

# Environmental Quality and Life Satisfaction: Subjective Versus Objective Measures of Air Quality

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Accepted: 20 October 2014 / Published online: 30 October 2014  
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**Abstract** The purpose of this paper is to investigate the influence of objective air quality on individual life satisfaction (LS) through the moderating effect of perceived air quality on the latter. Unlike previous studies, we incorporate both of the data from the 2010 Taiwan Social Change Survey and the monthly mean of Pollutant Standards Index (PSI) from fixed air quality monitoring stations to understand their association with individual well-being. A two-stage estimation approach is employed, in which individual perceived subjective air quality level is employed as an explanatory variable in LS regression models. The results show that the objective measure of air quality, PSI, is significantly associated with the perceived air quality and with LS, respectively. When the endogeneity of perceived air quality is considered in the relationship between objective air quality and life satisfaction, the results indicate that the perceived air quality has a positive influence on LS, while the effect of objective measure of air quality on the latter becomes insignificant. In sum, the objective air quality has an indirect effect, but no direct effect, on LS. Furthermore, individual's age, gender, health, and variables of environmental experience and behaviors are found to be significant determinants of LS. Discussions on the findings are provided.

**Keywords** Perceived air quality · Individual well-being · Micro data · PSI

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## 1 Introduction

The association between objective and subjective quality of life (hereinafter QoL) has long been a focus among researchers, while a consensus is yet to be reached. Previous studies from the perspectives of needs theory have demonstrated that an improvement in subjective QoL occurs as a result of social and economic development (cf. Kao and Liu 1984; Liao et al. 2005; Zinam 1989), although people's perception of and satisfaction with life in socio-economically disadvantaged communities is not necessarily lower than those in advantaged communities (see Lewis and Lyon 1986; Schuessler and Fisher 1985). On the other hand, comparison theory assumed that people make judgments based on relative values (Hagerty 1999, 2000; Veenhoven 1995). It is argued that objective conditions affect subjective perceptions indirectly through comparisons with other possible alternatives (Diener and Lucas 2000). The individual's own experience in the past or other people's may be used to make comparisons, although it is unclear what the comparison base/group may be (Hagerty 2000).

With respect to various domains of QoL, objective and subjective dimensions do not necessarily correspond to each other in either growth or decline (Liao 2009; Schuessler and Fisher 1985), with environmental quality as an exception. It is found that a better environmental quality, as measured by objective indicators of air pollution and the amount of waste, are correlated with higher satisfaction with residential environment (Liao 2009). However, the question of whether such a correlation contributes to residents' overall QoL remains unknown, despite the fact that a direct impact of air pollution on life satisfaction (hereinafter LS) has been highlighted (Luechinger 2009, 2010; MacKerron and Mourato 2009; Welsch 2006). This study attempts to examine the effect of objective air quality on individual LS through the influence of perceived air quality on the latter. Individuals' socio-demographic characteristics and cognitive evaluation associated with environmental quality are included in the analytic model as well.

## 2 Life Satisfaction and Air Quality

LS has been used to refer to a subjective indicator of QoL or subjective well-being (SWB) (Bardo and Bardo 1983; Brown 1993; Martin and Lichter 1983; Popenoe 1983; Ziegler and Britton 1981). It is also regarded as the measure of a cognitive or judgmental state which refers to an assessment of life as a whole (Andrews and Withey 1976; Campbell 1981; Emmons and Diener 1985; Tepperman and Curtis 1995; Tsou and Liu 2001). Such concept has been broadly used to refer to people's individual well-being and/or welfare (Chamberlain 1985; Oppong et al. 1988). It is an orientation that focuses on the problem of defining life quality in terms of quantifiable categories that measure various perceptions of human life conditions. Together with satisfaction measures in various life domains, these subjective indicators are suggested as being essential for understanding the impact of objective conditions and public policies upon individual well-being (Wilkening 1982). As an inter-disciplinary field of research, QoL theories have included perspectives from social, psychological, economic, and ecological approaches (Schuessler and Fisher 1985). These theories differ mainly in the centrality of cognition, affect and social interaction because of the inescapable heterogeneity of the "social" in the indicators (Land 1983).

In empirical studies, the components of the subjective QoL have been examined to reveal various dimensions as well as the reliability of people's perceptions and evaluation of their lives (Campbell et al. 1976; Chamberlain 1985; Lewis and Lyon 1986; Oppong

et al. 1988). Structural change, such as people's perceptions of economic development or population growth (Mastekaasa and Moum 1984; Popenoe 1983; Wilkening 1982) and factors associated with personal life stage or social bonds (Campbell et al. 1976; Lu and Shih 1997; Lu 1999) have been found to influence the subjective QoL. Likewise, physical and mental health (Michalos et al. 2001), voluntary work (Thoits and Hewitt 2001) and the socio-psychological characteristics of individuals (Falkenberg 1998) have been shown to influence LS and/or happiness.

In addition to the individual's socio-demographic and psychological characteristics, environmental quality is found to be an important domain when assessing QoL. Rehdanz and Maddison (2005) and Ng (2011) examine the impact of climate change on LS in a broader concept of environmental quality and suggest country-level adjustment for a better QoL. Recently, Van Praag and Baarsma (2005) evaluate the value of airport noise damage by aircraft noise nuisance around Amsterdam Airport using happiness survey data. In a similar vein, Welsch (2006) examine the relationship between the environment and LS using a set of panel data for ten European countries from 1990 to 1997 and find that objective measures of air pollution have significantly negative impacts on the national happiness level.

