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THE LIFE-SATISFACTION APPROACH**

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VALUING THE ENVIRONMENT USING THE LIFE-SATISFACTION APPROACH

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Abstract

This paper presents a comprehensive theoretical and methodological framework clarifying the relationship between non-market environmental valuation techniques, in particular hedonic and life-satisfaction methods. The paper shows how life-satisfaction scores can be used to test correctly the equilibrium condition in location markets required by the hedonic approach and that in the absence of equilibrium, the life-satisfaction approach is still a theoretically valid valuation technique. Valuation using the life-satisfaction approach suffers from caveats associated with the cardinalisation of utility, however. Using data from Ireland, we apply this framework to the valuation of amenities linked to respondents' dwelling areas using Geographic Information Systems (GIS).

Keywords: environmental valuation; life satisfaction; well-being; subjective well-being; hedonic pricing; location market; climate; air pollution; water pollution.

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Introduction

As changes in environmental quality have become of greater public concern and an important challenge for public policy, increasing attention has been paid by economists to finding means of eliciting the value of such changes. As most environmental amenities are not traded in markets and so do not have an obvious price, several methodologies have been developed to estimate their value and the benefits and costs of changes in their quality.² The literature on environmental valuation is now very extensive, with its methods typically classified as revealed-preference or stated-preference approaches.³

Revealed-preference approaches are indirect valuation methods which are based on the actual behaviour of individuals. These methods utilize complementarity and substitutive relationships between non-marketed and various marketed goods to infer the value attributed to public goods from market transactions in private goods. Examples include the travel cost method and the hedonic pricing (HP) method. On the contrary, stated-preference approaches, such as contingent valuation, contingent behaviour and conjoint analysis (i.e., choice experiments), are direct methods to elicit individual's preferences. They rely on asking people hypothetical questions to compute the willingness to pay for improvements of environmental quality or their willingness to accept payment in exchange of bearing a particular loss (Bateman *et al.*, 2002).

Recently, a novel method based on happiness surveys, the life satisfaction (LS) approach, has been introduced as an alternative tool to valuing amenities. Life-satisfaction scores have been used in a growing economics literature studying the determinants of individual quality of life (see, e.g. Easterlin, 1974 and 1995; Clark and Oswald, 1994; Granato *et al.*, 1996; Oswald, 1997; Clark, 1997; Frank, 1997; Winkelmann and Winkelmann, 1998; Di Tella *et al.*, 2001, 2003. For recent surveys, see Frey and Stutzer, 2002, 2005a), but the potential of the LS approach to value intangibles has only started to be recognized (Welsch, 2002, 2006; Van Praag and Baarsma, 2005; Kahneman and Sugden, 2005; Frey and Stutzer, 2005a).

The LS method shares some analogies with both revealed and stated-preference methods. Like in stated-preference methods, the LS approach uses a survey methodology. However, people are unaware that their responses will be used in deriving their preferences for public goods. Like revealed-preference methods, the LS approach elicits the preferences of individuals indirectly. However, a proxy for their utility is directly observable and reliance on private market transactions is not necessary to estimate the implicit prices of amenities.

Some recent studies have recognized the close ties between the HP and LS approaches (Frey *et al.*, 2004; Frey and Stutzer, 2005a, b; Stutzer and Frey, 2004; van Praag and Baarsma, 2005; Brereton *et al.* 2006a). However, except Brereton *et al.* (2006a), these studies lack a clear theoretical framework linking the approaches, and they consider the LS

²In this paper, the terms non-marketed goods, amenities, public goods and intangibles are used interchangeably.

³Perman *et al.*, 2003 or Tietenberg, 2006 provide good introductions to the subject.

valuation as complementary to HP (see e.g. van Praag and Baarsma, 2005 and Frey and Stutzer, 2005a).

In this paper, we present a complete theoretical and methodological framework to clarify the relationship between the HP and LS approaches to value location-specific attributes. Our theoretical model shows that when the key equilibrium condition in which hedonic pricing is based holds, and provided that LS scores are a good proxy for individual's utility, both approaches are equivalent. Thus, contrary to recent studies (e.g. van Praag and Baarsma, 2005 and Frey and Stutzer, 2005a), we conclude they do not complement one another. In disequilibrium, the HP approach is biased, but the LS approach, which is not based on the equilibrium condition, is theoretically valid. Moreover, we show that the equilibrium condition in which the HP approach is based has not always been correctly tested in the literature, and propose the use of LS scores to test for equilibrium in a straightforward way, with no need of further information from housing or labour markets.

Our methodological framework shows that using self-reported well-being as a proxy for the individual's utility function allows us to compute directly the implicit (or marginal) price of local environmental amenities and other measures of welfare change related to infra-marginal amenity changes (equivalent and compensating surpluses).

Using data on subjective well-being from Ireland in 2001, we apply this framework to the valuation of environmental attributes linked to each respondent's dwelling area using a Geographic Information System (GIS) data set. The novel use of highly spatially disaggregated data helps overcome the problem of not being able to capture the effects of factors which operate at a small scale, which has been identified by studies using cross-country observations (e.g. Welsch 2006).

The factors identified by our model as affecting individuals' LS, their quantitative impacts, and the associated monetary estimates, are comparable to those found in previous literature. We argue, however, that the monetary values suffer from an upward bias due to caveats associated with the cardinalisation of utility. The valuation of intangibles using the LS approach requires the estimation of the marginal utility of income which, due to adaptation and aspiration effects, tends to be small leading to large estimated welfare measures. In contrast, testing for the equilibrium condition is straightforward and does not suffer from these caveats.

The paper is structured as follows. Section 1 presents a brief literature review on the LS approach, underlining its recent application to the valuation of intangibles. Section 2 presents the theoretical model illustrating the relationship between the HP and LS approaches. The insights from this model contrast to those presented by the literature so far. Section 3 presents a comprehensive methodology on computing welfare measures with the LS approach. Section 4 describes the variables, data sources and estimation strategy used in our study. Section 5 presents the estimation results. Section 6 applies the methodology described in Section 3 to the calculation of the monetary value of location-specific factors using the LS valuation method for the Irish case. Section 7 concludes.

