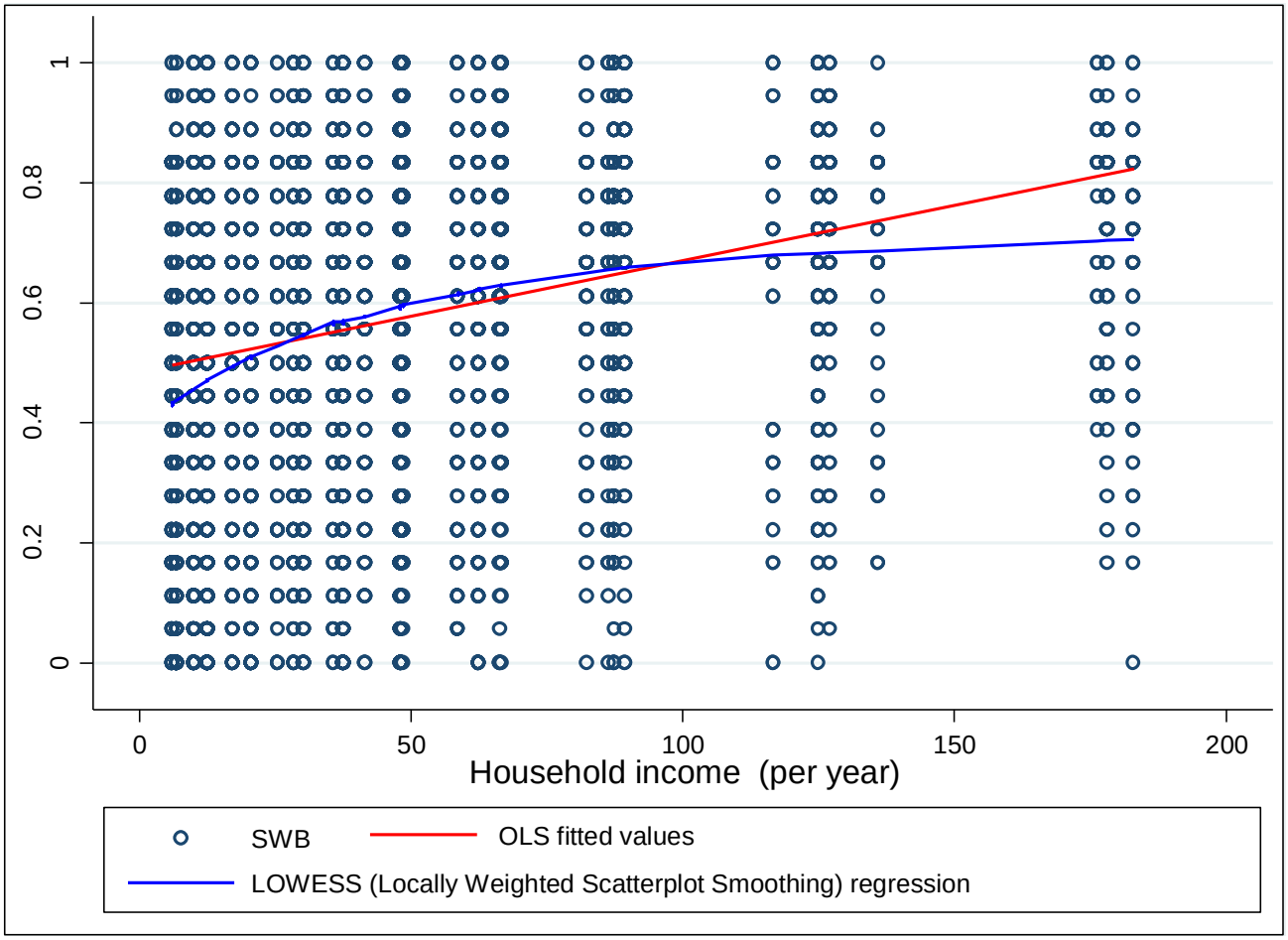


Fig. 1 Quantile regression estimates of independent variables for subjective well-being (SWB)

Note: Vertical axes indicate quantile regression coefficients for the indicated variable, and horizontal axes depict the quantiles of SWB. The first column of this figure represents quantile regression estimates under three different measures of HRQoL; EQ-5D, SF-6D and VAS. The second and third columns show income (in natural logarithm) and social relationship coefficients estimated under each measures of health.



Appendix Fig. A1 Life satisfaction vs. household income (income in 000's of US$)
Note: Concave (blue) line is a nonparametric (lowess) line of best fit, which allows the data to choose the functional form of SWB-income relationship; and straight (red) line is ordinary least (OLS) regression line when SWB is regressed on income. Log transformation of income would capture this concavity between SWB and income (i.e. the diminishing returns income).