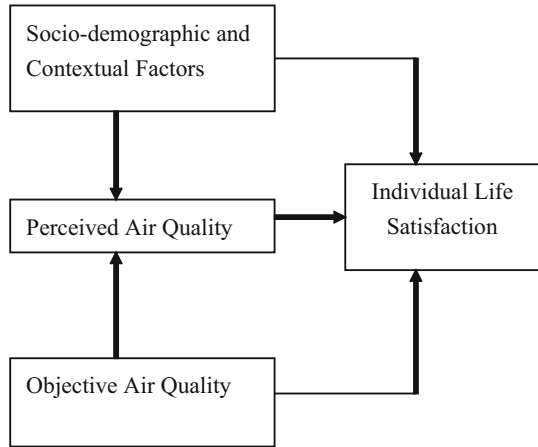
With a specific focus on local environmental quality, (Rehdanz and Maddison 2008) reveal the negative influence of perceived air pollution on noise on LS when controlling for socio-demographic variables and neighborhood characteristics. Furthermore, MacKerron and Mourato (2009), in highlighting the non-income aspects of people's life conditions, find that both objective and subjective measures of air pollution levels are significantly and negatively associated with the LS of the London residents using micro data. Similar results are found in studies using individual- or country-level data (Ferreira and Moro 2010; Luechinger 2009, 2010; Menz 2011; Welsch 2006). The examined objective indicators of air quality, such as air pollutants, include sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), and suspended particles (PM<sub>10</sub>). However, the relationship between the subjective and the objective environmental quality and the effect of such a relationship on individual's overall LS have not been fully explored, due to the fact that they are generally viewed as independent issues in the literature.

In this study, we intend to examine a direct effect of objective environmental quality on individual LS, and an indirect effect of the former through perceived environment quality on the latter. The analytical framework can be illustrated as Fig. 1. We first hypothesize that air quality constitutes an aspect of environment, which can be perceived by individuals. The second hypothesis is that satisfaction with air quality as well as individual contextual factors can affect individual subjective well-being. Furthermore, air quality may affect subjective well-being without mediation through perceived air quality.

In order to examine these relationships, we incorporated survey data and objective indicators of air quality to investigate the aforementioned relationships. Since the perceived air quality and LS are all subjective, the endogeneity needs to be considered.<sup>1</sup> Therefore, the perceived air quality and LS are regarded as endogenous variables. A two-stage estimation approach is employed. We first explore the relationships between air pollutant measures and perceived air quality. In the second stage, perceived air quality and objective measures of air quality are included as explanatory variables in the LS regression model.

<sup>1</sup> There exists the known causal relationships between objective indicators of air quality, health status, and life satisfaction. However, the relationship between health status and objective air quality is weak and ambiguous.

**Fig. 1** The relationships among objective air quality, perceived air quality and individual life satisfaction



People's attitudes towards and experiences of environmental issues are also found to affect subjective well-being (Ferrer-i-Carbonell and Gowdy 2007; Sirgy et al. 2010), since individuals may evaluate environmental quality based on their experiences and values related to such issues (Hagerty 2000; Veenhoven 1995). Comparison theory asserted that the evaluation of QoL or satisfaction is based on a process of mental calculus in which the standards of comparison are presumed to be adjustable rather than fixed (Veenhoven 1995). Whether an individual feels satisfied is closely associated with one's standards of comparison based on his/her own experience or others' (Campbell et al. 1976; Diener and Lucas 2000). It is, therefore, important to take into account an individual's attitudes and behaviors associated with the aspects of environmental quality when examining such an issue. Socio-demographic variables and contextual factors such as environmental characteristics in the neighborhood are also included in the model.

The remainder of this paper is organized as follows: Sect. 3 describes the data and provides variable definitions and descriptive statistics. The process of deriving the objective measures of air quality is explained as well. In Sect. 4, we illustrate the estimation procedures and report the empirical results. Finally, Sect. 5 presents the concluding remarks.

### 3 Econometric Model and Sample Data

#### 3.1 Econometric Model

In this paper, we attempt to investigate the relationships among objective air quality, perceived air quality and LS using micro data. A two-stage estimation approach is employed. In the first stage, we propose that air quality constitutes an important aspect of environmental quality which can be easily perceived by individuals. The perceived air quality will also depend on individual and contextual variables. In addition, we further examine the hypothesis that both perceived air quality and actual air pollution levels affect individual LS as indicated in Fig. 1. Since both of the individual LS and subjective air quality are subjective, we should take the endogeneity of subjective air quality into consideration when building the econometric model. A two stage estimation approach is

employed in this study, which is following the two stage estimation procedure proposed by Maddala (1983, chapter 8).

Thus, a two-stage estimation approach is specified as follows. In the first stage, we estimate the equation of perceived air quality as (1):

$$AIRQ = \alpha_1 P + \beta_1 X_1, \quad (1)$$

where  $AIRQ$  is the perceived air quality drawn from the TSCS survey;  $P$  is the objective air pollutant measure; and  $X_1$  is the vector of other explanatory variables such as respondent's gender, year of age, income and other environmental quality variables. Since the subjective air quality measure is based on a 5-point scale of perceived air quality, in which 5 is the best, an ordered probit regression model is employed to estimate the Eq. (1). The objective measure of air pollutants is included in the ordered probit regression model as an explanatory variable. Socio-demographic variables and neighborhood environmental characteristics are also included.

In the second stage, the predicted value of perceived air quality from the first stage is used as an explanatory variable in estimating the LS Eq. (2):

$$LS = \alpha_2 P + \beta_2 X_2 + \beta_{aq} \widehat{AIRQ}, \quad (2)$$

where LS is a respondent's reported LS which is measured with a 5-point scale, ordinal variable;  $\widehat{AIRQ}$  is the predicted value of subjective air quality of the respondent which we can get from the estimation result of Eq. (1), and  $X_2$  is the vector of other explanatory variables. Similarly, we employ the ordered probit regression model because reported LS (LS) is an ordered variable scaled from 1 to 5. The objective measure of air pollutants is also included in the regression as an explanatory variable as well as the predicted subjective air quality. In addition to the socio-demographic variables, the respondent's self-reported health, environmental experience variables, and environmental behavior variables are also included.

### 3.2 Sample Data

Two data sets are employed in this study, one survey data set and an actual air quality data set. Survey data are derived from the 2010 Taiwan Social Change Survey (TSCS) questionnaire No. 2, sponsored by the National Science Council and conducted by the Institute of Sociology and the Center for Survey Research at Academia Sinica in Taiwan (Chang et al. 2012). The main theme of this survey is environmental issues, including core questions of International Social Survey Programme (ISSP) module on Environment, as well as values, trust, and behaviors associated environment, and quality of life. Questions on household and individual characteristics are also collected.