1. The Life-satisfaction Approach as a Valuation Tool: a Review

Data on subjective well-being have been used in a growing economics literature on the determinants of individual happiness (for recent reviews see Frey and Stutzer 2002, 2005). This literature relies on happiness surveys where respondents are asked to evaluate their overall satisfaction with life, happiness, or positive and negative affects. Happiness functions are built where self-reported LS is related to individual, social and economic factors and, more recently, locational attributes. In particular, the scope of this literature is often used to answer questions such as “how do economic growth, unemployment and inflation, as well as institutional factors, such as good governance, affect individual well-being?” (Frey and Stutzer, 2005a).⁴

However, the potential of life-satisfaction data goes well beyond this. In particular, they can be used to infer the monetary value of non-marketed goods. One can use self-reported well-being as a proxy for the individual's utility function and compute directly the marginal rate of substitution between income and local amenities, their elasticity (with respect to income) and other welfare measures (equivalent and compensating surpluses). For example, Blanchflower and Oswald (2004a) found that a rise in income at the mean of ~\$60,000 per annum (above and beyond the income loss associated with unemployment) would be required to ‘compensate’ men for unemployment and that a “lasting marriage” is worth \$100,000 per annum. Welsch (2002) identified a negative effect of urban air pollution (in terms of nitrogen dioxide concentration) on average life satisfaction that translates into a marginal price of emissions of \$0.07 per ton.⁵ In a more recent study, Welsch (2006) finds a considerable monetary value associated with improvements in air quality in Europe (\$750 per capita per year for nitrogen and \$1400 for lead) during the 1990s. Frey *et al.* (2004) found that the willingness to pay (WTP) for a reduction of terrorism to rates that prevail in the more peaceful parts of each country is about 14% of annual household income in Paris, 32% in London, and around 41% in Belfast. Rehdanz and Maddison (2005a) analyzed the effect of climate on subjective well-being and found that “modest global warming with higher winter temperatures would increase people's happiness, particularly, for those living in the North. Those living in regions already characterized by very high temperatures would lose out” (p. 120).

The HP method, a more traditional environmental valuation method, exploits the relationship between characteristics of a location and house prices and wages (see Rosen 1974 and Roback 1982 for seminal contributions). When choosing between different locations, individuals make trade-offs that reveal something about the value they place on surrounding local amenities. This choice affects the levels of rents and wages. Thus, rental

⁴ As it is common in the literature, in this paper we use the terms ‘subjective well-being’, ‘life satisfaction’ and ‘happiness’ interchangeably.

⁵ As explained by Welsch (2002) this means that “for instance, a representative German citizen would need to be given more than \$1900 per year in order to accept the typical urban air pollution level prevailing in Japan” (p. 494).

price and wage differentials among locations can be used to compute the marginal (implicit) price of amenities and 'objective' quality of life rankings of different areas.

The hedonic market approach is based on strong assumptions of rationality, perfect information and no obstacles to the free mobility of individuals across different areas, which result in housing and labour markets perfectly compensating for differences in location-specific amenities. The valuation of local amenities elicited from individual choices on private markets might be biased in case of imperfections and bounded rationality (Freeman, 2003; Frey and Stutzer, 2004, 2005a; Kahneman and Sugden, 2005). An advantage of the LS approach is that it does not require the strong assumptions of rationality, perfect information and equilibrium in private markets, underlining revealed-preference methods.

Compared to conventional stated-preference methods, the LS approach, like the HP approach, does not capture the pure existence value of non-local environmental goods and services, but avoids problems of strategic behaviour and lack of consideration of budget constraints and trade-offs among several substitutes reported in contingent valuation studies (Kahneman and Sugden, 2005). The relationship between public goods and subjective well-being can be implicitly deduced without respondents being aware that their responses will be used to that end (Frey and Stutzer, 2005a; Welsch, 2002, 2006).

The main caveat of the LS approach is related to the economic significance of self-reported subjective well-being and its utilization as a proxy of the individual's indirect utility function. Despite a growing economics literature utilising subjective well-being scores as a proxy for utility, this issue is still controversial. On one hand, within the neoclassical economic framework, the abandonment of cardinal utility results in an objectivistic approach based on observing choice behaviour. On the other hand, recent studies attempt to demonstrate the validity of cardinality (Van Praag, 1991; Dixon, 1997; Ng, 1997) and of interpreting utility as hedonic experience in a more classical sense, and suggest a distinction between the concept of experienced utility (the classical hedonic subjective concept) and direct utility (which is objectively deduced by actual behaviour in the neoclassical framework of rational utility-maximizing individuals) (Kahneman *et al.*, 1997; Kahneman and Sugden, 2005).

In this context, LS surveys could become a useful policy tool by measuring experienced utility. The natural question is then whether LS scores are good proxies for experienced utility. Psychologists have been using self-reported LS scores since the 1960s and there is an extensive literature providing evidence of a strong correlation between LS scores and the unobservable concept of utility. According to this literature, LS indexes are reliable, consistent over time, valid and interpersonally comparable (Diener, 1984; Costa and McCrae, 1988; Headey and Wearing, 1989; Sandvik *et al.*, 1993; Fernández-Dols and Ruiz-Belda, 1995; Diener *et al.*, 1999). Valuation of intangibles using LS scores requires, in addition, the estimation of the marginal utility of income which, due to adaptation and aspiration effects, tends to be small leading to large estimated welfare measures. We come back to this point when we discuss our empirical estimates in Section 6.

Another challenge with the LS approach arises when we want to measure the effect on happiness of factors that operate on a small (but daily) scale. It could be the case that the effects of these factors are not picked up by regression analysis of people's overall satisfaction with life (Kahneman and Sugden, 2005). In order to capture all the attributes from which people derive utility, a more direct method has been suggested, the moment-based happiness. Instead of performing a survey of the people's overall happiness, moment by moment hedonic experience in the course of their daily activity is measured.⁶ However, these moment-based methods are costly in terms of time and resources. We argue that the utilization of GIS modelling to link even small location-specific attributes with the respondent's residence, and the associated high level of spatial disaggregation achieved, can help overcome part of this problem in our LS regression, especially when compared to previous cross-country studies.