Surveys are delivered to randomly selected adults aged 18 years or older within each selected municipality. A three-stage stratified sampling design is used based on the consideration of the urbanization level of townships and four geographical areas in Taiwan, with the latter differ in terms of environmental measures. Township is used as the primary sampling unit (PSU) and village or li under township as the second. The probability proportional to size (PPS) sampling method is used in the first two stages—township and village or li under townships, respectively. Finally, household-registered residents in each village/li are systematically selected to obtain a representative sample of Taiwan's population. Face-to-face interviewing technique is used to collect survey data. A total of 2,209 complete cases is obtained with a response rate of 50 %. For the purpose of this study, a

total of 1,055 complete cases are analyzed after the exclusion of a split-ballot sample for an experimental design and item nonresponse such as can't choose, don't know, and refusals.

In order to obtain the objective measures of air quality to which the respondents are exposed, we use the monthly air quality data for June 2010 at each respondent's nearest Environmental Protection Administration (EPA) air quality monitoring stations to correspond the period of survey data collection during July and August in the same year. In 2010, there are 76 fixed air quality monitoring stations distributed across the country, among which 31 stations are included in this study. Each monitoring station provide several air quality indicators including Pollutant Standards Index (PSI),  $PM_{10}$ , ozone ( $O_3$ ), sulfur dioxide ( $SO_2$ ), nitrogen dioxide ( $NO_2$ ), and carbon monoxide (CO).<sup>2</sup>

In this study, we employ the percentage of days with  $PSI \leq 50$  in June, 2010, which have not been examined in previous SWB literature. The PSI indicator provides a uniform system for measuring pollution levels for the five major air pollutants of  $PM_{10}$ ,  $O_3$ ,  $SO_2$ ,  $NO_2$  and CO, which is based on a scale devised by the United States Environmental Protection Agency (USEPA) to provide a concise but comprehensive summary of air quality. The PSI is reported as a number on a scale of 0–500. If  $PSI \leq 50$ , the air quality is considered to be in “GOOD” condition. In June 2010, the mean of PSI was 42.43 and the average percentage of  $PSI \leq 50$  was 77.84, which indicates that almost 80 % of the air quality is considered to be in good condition.

### 3.3 Variable Definition and Descriptive Statistics

The definitions and descriptive statistics of variables used to investigate the relationships among objective and subjective air quality and individual LS are reported in Tables 1, 2. The main measures of individual LS and subjective air quality drawn from the TSCS survey, LS of the respondents, LS, is measured with a 5-point scale and the sample mean is 3.29. Respondent's perception of air quality, AIRQ, is also measured on a 5-point scale, with 5 indicating very good and 1 very bad. The sample mean of the subjective measure of air quality is 3.48.

In addition to the indicators of air quality, several types of variables are employed in our empirical study. These variables include social demographic variables, respondent physical conditions, environmental experience, environmental behaviors and external environment variables. The variable definitions and descriptive statistics are also reported in Tables 1, 2, respectively.

The socio-demographic variables include the respondent's gender (SEX), age (AGE), monthly income (INCOME), marital status (MARRIED), working status (JOB), education (EDU), RELIGION and residential area (URBAN). HEALTH represents the respondent's

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<sup>2</sup>  $PM_{10}$  refers to a particle with a diameter of 10 micrometers or less. Sources of particle matter can be dust on the street, the burning of fossil fuels in vehicles, open combustion, construction works, and agricultural plowing. If other pollutants adhere to those particles, they will reinforce harmfulness to the respiratory system. Sulfur dioxide ( $SO_2$ ) is mainly generated from the combustion of petroleum or coal. It is a colorless gas with a penetrating odor, and easily dissolves in water to form sulfurous acid. It can oxidize to the sulfate in the air that is the main substance that causes acid rain. Nitrogen dioxide is a kind of red-brown gas with a stimulative smell, and easily dissolves in water to form nitrous acid and nitric acid. The oxidization of nitrate is one of the factors causing acid rain. Ozone is one kind of secondary pollutant that is generated by nitrogen oxides or reactive hydrocarbons after they are activated by the sunlight. It is a highly active oxidization gas, and stimulative to the respiratory system in that it will cause coughing, asthma, headaches, weariness, and lung injuries, especially affecting children, the old, patients, and those exercising outdoors. Carbon monoxide is generated by the incomplete combustion of petrochemical fuels. It is colorless, smell-less and lighter than air.

**Table 1** Definitions of variables and sample characteristics

Variable name	Description	Mean (SD) <sup>a</sup>
Dependent variables		
AIRQ	Subjective air quality measure, 1–5 scale for the feeling of air quality, 5 is the best	3.48 (0.98)
LS	Life satisfaction, respondent's subjective reported well-being, 1–5 scale, 5 is the most satisfied	3.29 (0.70)
Objective air quality variables		
PSI	The percentage of days with of PSI <50 in June, 2010, %	77.86 (12.33)
Socio-demographic variables and health		
SEX	Dummy (male = 1, female = 0)	0.50 (0.50)
AGE	Age of respondent	46.16 (16.39)
MARRIED	Dummy (=1 if respondent is married, 0 otherwise)	0.60 (0.49)
INCOME	Monthly income (1,000 NT\$)	27.10 (28.54)
URBAN	Dummy (=1 if respondent lives in urban area, 0 otherwise)	0.24 (0.42)
JOB	Dummy (=1 if respondent has a full time job, 0 otherwise)	0.50 (0.50)
EDU	Education year	11.68 (4.39)
RELIGION	8-point scale, 1–8, 1 if respondent never participated in religious activity, 8 if respondent participated in religious activities several times a week	2.43 (1.72)
HEALTH	5-point scale, 5 if respondent reported in the best health condition, 1 if respondent is in the worst health condition	3.43 (0.83)
Environmental experience variables		
LOSS	Dummy (=1 if respondent or his/her family has experienced a property loss or a physical or emotional loss because of a problem of environmental pollution, 0 no)	0.15 (0.35)
FATALISM	Dummy (=1 if respondent agreed that it's humanity's fate to be damaged by environmental pollution, and there is nothing to prevent the damage from it, 0 disagree)	0.08 (0.27)
CONTRAST	The chances of the respondent's residence being affected by environmental pollution as compared to other families in Taiwan, 1 if more, 2 if the same and 3 if less	2.41 (0.63)
Environmental behavior variables		
PARTICIPATION	Dummy =1 if the respondent has participated in community activities of environmental protection, 0 never	0.26 (0.44)
RESPONSE	Dummy =1 if the respondent has reported situations that have caused environmental pollution in your community, 0 never	0.43 (0.50)
Neighborhood environmental variables		
PLANT	Dummy (=1 if there is a plant or store within 50 m of the respondent's residence, 0 no)	0.23 (0.42)
TEMPLE	Dummy (=1 if there is a temple within 50 meters of the respondent's residence, 0 no)	0.40 (0.49)

**Table 1** continued

Variable name	Description	Mean (SD) <sup>a</sup>
GAS Station	Dummy (if there is a gas station within 50 m of the respondent's residence, 0 no)	0.13 (0.33)
NIGHT Market	Dummy (=1 if there is a night market within 50 m of the respondent's residence, 0 no)	0.12 (0.33)
RESTAURANT	Dummy (=1 if there is a greasy and smoky restaurant or street vendor within 15 m of the respondent's residence, 0 otherwise)	0.24 (0.43)
ROAD	Dummy (=1 if there is a road with heavy traffic within 15 m of the respondent's residence, 0 no)	0.30 (0.46)
OBS		1,055

<sup>a</sup> The numbers in parentheses are the standard errors

self-reported physical condition. Table 1 indicates that half of the sampled respondents are male and the respondent's mean age is about 46 years old. Fewer than 60 % of the respondents are married and the individual's average monthly income is about NT\$26,930 (US\$950). Also, half of the respondents have a full time job, the respondents have an average of 11.7 education years, and 86 % reported in a good health condition. Moreover, almost one quarter of the respondents are living in urban areas.

The environmental experience variables include three variables. LOSS is a dummy variable which is 1 if the respondent or his/her family has experienced a property loss or a physical or emotional loss because of a problem of environmental pollution. FATALISM is a dummy variable, which equals 1 if the respondent agreed that it's humanity's fate to be damaged by environmental pollution, and there is nothing to prevent the damage from it. More than 90 % of the respondents disagreed so. CONTRAST represents the chances of the respondent's residence being affected by environmental pollution as compared to other families in Taiwan. Most of the respondents think that the chance of their residence being affected by environmental pollution is the same as or less than other families in Taiwan.

Environmental behaviors include two variables. PARTICIPATION indicated whether the respondent has participated in community activities of environmental protection, whilst RESPONSE is concerned with whether the respondent has reported situations that have caused environmental pollution in their community. Oliver (1984) indicated that those currently active in the community are more willing to take action because they believed that, if they do not, nobody else would. When environmental issues trigger a collective response, those with negative feelings towards their neighbors are more likely to demonstrate their concerns. Table 2 shows that more than a quarter of the respondents have participated in community activities of environmental protection and around 43 % of them have reported situations that caused environmental pollution in the community.

Six variables of neighborhood environmental characteristics, which may caused air pollution, are employed from the TSCS survey, including whether there exists a plant (PLANT), a temple (TEMPLE), a gas station (GAS STATION), a night market (NIGHT MARKET), a greasy or smoky restaurant or street vendor (RESTAURANT), and a road with heavy traffic (ROAD) near the respondent's residence. Each neighborhood characteristics is a dummy variable (1 = yes and 0 = no). Nearly a quarter of the respondents in the sample indicate a plant or a greasy restaurant in his/her neighborhood. Temple has the highest proportion among these neighborhood environmental characteristics (40 %). In



**Table 2** Sample distributions of variables

Variables	Frequency	%
<b>AIRQ</b>		
1 Very poor	44	4.1
2 Poor	128	11.8
3 Neither good nor poor	301	27.7
4 Good	484	44.6
5 Very good	128	11.8
<b>LS</b>		
1 Very dissatisfied	8	0.7
2 Dissatisfied	75	6.9
3 Fairly satisfied	648	59.7
4 Pretty satisfied	304	28.0
5 Very satisfied	50	4.6
<b>AGE</b>		
18–29 years	204	18.8
30–39 years	195	18.0
40–49 years	237	21.8
50–59 years	225	20.7
More than 60 years	224	20.6
<b>INCOME</b>		
No income	152	14.0
<NT\$19,999	354	32.6
NT\$20,000–NT\$39,999	319	29.4
NT\$40,000–NT\$59,999	156	14.4
NT\$60,000–NT\$79,999	45	4.1
More than NT\$80,000	44	4.1
Missing <sup>a</sup>	15	1.4
<b>RELIGION</b>		
1 Never	441	40.6
2 Seldom (less than once a year)	266	24.5
3 About once a year	122	11.2
4 Several times a year	152	14.0
5 Once a month	24	2.2
6 Two or three times a month	24	2.2
7 Once a week	36	3.3
8 Several times a week	20	1.8
<b>EDU (year)</b>		
Elementary school or less	195	18.0
Junior high school or equivalent	140	12.9
Senior high school or equivalent	319	29.4
College degree or beyond	431	37.7
<b>HEALTH</b>		
1 Very poor	11	1.0
2 Poor	117	10.8
3 Good	446	41.1

**Table 2** continued

Variables	Frequency	%
4 Pretty good	424	39.1
5 Very good	87	8.0
CONTRAST		
1 More	80	7.4
2 The same	469	43.2
3 Less	532	49.0
Missing <sup>a</sup>	4	0.4
PSI		
50–60	74	6.8
60–70	374	34.5
70–80	238	21.9
80–90	236	21.8
90–100	163	15.0

<sup>a</sup> Missing data include can't choose, don't know, and refusals

addition, around 12 % of them report a gas station or a bazaar and 30 % report a road with heavy traffic within 15 m of their residence.

From Table 1, it can be found that the descriptive statistics of the sample for this study (1,055 observations) and the whole sample with missing data (1,085 observations with missing data in some variables) are similar, with slight changes. This missing pattern can be seen as missing at random (MAR), in which the probability of missing data on a variable (Y) is not a function of its own value after controlling for other variables in the design (Allison 2001). The missing data in our model, however, should be ignorable since the loss of information is limited. Even for the income variable, which is the most sensitive question and has the most missing data among those with missing values, the proportion is only about 1 % of the complete cases. It is then reasonable to assume MAR mechanism for the missing data. Therefore, we believe that dropping the observations with incomplete information would not affect the main estimation results of this study.