2. Common (and Uncommon) Ground between the Life-satisfaction and Hedonic Approaches: Some Theory

Recent studies (Stutzer and Frey, 2004; Van Praag and Baarsma, 2005; Frey and Stutzer, 2005a; and Brereton *et al.* 2006a) identify a common ground between the HP and LS approaches. Both approaches can be applied to analyze the effects of location-specific attributes on quality of life of individuals and preferences about different locations. In particular, the literature focuses on two related aspects: (i) happiness functions can be used to test the equilibrium condition on location markets and, (ii) the LS valuation technique is considered as complementary to HP in valuing local amenities.

In this section, building on Brereton *et al.* (2006a) we show that some of the conclusions reached by previous studies are incorrect, and propose a straightforward way to test for the equilibrium condition in the location market with no need of information on rents or wages.

In the standard HP framework (see e.g. Roback, 1982; Blomquist *et al.* 1988), in equilibrium, the individual's indirect utility is equalized across locations and given by:

$$v^k = v(w^k, r^k, a^k) = \bar{v} \quad \forall k \quad (1)$$

where v^k the indirect utility function of a representative individual, w^k is the wage, r^k is the rental price of land and a^k in an index of local amenities in location k .

Totally differentiating (1), rearranging and suppressing the superindices for notational simplicity we can obtain the implicit price of amenities as:

$$\frac{v_a}{v_w} = -\frac{v_r}{v_w} \frac{dr}{da} - \frac{dw}{da} \quad (2)$$

⁶ Experience Sampling Methodology (Csikszentmihalyi and Hunter, 2003) and the less intrusive Day Reconstruction Method (Kahneman *et al.* 2004a, b) are examples in the literature.

Equation (2) provides not only the implicit price of amenities but a test of the equilibrium condition on which the HP approach is based. Using data on subjective well-being as a proxy for indirect utility, v^k , all the elements in (2) can be estimated. Brereton *et al.* (2006a) used (2) to test for the existence of equilibrium in the Irish location market, by running three regressions: a life satisfaction regression and hedonic housing and wage regressions (to estimate dr/da and dw/da , respectively), and comparing the coefficients. Their results showed that Irish location-specific amenities have a direct impact on subjective well-being (utility), and that private markets are not compensating for that impact.

This insight contrasts with the conclusion of Stutzer and Frey (2004).⁷ Their aim is to test whether commuting time is entirely compensated by private markets in Germany, using a LS regression. They assume explicitly that if the coefficient of commuting time is equal to zero ($v_a = 0$), then the location market is in equilibrium. They found that individuals' LS is negatively affected by commuting time, therefore they rejected their null hypothesis and conclude that private markets in Germany do not compensate for longer commuting time. As it is evident from (2), the LS regression alone is not capable of offering any information on whether there is equilibrium in the location market. What Stutzer and Frey (2004) actually tested was not the equilibrium condition, but only a small part of the total variation of utility v_a . Moreover, the only thing that can be said when $v_a = 0$ is that the individual's utility is not affected by that particular factor; i.e. it is neither an amenity nor a disamenity and private markets would not need to compensate for it.

In addition, equation (2) shows that, when the equilibrium condition holds, both approaches, the LS and HP, are equivalent, and should provide, in theory, the same marginal price for environmental amenities.⁸ This insight contrasts with the interpretation of Van Praag and Baarsma (2005), Frey and Stutzer (2005a) and Frey *et al.* (2004) of LS and HP as complementary methods. Indeed, Van Praag and Baarsma (2005) explicitly argue that the cost of noise nuisance from the Amsterdam airport to local residents is given by the sum of the hedonic differential and a residual cost that can be computed using LS. They continue that, if the equilibrium condition is rejected, which the authors find to be the case by looking at the housing market in Amsterdam, the residual cost captures the total cost of airport noise. As it is clear from equation (2), in equilibrium, the implicit value of amenities obtained using HP (the RHS of (2)) is equal to the marginal value obtained using LS (the LHS of (2)), and thus both approaches are substitutes, not complements. The LS approach always provides the total benefit (cost) of the amenity (disamenity) being valued. Van Praag and Baarsma's (2005) distinction between total and residual benefit (cost) is not supported by the theory. Moreover to reject the equilibrium condition, the labour market as well as the housing market must be accounted for.

⁷ See also, on the same subject, Frey and Stutzer (2005b).

⁸ In hedonic regressions, to compute the LHS of (2) the term $-v_r/v_w$ is equalized, by Roy's identity, to the amount of residential land I_c .

Now, we turn to the disequilibrium situation. In disequilibrium the individuals' utility is not equalized across locations and thus (1) does not hold with equality. Consequently, the total variation in utility is not equal to zero and the implicit marginal price in this case would be given by:

$$\frac{v_a}{v_w} = \frac{dv}{da} \left(\frac{1}{v_w} \right) + \frac{v_r}{v_w} \frac{dr}{da} - \frac{dw}{da} \quad (3)$$

As it is clear from equation (3), in disequilibrium, the HP approach can provide only biased estimates of the implicit price of amenities as the term $dv/da(1/v_w)$ is ignored, but the LS approach which does not rely on the equilibrium condition would still be capable of providing the correct marginal price of the amenities.

In our paper, in order to test empirically the equilibrium condition to assess the appropriateness of the HP approach, we could, as in Brereton *et al.* (2006a), estimate the coefficients of the different components of equation (2) and add them up to verify if the equality holds. Instead, we propose a more straightforward test, by simply comparing LS scores across locations. Since LS is a proxy for indirect utility (v^k), according to equation (1), the market is in equilibrium if LS is constant across the k areas, i.e. if $LS^k = \bar{v} \quad \forall k$.