## 4 Model Specification and Empirical Results

### 4.1 Perceived Air Quality

A sample with 1,055 respondents is used for the empirical estimation of the ordered probit model for perceived air quality. Table 3 presents the maximum likelihood estimation results of ordered probit model, Eq. (1). Table 3 presents the maximum likelihood estimation results of ordered probit model. As shown in Table 3, the socio-demographic variables, such as respondent's gender (SEX), age (AGE), monthly income (INCOME), marital status (MARRIED), working status (JOB), education (EDU), RELIGION and residential area (URBAN) are included as  $X_1$  in Eq. (1). Furthermore, the explanatory variables  $X_1$  also include six neighborhood environmental characteristic variables such as a plant (PLANT), a temple (TEMPLE), a gas station (GAS STATION), a night market (NIGHT MARKET), a greasy or smoky restaurant or street vendor (RESTAURANT), and a road with heavy traffic (ROAD) near the respondent's residence, in empirical model of Eq. (1). The results indicate that objective air quality, PSI, is found to be an important

**Table 3** Ordered probit regression results for perceived air quality

Variables	Coefficients
PSI	0.019*** (0.003)
SEX	0.047 (0.069)
AGE	0.007** (0.003)
MARRIED	-0.056 (0.076)
INCOME	-0.000 (0.001)
URBAN	-0.093 (0.083)
RELIGION	-0.019 (0.020)
JOB	0.007 (0.079)
EDU	0.010 (0.011)
PLANT	-0.712*** (0.082)
TEMPLE	0.019 (0.072)
GAS STATION	0.094 (0.109)
BAZAAR	0.016 (0.109)
RESTAURANT	-0.264*** (0.087)
ROAD	-0.291*** (0.081)
Cut1	-0.392 (0.326)
Cut2	0.449 (0.322)
Cut3	1.388*** (0.322)
Cut4	2.882*** (0.330)
	1,055

The numbers in parentheses are the standard errors of the estimates

\*  $p < .1$ ; \*\*  $p < .05$ ;

\*\*\*  $p < .01$

factor associated with perceived air quality. The coefficient of PSI is positive and statistically significant at the 0.01 level as expected, given that PSI provides a concise and comprehensive summary of air quality of the respondent's residence.

Three variables of neighborhood environmental condition (PLANT, RESTAURANT and ROAD) have statistically significant effects on perceived air quality. The expected negative sign for the coefficients of PLANT and RESTAURANT indicates that those who are living around a plant, factory, greasy restaurants, or street vendors are less satisfied with air quality. This is quite reasonable because plants and restaurants are apt to emit air pollutants and/or smelly gas into the air. The coefficient for ROAD is also negative and

significant, indicating that those who lived around roads with heavy traffic are less satisfied with the air quality since heavy traffic generates waste gas.

Table 3 also shows that the influences of socioeconomic variables on perceived air quality are relatively minor and most of them do not reach statistical significance except for AGE. Due to the commonly found U-shaped effect of age on SWB (e.g. Tsou and Liu 2001), age square divided by 100 (AGESQ/100) is used in the following analysis.

## 4.2 Life Satisfaction

In this subsection, we examine the mediating effect of perceived air quality in the relationship between objective air quality and LS with three different kinds of regression models. Socio-demographic characteristics, environmental experience, and environmental behaviors of the respondents are also included in the three models to understand their influence on LS. We first investigate the relationship between LS and objective air quality measure. In this model (R1), the perceived air quality is not included in the ordered probit regression model. The model specification can be regarded as a reduced form of LS.

Secondly, the perceived air quality is incorporated in the regression model of LS (R2). The perceived air quality (AIRQ) is regarded as an exogenous variable, which is similar to the model specification in previous studies.<sup>3</sup> Finally, we take the endogeneity of the subjective air quality into consideration, based on the estimation results of perceived air quality regression (Table 3), to obtain the predicted value of perceived air quality. Instead of using AIRQ, we employ the predicted value of subjective air quality (AIRQHAT) as an explanatory variable to examine its effect on LS. The influence of objective measure of major air pollutants on LS is examined in the model (R3) as well by repeating the estimation procedures as in R2.

The results of ordered probit regression estimation models are shown in Table 4. As shown in Table 4, beside the objective air quality (PSI) and subjective air quality (AIRQ), the socio-demographic variables, such as respondent's gender (SEX), age (AGE), age square (AGESQ/100), monthly income (INCOME), marital status (MARRIED), working status (JOB), education (EDU), RELIGION, residential area (URBAN), health status (HEALTH), environmental experience variables (LOSS, FATALISM, CONTRAST), and environmental behavior variables (PARTICIPATION, RESPONSE) are included as  $X_2$  in Eq. (2). In order to address the role of perceived air quality (i.e. AIRQ or AIRQHAT) in the relationship between objective air quality and LS, we start with the discussion on its mediating effect in the three models. The influences of other variables on LS followed. When perceived air quality is not considered, the results of R1 indicate that PSI has a significantly positive effect on individual LS. This finding is expected and consistent with previous research. Since R1 is the reduced form of LS, it is possible that a good air quality has a direct or indirect (or both) positive effect on individual LS.

In R2, AIRQ is found to significantly contribute to LS, while the significant effect of objective air quality measure in R1 becomes insignificant. More explicitly, the significance of PSI disappears when the perceived air quality is considered as an exogenous explanatory variable in the LS regression. Such a change may be attributed to the significant correlation between PSI and perceived air quality. Therefore, it is inappropriate to incorporate only objective, but no subjective, air quality measure in the LS regression.

<sup>3</sup> Such an approach has been used in previous studies in related to life satisfaction and perceived environmental quality (Van Praag and Baarsma 2005; Rehdanz and Maddison 2008; MacKerron and Mourato 2009) as well as objective measure of air quality.