Table 1 shows the average LS scores in the 34 local authorities⁹ in Ireland (see also Figure A.1 in the Appendix). They originate from a survey of a representative sample of 1,500 men and women, aged 18 and over and living in Ireland, carried out in 2001.¹⁰ The LS indicator is based on a seven-point scale whereby respondents rated their overall satisfaction with life, with 1 being the lowest.

The resulting average LS score in Ireland is 5.47 on the seven-point scale (between 'good' and 'very good'). The lower value is found in the East of Ireland, in Dublin South (4.60 with standard deviation of 1.18) and the higher in the West, in Galway County (6.93 with a standard deviation of 0.26). Thus, Table 1 underlines a certain variation in the self-reported LS among local authorities. The same can be said when the areas of reference are electoral divisions (ED) instead of the local authorities.¹¹

Under the assumption that personal traits are averaged out, parametric and non-parametric statistical tests were carried out to investigate the significance of LS differences across local authorities and EDs. Every test performed showed that these differences were significant at 1% level.¹²

⁹ The Republic of Ireland is divided into 34 different administrative regions called Local Authority areas. These generally equate to one body per county and one for the three major urban areas of Galway City, Limerick City and Cork City. Dublin is divided into four and Tipperary is divided into two local authority areas.

¹⁰ For more details on the data, please see Section 5.

¹¹ Electoral division is the smallest enumeration area used by the Irish Central Statistics Office in the collection of Census Data. There are over 3,440 electoral divisions in the Republic of Ireland. They are relatively small, particularly in the city regions. The size of the EDs considered in our sample ranges from 18 hectares (cities) to 6,189 hectares (open countryside) with total populations ranging from 47 individuals to 8,595.

¹² Tests were carried out under the null hypothesis that there are no differences between the mean of the self-reported LS among different areas in Ireland against the alternative hypothesis that there exist at least two locations

Table 1 about here

As Brereton *et al.* (2006a), we can affirm that in Ireland housing and labour market do not (fully) compensate for differences in location-specific attributes. Thus, the HP approach cannot provide correct monetary estimates of the value of environmental amenities, but the LS approach, in theory, could. The next section discusses how these values can be estimated.

3. Methodology for Valuing Amenities with the Life-satisfaction Approach

3.1. The Marginal Price of an Amenity

From basic consumer theory we know that the marginal rate of substitution (MRS) between good y and a is the rate at which y can be substituted for a at the margin while holding the level of utility constant. If y is income and a the level of a local amenity, the MRS between y and a yields the monetary value placed on a marginal change in the level of the amenity:

$$MRS = -\frac{V_a}{V_y} \quad (4)$$

Using self-reported happiness as a proxy for the utility function, the MRS can be easily computed using (4). For example, in the case of atmospheric pollution, the ratio of marginal utilities would yield a measure in terms of euro per microgram of pollutant.

Moreover, the responsiveness of income to a percentage change in the level of the amenity considered to keep utility constant can be computed directly applying the elasticity formula:

$$\eta = \frac{\partial y}{\partial a} \frac{a}{y} = \frac{\text{percentage change in income}}{\text{percentage change in amenity}} \quad (5)$$

3.2. Infra-marginal Amenity Changes

Welfare economics suggests two monetary measures to account for the welfare effect of amenities change: (i) Compensating Surplus (CS) and (ii) Equivalent Surplus (ES).

CS is the amount of money that would keep the individual at the original level of utility when a change in the provision of the amenity has occurred. ES is the amount of money that

where the LS is different (Newbold *et al.*, 2003). We tested this with reference to both local authorities and EDs. The Bartlett's chi-squared statistic, lead to rejecting the assumption that the population variance LS are equal across both local authorities and EDs at 1% significance level (chi-squared equal to 307.55 and 203.54 respectively). Consequently, the use of One Way Analysis of Variance (ANOVA) could be flawed. In order to avoid any flaw, we used the non-parametric analog to the one-way ANOVA, namely the Kruskal-Wallis test, which lead to the rejection of the null hypotheses of equality of means at the 1% significance level. Performing ANOVA lead to the same conclusion.

would move the individual to the new level of utility when a change in the provision of the amenity has not occurred (Freeman, 2003).

Since with the LS approach the indifference curve over y and a is estimated directly, the monetary value of infra-marginal amenity changes among different locations can also be estimated directly without any further assumptions related to weak-complementarity and the expenditure function (Perman *et al.*, 2003 and Welsch, 2006). In other words, we do not need to estimate the Marshallian demand function and the related consumer surplus to get a monetary value of the welfare change (Bockstael and McConnell, 1993).

Consider an individual moving from area a to area b , where the provision of amenities is larger than in area b ($a_a > a_b$). We can compute a pseudo ES, as the minimum amount of income that the individual living in area b would need in order to reach a level of utility he would otherwise attain living in a . This compensation equalizes individuals' utility (their LS) across different locations. Implicitly:

$$v(w^a, r^a, a^a) = v(w^b + ES, r^b, a^b) \quad (6)$$

Alternatively, we can look at the problem in terms of CS. In this case, the pseudo CS will be the maximum WTP of individuals living in b for an improvement in the quality of public goods (a hypothetical construction of schools or hospitals, a reduction of air and water pollution, etc.) in the area of interest.

$$v(w^a - CS, r^a, a^a) = v(w^b, r^b, a^b) \quad (7)$$

4. Data and Estimation Strategy

For the empirical analysis, data on individual's subjective well-being and on socio-demographic and socio-economic characteristics come from a 2001 survey of a representative sample of 1,500 men and women, aged 18 and over and living in Ireland.

Data on location-specific factors have been linked to individuals' LS and characteristics by matching the respondents' ED using GIS (as in Brereton *et al.*, 2006b) as it is recognized that at local level "the linkage between environment and happiness is even more articulate than it is with respect to national data" (Welsch, 2006 p. 11). The use of GIS modelling provides a methodological improvement over previous studies which use LS valuation of location-specific amenities. Such studies either control for one attribute only (for instance, perception of noise in Van Praag and Baarsma, 2005) or they use macro-econometric LS function where each country is a cross-sectional unit (Welsch, 2006; Stutzer and Frey, 2005a). Linking respondents to their objective living circumstances at a very high level of disaggregation - the ED where the individual's dwelling is situated - can improve the analysis considerably by addressing an important dimension of individual heterogeneity: where the individual lives.

A micro-econometric linear happiness function was estimated by using OLS with cluster robust standard errors to adjust for the possible within-ED correlation (Moulton, 1990) as follows¹³:

$$LS_{i,k} = \alpha + \beta_1 \mathbf{x}_{i,k} + \beta_2 y_{i,k} + \beta_3 \mathbf{a}_{i,k} + \varepsilon_{i,k} \quad (8)$$

As dependent variable we considered the LS scores and, as explanatory variables, we considered a set of individual's demographic and socio-economic characteristics ($\mathbf{x}_{i,k}$), income ($y_{i,k}$), and a vector of location-specific variables ($\mathbf{a}_{i,k}$) disaggregated at ED level. Demographic and socio-economic variables include age, age-squared (to capture for a potential U shape in age), gender, employment status, marital status (single, married, cohabiting, widowed and separated/divorced), educational attainment (lower secondary/junior high school, upper secondary/senior high school and university degree), family size, family size squared, and number of visits to a doctor during the previous year. The survey's dataset contained a measure of gross household income.¹⁴ To adjust for the number of adults and children living in the household, household income was divided by an equivalence factor.¹⁵

'Objective' location-specific social and economic factors consist of unemployment rate at ED level (CSO, 2003) violent crime rate at local authority level¹⁶ (measured as the number of homicides per 100,000; Garda Síochána, 2001), population density by local authority (measured as total population divided by total area in km²; CSO, 2003) and population change between 1996 and 2002 (CSO, 2003). A dummy variable for the Dublin region was included to capture the effects related to living in the Capital that are not otherwise captured.¹⁷

The set of location-specific amenities particularly relevant to our study includes climate variables, proximity to infrastructures, and environmental amenities.

Climate variables include January mean daily minimum air temperature, July mean daily maximum air temperature, mean annual duration of bright sunshine and mean annual wind speed (from Collins and Cummins, 1996).

Dummy variables were created in order to control for proximity to bus lines and rail stations considered as "excellent" by the Irish National Spatial Strategy (DELG, 2002), major

¹³ An Ordered Probit analysis was conducted as well, obtaining similar results in terms of signs, statistical significance of the coefficients, and resulting welfare measures (Table A1 in the Appendix).

¹⁴ Missing values represented 23.7 percent of those interviewed and were imputed based on the respondent's socio-demographic characteristics including age, gender, marital status, education level, area inhabited and employment status. The original income variable was divided in 10 categories, so mid-points were used (as in Stutzer, 2004). The survey was carried out when Ireland was still using the Irish Pound, so we converted to euros using the fixed rate of IR£1 = €1.26974.

¹⁵ The equivalence factor is computed, following Joung *et al.* (1997), as the square root of the sum of the number of persons aged 18 years or over living in the household plus the number of dependent children multiplied by a factor of 0.7.

¹⁶ If not specified otherwise, variables are disaggregated at ED level.

¹⁷ Ireland has a total population of 4 million and it is considered a homogenous country. What we have called as Dublin region coincides with the Dublin Regional Authority, which population is 1.122 million, and comprises four administrative areas: Dublin city, Dublin Fingal, Dun Laoghaire and South Dublin (CSO, 2003). See Figure A1 in the Appendix.

roads (national primary and national secondary) (NRA, 2003); and to capture the effect of various distances from national, regional and international airports (UII, 2005).¹⁸

Local air pollution is expressed in terms of annual mean ambient mass concentration of PM₁₀ in micrograms per cubic meter. Ireland is divided into four air quality zones in order to implement the European Directive on Air Quality Assessment and Management (see for instance, CEC, 1996 and EPA, 2001). Air quality is considered homogeneous within each of the 4 areas. They are Dublin city and environs (zone A), Cork city and environs (zone B), 16 urban areas with population greater than 15,000 (zone C) and the rural areas in the rest of the Country (zone D) (see Figure A2). In 2001, zone B, C and D were monitored on a daily basis using two fixed stations in B and D and a mobile unit in zone C placed in locations representative of the entire areas. Zone A was monitored with seven fixed monitoring stations positioned in different areas in Dublin city and Dun Laoghaire (see Figure A1). Pollution levels recorded in the monitoring stations were assigned to our observations on the basis of the proximity of the respondent's ED to the monitoring stations. In the case the respondent's ED was near to more than one monitoring station, a weighted average of the different values was attributed as local mass concentration of PM₁₀.

Other environmental variables consist of dummy variables capturing proximity to Natural Heritage Areas (NHA are designated by the Irish Government as areas of outstanding natural beauty), blue flag beaches, seriously polluted rivers and waste facilities.¹⁹

Table 2 shows the descriptive statistics for the variables considered. 27% of the individuals in our sample lives in Dublin area, 52% are female and 52% are married. The average of LS is relatively high, 5.4, between 'good' and 'very good' LS, with a standard deviation of 0.98. Only about 2.20% report a low LS score ('as bad as can be', 'very bad', 'bad'), while about 84% report a good LS score ('good', 'very good', 'as good as can be'). Within this group, those stating they are 'as good as can be' are 14.18% of the total.

Table 2 about here

5. Estimation results

Table 3 shows the coefficients from the OLS estimation of equation (8).²⁰ Its R-squared (0.25) is similar to those found in the literature.

As for the demographic and personal socio-economic circumstances, the main findings are in line with previous studies (in particular see Brereton *et al.*, 2006a). The

¹⁸ The dummy variables for proximity to bus lines and rail stations take value of one when the bus lines or the rail stations are located 2 Km from the respondent's ED; 'major road' captures the presence of a secondary or primary road within the respondent's ED; the distances from the airports considered are 5, 20 and 60 Km (see Table 2).