**Table 4** Ordered probit regression results for life satisfaction without subjective air quality

Variables	(R1)	(R2)	(R3)
SEX	-0.197*** (0.074)	-0.216*** (0.075)	-0.213*** (0.075)
AGE	-0.025* (0.014)	-0.025* (0.014)	-0.028* (0.014)
AGESQ/100	0.029** (0.014)	0.028** (0.014)	0.031** (0.014)
MARRIED	0.086 (0.088)	0.100 (0.088)	0.110 (0.089)
INCOME	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)
URBAN	-0.017 (0.086)	0.002 (0.087)	0.014 (0.088)
JOB	-0.103 (0.086)	-0.116 (0.086)	-0.108 (0.086)
EDU	0.015 (0.011)	0.014 (0.011)	0.014 (0.011)
RELIGION	0.018 (0.021)	0.018 (0.021)	0.021 (0.021)
HEALTH	0.403*** (0.045)	0.396*** (0.046)	0.398*** (0.046)
LOSS	-0.164 (0.103)	-0.087 (0.105)	-0.126 (0.105)
FATALISM	0.380*** (0.132)	0.355*** (0.132)	0.368*** (0.132)
CONTRAST	0.168*** (0.058)	0.102* (0.061)	0.154*** (0.059)
PARTICIPATION	-0.027 (0.087)	-0.021 (0.087)	-0.027 (0.087)
RESPONSE	0.128* (0.077)	0.146* (0.077)	0.140* (0.077)
PSI	0.006** (0.003)	0.004 (0.003)	0.003 (0.003)
AIRQ		0.147*** (0.040)	
AIRQHAT			0.167* (0.094)
Cut1	-0.561 (0.485)	-0.408 (0.487)	-0.678 (0.489)
Cut2	0.501 (0.471)	0.663 (0.474)	0.384 (0.476)
Cut3	2.514*** (0.474)	2.690*** (0.478)	2.401*** (0.479)
Cut4	3.860*** (0.483)	4.048*** (0.487)	3.749*** (0.487)
N	1,055	1,055	1,055

The numbers in parentheses are the standard errors of the estimates

\*  $p < .1$ ; \*\*  $p < .05$ ;

\*\*\*  $p < .01$

We then consider the endogeneity of the subjective air quality into the model specification of LS. In R3, the predicted value of perceived air quality, AIRQHAT, is incorporated in LS regression. Similar to the results of R2, AIRQHAT is found to be positively

associated with LS, whilst the coefficient of PSI remains positive but insignificant. Therefore, it is reasonable to conclude that the objective air quality has an indirect effect on LS through its association with perceived air quality, but has no direct effect on LS as evidenced by using the Taiwan data. This result is different from previous studies and needs further examination.

The results also show that the respondent's LS is significantly associated with several socio-demographic variables, including SEX, AGE, and AGESQ/100 across the three regression models. Females are more satisfied with their life than their counterparts. The effect of AGE on LS is negative while that of AGESQ/100 is positive, meaning that there exists a noteworthy U-shaped relationship between LS and age. The estimated coefficients of AGE and AGESQ/100 are very close, suggesting that people who are the most dissatisfied with life are those around 50 years old in Taiwan. In other words, the middle-aged are not as satisfied with life as the younger respondents and the elderly.

The coefficient of INCOME is positive but not statistically significant in this study. In the literature, the phenomenon is called the "Easterlin paradox." The previous studies indicated that "Easterlin Paradox" exists in many developed countries, such as the United States, Britain, and Japan (Blanchflower and Oswald 2004; Layard 2005; Oswald 1997). In previous Taiwan SWB studies, some research show that there exists a positive relation between income and SWB, such as Tsou and Liu (2001) and Kent and Wu (2014). However, some seminar works show that the relation is positive but not significant. (Tao 2005; Liao et al 2005; Tsui 2014).

As previous results had indicated, self-reported health is strongly associated with individual's LS and the effect is consistent across the models. It is virtually true that healthier people are more satisfied with the life. The effects of environmental experience and behaviors are the same across the models. The results in Table 4 indicate FATALISM and CONTRAST are positively correlated with the reported LS. In other words, those who attribute environmental pollution to humanity's fate and those who indicate that their residence is less likely to be damaged by environmental pollution are more satisfied with life than their counterparts. With respect to environmental behaviors, the effect of RESPONSE is found to be positive on LS. The respondents who have ever reported situations that have caused environmental pollution in their community are more satisfied with their life than those who never do so.

Also shown in Table 4, the results of R2 and R3 are found similar, with slight changes of coefficients, suggesting that our results are robust in different model specifications. The model estimations of Table 4 lead to consistent findings for the socio-demographic variable, health, and variables of environmental experience and behaviors. In summarizing the results, we can conclude that subjective air quality indicator directly affect the respondent's LS, whilst objective air quality affects individual LS through perceived air quality, controlling for socio-demographic and environmental variables.

## 5 Conclusion and Discussion

With increasing concern for environmental quality, the direct impact of air pollution on LS has been a focus in recent studies (Luechinger 2009, 2010; MacKerron and Mourato 2009; Welsch 2006). As indicated in the literature, subjective and/or objective environmental quality have been shown to be important determinants of individual LS. However, to our best knowledge, no previous seminar work tries to answer the following question: What is the relationship between objective air quality and life satisfaction? Does air pollution

directly affect individual well-being without the mediating effect of perceived air quality? Or, does air pollution affect individual well-being merely through individual satisfaction with air quality?

Furthermore, few have taken into account the endogenous role of perceived air quality in such a relationship. This study examines the impact of objective air quality measure as well as that of subjective air quality measure on individual LS. The results show that objective air quality as measured by PSI serves as an important determinant of perceived air quality of individuals. Furthermore, we incorporate the objective measures of air quality regarded as an exogenous variable, as in previous studies in the LS equation and found results consistent with previous research (Ferreira and Moro 2010; Luechinger 2009, 2010; Menz 2011; Welsch 2006), in which LS is marginally significantly associated with objective air quality.

When subjective air quality is regarded as an endogenous variable and shows its influence on LS, the effect of objective air quality becomes insignificant. Therefore, we can conclude that the objective air quality had an indirect, but no direct, effect on individual LS through perceived air quality, as demonstrated by using Taiwanese data. A similar scenario can be found in the relationship between health and subjective well-being, where health condition measured by medical records has no or minor effect on happiness but self-rated health status does significantly (see Michalos et al. 2000), despite the association between objective and subjective health status (Argyle 1997). The mediation of subjective measures of certain QoL domains in the relationship between the objective indicators and overall QoL deserves further examination.

Our findings also evidence the importance of incorporating both objective and subjective measures of air quality in understanding their influences on individual's well-being. As indicated in previous studies, objective conditions can be used to assess the level of life (Hagerty et al. 2001), while the subjective perception reveals the subjective evaluation of the life experience (Campbell et al. 1976; Veenhoven 1996). The results of this study also echo a previous study that objective indicators correspond to subjective evaluation in regard to environmental quality (Liao 2009). As the comparative theory asserts that it is possible that objective conditions affect subjective perceptions indirectly through comparisons with other possible alternatives (Diener and Lucas 2000). The contribution of either objective or subjective dimensions of QoL domains to overall QoL is further confirmed, suggesting the consideration of both dimensions for a comprehensive assessment of overall QoL.

Furthermore, people who attribute environmental pollution to humanity's fate, those who indicate their residence is less likely to be damaged by environmental pollution, and those who have reported such an issue in their community are more satisfied with their life than their counterparts. The effect of FATALISM on LS may be the consequence of the practice of Taoism in the daily life of Taiwanese respondents. As Lu (2001: 411) explains, "*Happiness in Taoism is the personal liberation from all human desires, through following the Natural force, ...accepting fate calmly, and facing life with a peaceful mind*" in order to reach the ultimate goal of merging with the Nature. It is then reasonable for these respondents to have fewer concerns or worries about the impact of environmental pollution, which is seen as fate to be accepted, and, therefore, report higher levels of LS than those who have more concerns. In addition, local actions that respond to an outside threat often lead to mobilization of community resources. The consequence may, then, lead to greater well-being for the community and reduced vulnerability when encountering risk and disaster (Flint and Luloff 2005). These respondents may have taken actions or been involved in the process so they feel more satisfied with life than those who did not.

Although our findings on the effect of Taoism may be seen unique to some extent, more support is needed to conclude the influence of folk psychology on subjective well-being.

For policy implication, these results may provide some practical implications for those burgeoning measures of the well-being and LS of societies such as the Your Better Life Index of OECD. Your Better Life Index (YBLI) is launched in May 2011 and uses both objective and subjective indicators to measure eleven topics in SWB. Although only three out of the 24 indicators in YBLI are subjective indicators, it nevertheless indicates the importance of subjective measures as this paper does. Furthermore, it should be considered that more subjective indicators are included in measures of the well-being and LS of societies such as YBLI.

## References

- Allison, P. D. (2001). *Missing data*. Thousand Oaks, CA: Sage Publications.
- Andrews, F. M., & Withey, S. B. (1976). *Social indicators of well-being: Americans' perceptions of life quality*. New York: Plenum Press.
- Argyle, M. (1997). Is happiness a cause of health? *Psychology and Health*, *12*, 769–781.
- Bardo, J. W., & Bardo, D. J. (1983). A re-examination of subjective components of community satisfaction in a British new town. *Journal of Social Psychology*, *120*, 35–43.
- Blanchflower, D. G., & Oswald, A. J. (2004). Well-being over time in Britain and the USA. *Journal of Public Economics*, *88*, 1359–1386.
- Brown, R. B. (1993). Rural community satisfaction and attachment in mass consumer society. *Rural Sociology*, *58*(3), 387–403.
- Campbell, A. (1981). *The sense of well-being in America*. New York: McGraw-Hill.
- Campbell, A., Converse, P. E., & Rodgers, W. L. (1976). The perceived quality of life and its implications. In A. Campbell, P. E. Converse, & W. L. Rodgers (Eds.), *The quality of American life* (pp. 471–508). New York: Russell Sage Foundation Press.
- Chamberlain, K. (1985). Value dimensions cultural differences and the prediction of perceived quality of life. *Social Indicators Research*, *17*, 345–401.
- Chang, Y. H., Tu S. H., & Liao P.S., (2012). 2010 Taiwan Social Change Survey (Round 6, Year 1): Environment (C00221\_2) [Data file]. Available from Survey Research Data Archive, Center for Survey Research, Research Center for Humanities and Social Sciences, Academia Sinica. doi:[10.6141/TW-SRDA-C00221\\_2-1](https://doi.org/10.6141/TW-SRDA-C00221_2-1).
- Diener, E., & Lucas, R. E. (2000). Explaining differences in societal levels of happiness: Relative standards, need fulfillment, culture, and evaluation theory. *Journal of Happiness Studies*, *1*, 41–78.
- Emmons, R. A., & Diener, E. (1985). Factors predicting satisfaction judgment: A comparative examination. *Social Indicator Research*, *16*, 157–167.
- Falkenberg, A. W. (1998). Quality of life efficiency, equity and freedom in the United States and Scandinavia. *Journal of Socio-Economics*, *27*(1), 1–27.
- Ferreira, S., & Moro, M. (2010). On the use of subjective well-being data for environmental valuation. *Environmental & Resource Economics*, *46*, 249–273.
- Ferrer-i-Carbonell, A., & Gowdy, J. M. (2007). Environmental degradation and happiness. *Ecological Economics*, *60*, 509–516.
- Flint, C. G., & Luloff, A. E. (2005). Natural resource-based communities, risk, and disaster: An intersection of theories. *Society and Natural Resources*, *18*, 399–412.
- Hagerty, M. R. (1999). Unifying livability and comparison theory: Cross-national time-series analysis of life-satisfaction. *Social Indicators Research*, *47*, 343–356.
- Hagerty, M. R. (2000). Social comparisons of income in one's community: Evidence from national surveys of incomes and happiness. *Journal of Personality and Social Psychology*, *78*, 764–771.
- Hagerty, M. R., Cummins, R. A., Ferriss, A. L., Land, K., Michalos, A. C., Peterson, M., et al. (2001). Quality of life indexes for national policy: Review and agenda for research. *Social Indicators Research*, *55*, 1–96.
- Kao, C. H. C., & Liu, B. C. (1984). Socioeconomic advance in the Republic of China (Taiwan): An intertemporal analysis of its quality of life indicators. *American Journal of Economics and Sociology*, *43*(4), 399–412.
- Kent, S. H., & Wu, S. Y. (2014). Living happily ever after? The effect of Taiwan's National Health Insurance on the happiness of the elderly. *Journal of Happiness Studies*, *15*, 783–808.