¹⁹ GIS Heritage Data for Ireland available at www.heritagedata.ie. The dummy variable takes the value of one when a NHA is within the respondent's ED. Environmental Datasets —including blue flag beaches, polluted rivers, waste facilities — were provided by EPA Ireland (www.epa.ie) in electronic format. The variable 'Blue flag beach' takes value of one when there is an EU-designated high-quality beach within the respondent's ED. 'Seriously polluted river' captures the presence of biologically polluted water bodies within 2 km from each ED (EPA, 2005). Waste facility is a composite variable capturing the presence of a landfill or a hazardous waste facility within the respondent's ED (see Table 2).

coefficient of being unemployed (-0.64) is large, significant at 1% level and negatively is large (-0.41) and significant at 5% level. As for education, higher levels of education have an expected positive effect on LS. Nonetheless, only the coefficient of lower secondary is statistically significant. The number of visits to the doctor is negatively correlated with individual's well-being (-0.11), and its coefficient is significant at 1% level. Equivalent income affects positively individual's LS and is significant at 1% level, however its estimated coefficient is very small (0.0000281). This result is in line with the literature in happiness economics which finds a weak relationship between income and LS scores over time and space (see e.g., Easterlin 1974 and 2001; Bruni and Porta, 2005).

Regarding location-specific variables the coefficient of the dummy variable for Dublin region is negatively correlated (-0.35) with LS but is not significant at conventional significance level. This can be expected as our model controls for a considerable amount of factors (such as employment, pollution, climate or access to infrastructures) that explain the differences between living in Dublin and living in the rest of the country in terms of individual's LS. Indeed, in models without location-specific amenities, the Dublin Dummy variable was significant.

As for the climate variables, the coefficient on January minimum temperature (0.43) is positive and significant at 5% level, indicating preferences for warmer climate in winter. Mean annual precipitation and wind speed have the expected sign (negative) but both are insignificant at standard significance levels.

Regarding environmental variables, as we would expect, vicinity to seriously polluted rivers is negatively related to LS. The impact is large (-0.32). Being exposed to local air pollution in terms of mass concentration of PM10 also significantly reduces individual's well-being (the coefficient is -0.03).

Table 3 about here

6. Monetary Valuation of Location-specific Amenities

Our model clearly identifies that warmer winter climate, river pollution and local mass concentration of PM10 affect individuals' LS. A method for assessing the monetary values of these factors consists of computing their MRS with income according to (4). The shadow cost for PM10, computed in this way, using the estimated coefficients from Table 3, is 1,100 euro per microgram per cubic meter, which is comparable to the estimates of Welsch (2006) for lead and NO₂. In other words, the average individual in our sample would be willing to pay this amount for a one-unit decrease (one microgram per cubic meter –which is an improvement of 5% over the average value) in air pollution. We also obtained a high marginal price (15,300 euro) for an additional degree of temperature in January.

²⁰ The same results in terms of statistical significance of coefficients and marginal prices were obtained with an Ordered Probit model. In what follows we shall discuss only the results from the OLS regression. See Table A1 in the Appendix for the Ordered Probit results.

In terms of elasticities (at the mean values), a 1% drop in PM10 or an increase in January minimum temperature would move the individual to the next category in the well-being scale (around a 14% increase in well-being).

Infra-marginal changes in welfare can be measured too. In our case, because of the linear specification of the micro-econometric happiness function, CS and ES provide the same measure:

$$CS = ES = \frac{\beta_3(a_a - a_b)}{\beta_2} \quad (9)$$

where $(a_a - a_b)$ is the discrete change in temperature (among two different areas). In our application, an individual moving from, say, Dublin City —where the mean annual level of mass concentration of PM10 in 2001 is 25.74 $\mu\text{g}/\text{m}^3$ — to the less polluted Limerick City (South of Ireland; see Figure A1 in the Appendix), where the average PM10 concentration is lower, 24 $\mu\text{g}/\text{m}^3$, would be willing to pay, *ceteris paribus*, around 3,000 euro per year. The same measures can be computed for the same individual for changes in average minimum January temperature. In this case, given the average in 2001 of 2.6°C in Dublin City and 2.4°C in Limerick City, the individual would have to be compensated, *ceteris paribus*, by around 5,600 euro in order to tolerate a colder climate.²¹

For river pollution, the compensation to an individual for deterioration in water quality is around 11,400 euro. This number is again high. In this case, however, the dichotomous form of the dummy variable implies that this shadow cost is not technically a marginal price but a discrete change from 'good' to 'bad' water quality. In addition, water quality appears to be a greater problem in Ireland than air quality (EPA, 2005).

Overall, although comparable in magnitude with those from previous studies, the monetary values we obtain for winter warmer climate and pollution are large. This is due, in part, to a common but overlooked problem associated with the cardinalisation of utility when using LS as a valuation tool: a small estimated coefficient for the marginal utility of income (see e.g. Blanchflower and Oswald 2004a, b; Alesina *et al.*, 2004). For example, in our study the estimated coefficient on equivalent income is 0.0000281. Two factors have been pointed out to explain such small figures. The first one is measurement error in the income variable (in our study, for example, income is self-reported and missing values were imputed) which biases its estimated coefficient downwards. The second one is adaptation and aspiration effects. While an increase in income initially provides extra pleasure, this effect is usually only transitory (see e.g., Easterlin, 1974, 1995, 2001; Stutzer, 2004; Bruni and Porta, 2005). In micro-econometric happiness functions, the effect captured is mainly the marginal utility after adaptation (the long-run marginal utility). Therefore, the utility consequences of changes in income are underestimated. This effect would also bias estimated welfare measures upwards.

²¹ A recent study from Rehdanz and Maddison (2005b) shows that households in Germany are WTP an amount ranging from 2,250 euro to 3,560 euro for a one degree centigrade increase in January temperature. By contrast,

It is important to point out that, although this upward bias would lead to caution in the interpretation of the figures obtained using the LS approach as upper-bound estimates, none of these caveats are present in the use of LS scores to test for the equilibrium condition in location markets.