- Land, K. (1983). Social indicators. *Annual Review of Sociology*, 9, 1–26.
- Layard, R. (2005). *Happiness: Lessons from the new science*. New York: The Penguin Press.
- Lewis, S., & Lyon, L. (1986). The quality of community and the quality of life. *Sociological Spectrum*, 6, 397–410.
- Liao, P. S. (2009). Parallels between objective indicators and subjective perceptions of quality of life: A study of metropolitan and county areas in Taiwan. *Social Indicators Research*, 91(1), 99–114.
- Liao, P. S., Fu, Y. C., & Yi, C. C. (2005). Perceived quality of life in Taiwan and Hong Kong: An intraculture comparison. *Journal of Happiness Studies*, 6, 43–67.
- Lu, L. (1999). Personal or environmental causes of happiness: A longitudinal analysis. *Journal of Social Psychology*, 139, 79–90.
- Lu, L. (2001). Understanding happiness: A look into the Chinese folk psychology. *Journal of Happiness Studies*, 2, 407–432.
- Lu, L., & Shih, J. B. (1997). Sources of happiness: A qualitative approach. *Journal of Social Psychology*, 137, 181–187.
- Luechinger, S. (2009). Valuing air quality using the life satisfaction approach. *Economic Journal*, 119, 482–515.
- Luechinger, S. (2010). Life satisfaction and transboundary air pollution. *Economics Letter*, 107, 4–6.
- MacKerron, G., & Mourato, S. (2009). Life satisfaction and air quality in London. *Ecological Economics*, 68, 1441–1453.
- Maddala, G. S. (1983). *Limited-dependent and qualitative variables in econometrics*. New York: Cambridge University Press.
- Martin, J. K., & Lichter, D. T. (1983). Geographic mobility and satisfaction with life and work. *Social Science Quarterly*, 64, 524–535.
- Mastekaasa, A., & Moum, T. (1984). The perceived quality of life in Norway: Regional variations and contextual effects. *Social Indicators Research*, 14, 385–419.
- Menz, T. (2011). Do people habituate to air pollution? Evidence from international life satisfaction data. *Ecological Economics*, 71, 211–219.
- Michalos, A. C., Hubley, A. M., Zumbo, B. D., & Hemingway, D. (2001). Health and other aspects of the quality of life of older people. *Social Indicators Research*, 54, 239–274.
- Michalos, A. C., Zumbo, B. D., & Hubley, A. (2000). Health and the quality of life. *Social Indicators Research*, 51, 245–286.
- Ng, Y. K. (2011). Consumption tradeoff vs. catastrophes avoidance: Implications of some recent results in happiness studies on the economics of climate change. *Climate Change*, 105, 109–127.
- Oliver, P. (1984). If you don't do it, nobody else will': Active and token contributors to local collective action. *American Sociological Review*, 49, 601–610.
- Oppong, J. R., Ironside, R. G., & Kennedy, L. W. (1988). Perceived quality of life in a centre-periphery framework. *Social Indicators Research*, 20, 605–620.
- Oswald, A. J. (1997). Happiness and economic performance. *Economic Journal*, 107, 1815–1831.
- Popenoe, D. (1983). Urban scale and the quality of community life: A Swedish community comparison. *Sociological Inquiry*, 53, 404–418.
- Rehdanz, K., & Maddison, D. (2005). Climate and happiness. *Ecological Economics*, 52, 111–125.
- Rehdanz, K., & Maddison, D. (2008). Local environmental quality and life-satisfaction in Germany. *Ecological Economics*, 64, 787–797.
- Schuessler, K. F., & Fisher, G. A. (1985). Quality of life research and sociology. *Annual Review of Sociology*, 11, 129–149.
- Sirgy, M., Joseph, R. N., Widgery, D., Lee, D. J., & Grace, B. Y. (2010). Developing a measure of community well-being based on perceptions of impact in various life domains. *Social Indicator Research*, 96, 295–311.
- Tao, H. L. (2005). The effects of income and children on marital happiness—evidence from middle- and old-aged couples. *Applied Economics Letters*, 12, 521–524.
- Tepperman, L., & Curtis, J. (1995). A life satisfaction scale for use with national adult samples from the USA, Canada and Mexico. *Social Indicator Research*, 35, 255–270.
- Thoits, P. A., & Hewitt, L. N. (2001). Volunteer work and well-being. *Journal of Health and Behavior*, 42, 115–131.
- Tsou, M., & Liu, J. (2001). Happiness and domain satisfaction in Taiwan. *Journal of Happiness Studies*, 2, 269–288.
- Tsui, H. (2014). Income and happiness: The effect of absolute income, relative income and expected income. *Journal of Policy Modeling* (forthcoming).
- Van Praag, B., & Baarsma, B. (2005). Using happiness surveys to value intangibles: The case of airport noise. *Economic Journal*, 115, 224–246.

- Veenhoven, R. (1995). The cross-national pattern of happiness: Test of predictions implied in three theories of happiness. *Social Indicators Research*, *34*, 33–68.
- Veenhoven, R. (1996). Developments in satisfaction research. *Social Indicators Research*, *37*, 1–45.
- Welsch, H. (2006). Environment and happiness: Valuation of air pollution using life satisfaction data. *Ecological Economics*, *58*, 801–813.
- Wilkening, E. A. (1982). Subjective indicators and the quality of life. In R. M. Hauser, D. Mechanic, A. O. Haller, & T. S. Hauser (Eds.), *Social structure and behavior* (pp. 429–441). New York: Academic Press.
- Ziegler, J. A., & Britton, C. R. (1981). A comparative analysis of socioeconomic variations in measuring the quality of life. *Social Science Quarterly*, *62*, 303–312.
- Zinam, O. (1989). Quality of life, quality of the individual, technology and economic development. *American Journal of Economics and Sociology*, *48*, 55–68.