7. Conclusion and Further Research

This paper presents a comprehensive theoretical and methodological framework for the valuation of environmental and other location-specific amenities using the novel life-satisfaction approach. In doing so, we clarify the ties between this method and standard environmental valuation techniques, in particular hedonic pricing. In particular, we show how life satisfaction scores can be used to test correctly for the equilibrium condition in the location market required by the hedonic pricing approach in a straightforward way, which does not require information from housing or labour markets. We further demonstrate that in equilibrium the two methods are substitutes, i.e. the monetary values yielded by either hedonic market models or life-satisfaction approaches are identical. When the location market is out of equilibrium, however, as we show to be the case in Ireland, only the life-satisfaction approach provides theoretically sound monetary valuations.

Using self-reported well-being as a proxy for the utility of individuals allows the implicit (or marginal) price of local environmental amenities to be computed directly. It also allows the direct computation of other welfare measures related to infra-marginal amenity changes (equivalent and compensating surpluses). By using highly spatially disaggregated data (we use GIS to link environmental attributes to each respondent) we attempt to capture the effects of factors which operate at a small scale, which are not captured in previous cross-country studies.

The factors identified by our model as affecting individuals' LS (warmer winter climate, river pollution and local mass concentration of PM10) and the quantitative impacts of these factors are similar to those found in previous literature. Overall, the impacts of environmental attributes on utility are large and result in large monetary estimates. We argue, however, that there is an upward bias in these monetary estimates resulting from a small estimated marginal utility of income used in their calculation, and that they should be interpreted with caution as upper bounds. This is a key empirical caveat of the LS approach. Further investigations on the economic meaning of the relationship between subjective well-being as a proxy for long-run experienced utility and income need to be carried out. This caveat, however, does not affect the use of LS scores to test for the equilibrium condition in location markets.

estimates of the marginal WTP for July temperatures range from 4,162 euro to 6,661 euro to avoid a one degree centigrade increase. See also Maddison and Bigano, 2003 for a similar hedonic study conducted for Italy.

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Table 1
Average Life Satisfaction scores by Local Authority Area in Ireland (2001)

Local Authority	Mean LS	Std. Dev. LS	Freq.	%
Carlow	5.59	1.37	17	1.2%
Dublin City	4.73	0.96	171	11.6%
Dublin South	4.60	1.18	67	4.6%
Dublin Fingal	5.57	0.65	82	5.6%
Dun Laoigaire	5.21	0.79	75	5.1%
Kildare	5.22	0.90	23	1.6%
Kilkenny	5.63	0.61	30	2.0%
Laois	5.45	0.69	20	1.4%
Longford	5.27	0.47	11	0.7%
Louth	5.51	0.68	39	2.7%
Meath	5.71	0.46	41	2.8%
Offaly	5.36	0.87	59	4.0%
Westmeath	5.25	0.87	36	2.5%
Wexford	5.51	0.82	45	3.1%
Wicklow	6.33	0.92	43	2.9%
Cork City	5.25	1.06	65	4.4%
Cork County	5.70	1.01	102	6.9%
Clare	5.35	0.56	49	3.3%
Kerry	5.74	0.56	54	3.7%
Limerick City	5.96	0.68	25	1.7%
Limerick County	5.80	0.59	45	3.1%
Tipperary North	5.46	0.81	26	1.8%
Tipperary South	6.59	0.76	37	2.5%
Waterford City	6.00	1.26	6	0.4%
Waterford County	4.80	0.41	20	1.4%
Galway City	6.65	0.81	20	1.4%
Galway County	6.93	0.26	56	3.8%
Leitrim	5.00	1.41	2	0.1%
Mayo	5.87	0.98	46	3.1%
Roscommon	5.39	0.92	28	1.9%
Sligo	5.39	0.70	18	1.2%
Cavan	5.21	0.78	24	1.6%
Donegal	5.17	0.83	64	4.4%
Monaghan	5.26	0.75	23	1.6%
Overall Ireland	5.47	0.99	1469	100%

Table 2
Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max	Freq.	%
Life satisfaction	1474	5.469471	0.989808	1	7	-	-
as bad as can be	-	-	-	-	-	3	0.2
very bad	-	-	-	-	-	4	0.27
bad	-	-	-	-	-	26	1.76
alright	-	-	-	-	-	197	13.36
good	-	-	-	-	-	488	33.11
very good	-	-	-	-	-	547	37.11
as good as can be	-	-	-	-	-	209	14.18
Age							
Age	1492	43.61193	17.10202	18	90	-	-
Age-squared	1492	2194.284	1627.333	324	8100	-	-
Gender							
Male	-	-	-	-	-	718	47.87
Female	-	-	-	-	-	782	52.13
Marital status							
Single (never married)	-	-	-	-	-	525	35.26
Married	-	-	-	-	-	778	52.25
Co-habiting	-	-	-	-	-	36	2.4
Separated or divorced	-	-	-	-	-	46	3.07
Widow	-	-	-	-	-	104	6.93
Family size	1487	3.406187	1.607658	1	11	-	-
Family size-squared	1487	14.18494	12.53008	1	121	-	-
No. visits to doctor	1497	1.425518	1.24637	0	4	-	-
> 6	-	-	-	-	-	146	9.75
4-5 times	-	-	-	-	-	119	7.95
2-3 times	-	-	-	-	-	383	25.58
Once only	-	-	-	-	-	427	28.52
Never	-	-	-	-	-	422	28.19
Economic							
Equivalent income	1482	13,521.22	6,725.783	719.8749	44,440.9	-	-
Regional							
Dublin area	-	-	-	-	-	398	26.53
Rest of Ireland	-	-	-	-	-	1102	73
Local attributes							
Unemployment rate (%)	1479	5.797938	3.26504	1.33	16.49	-	-
Murder rate ²²	1494	1.524324	1.41303	0	5.42	-	-

²² Number of homicides per 100,000.

Population density ²³	1480	13.60833	24.10738	0.013251	149.9565	-	-
Population change %('96-'02)	1460	10.70301	23.05476	-25.4	181.7	-	-
Local climate							
January minimum temperature (°C)	1500	2.322667	0.64459	0	4	-	-
Precipitation (mm)	1500	987.2	268.2613	0	2000	-	-
Annual sunshine (hours/year)	1480	1,391.554	90.76501	1200	1500	-	-
July maximum temperature (°C)	1488	18.582	3.597578	17	20	-	-
Wind speed (m/s)	1480	5.688514	0.747954	4	7	-	-
Transport							
Excellent bus lines (2Km)	-	-	-	-	-	773	51.53
Excellent railways stations (2Km)	-	-	-	-	-	342	22.80
Major road (within ED)	-	-	-	-	-	801	53.40
Airport (5Km)	-	-	-	-	-	173	11.53
Airport (20Km)	-	-	-	-	-	71	4.73
Airport (60Km)	-	-	-	-	-	423	28.20
Local environment							
NHA (within ED)	-	-	-	-	-	209	13.93
Blue flag beach (5Km)	-	-	-	-	-	634	42.44
Seriously polluted river (within ED)	-	-	-	-	-	228	15.20
Waste facility (within ED)	-	-	-	-	-	106	7.07
Emissions of PM10 (µg/m ³)	1500	20.79024	3.68767	19	38		

Note: the first five columns show the standard descriptive statistics for the continuous variables (number of observations, mean, standard deviation, minimum and maximum). The last two columns show the frequency and percentage for the dummy variables. In the case of transport and environmental variables, the frequency represents the number of individuals living in proximity to transport facilities and environmental amenities. Distance is indicated in brackets.

²³ Total population divided by total area in km²

Table 3
OLS Regression with Adjusted Standard Errors for Clustering on Electoral Division;
Dependent Variable: Life Satisfaction

Variables		Coefficient	t
Age	Age	0.003153	0.36
	Age-squared	0.000014	0.16
Gender	Female	0.041062	0.68
Employment status	Unemployed	-0.637303***	-3.7
Marital status (married and co-habiting)	Widowed	0.086060	0.67
	Separated or divorced	-0.413510**	-2.23
	Single	0.055284	0.62
Education (Primary)	Lower secondary/Junior high school	0.227991*	1.77
	Upper secondary/Senior high school	0.151568	1.62
	Degree	0.115898	1.09
Family	Family size	0.095310	1.39
	Family size-squared	-0.009297	-1.19
Health	Number of visits to doctor	-0.108504***	-3.79
Economic status	Equivalent income	0.000028***	5.39
Social location-specific factors	Unemployment rate	-0.031764	-1.17
	Murder rate (,000)	0.000182	0.000
	Population density	-0.000463	-0.18
	Population change ('96-'02)	0.001605	0.7
Regional	Living in Dublin Area	-0.358779	-1.33
Climate variables	January min temperature	0.432251**	2.33
	Precipitation	-0.000400	-0.82
	Annual sunshine	-0.000221	-0.16
	July max temperature	-0.020429	-0.12
	Wind speed	-0.052734	-0.42
Transport (Proximity to respondent's electoral division ED)	Excellent Bus lines (2Km)	-0.199238	-1.05
	Excell. Rail stations (2Km)	-0.153771	-0.96
	Major roads (within ED)	-0.014860	-0.11
	Airport (5Km)	0.015371	0.07
	Airport (20Km)	-0.369137	-1.41
	Airport (60Km)	0.057798	0.4

Environment (Proximity to respondent's electoral division ED)	NHAs (within ED)	-0.030642	-0.12
	Waste facility (within ED)	-0.267124	-1.18
	Blue flag beach (5 Km)	-0.147748	-0.62
	Seriously polluted rivers (2 Km)	-0.320937**	-2.23
	PM ₁₀	-0.031922*	-1.91

Note: In parenthesis, the reference group for dummy variables and the ED's proximity to the location-specific amenities.

***, **, and * denote significance at the 1% 5%, and 10% levels, respectively.

Appendix

Fig. A1. Average Well-being by Local Authority Area (seven point scale, 1 – 7)

Source: Base maps from Ordnance Survey Ireland (license pending)

Fig. A2. Ireland National Air Quality Zones

Source: Environmental Protection Agency Ireland (EPA, 2005)

Table A1
Ordered Probit Regression with Standard Errors Adjusted for Clustering on
Electoral Division; Dependent Variable: Life Satisfaction

Variables		Coefficients	Z statistic
Age	Age	0.005193	0.49
	Age-squared	0.000008	0.07
Gender	Female	0.052325	0.73
Employment status	Unemployed	-0.721392***	-3.88
Marital status (Reference group: married and co- habiting)	Widowed	0.118157	0.76
	Separated or divorced	-0.467548**	-2.46
	Single	0.088587	0.82
Education (Reference group: primary school)	Lower secondary/Junior high school	0.291027*	1.8
	Upper secondary/Senior high school	0.175409	1.52
	Degree	0.132373	1.03
Family	Family size	0.128691	1.57
	Family size-squared	-0.012403	-1.33
Health	Number of visits to doctor	-0.131021***	-3.66
Economic status	Equivalent income	0.000035***	5.31
Social location-specific factors	Unemployment rate	-0.039694	-1.11
	Murder rate (.000)	-0.014311	-0.23
	Population density	0.000112	0.03
	Population change ('96-'02)	0.002149	0.75
Regional	Living in Dublin Area	-0.461262	-1.37
Climate variables	January min temperature	0.535731**	2.22
	Precipitation	-0.000558	-0.87
	Annual sunshine	-0.000130	-0.07
	July max temperature	-0.017180	-0.08
	Wind speed	-0.072498	-0.45
Transport (Proximity to respondent's electoral division ED)	Excellent Bus lines (2Km)	-0.272465	-1.1
	Excell. Rail stations (2Km)	-0.190968	-0.95
	Major roads (within ED)	-0.040101	-0.23
	Airport (5Km)	0.041083	0.14
	Airport (20Km)	-0.410716	-1.41
	Airport (60Km)	0.079493	0.43

Environment (Proximity to respondent's electoral division ED)	NHAs (within ED)	-0.016699	-0.05
	Waste facility (within ED)	-0.343887	-1.27
	Blue flag beach (5 Km)	-0.157219	-0.54
	Seriously polluted rivers (2 Km)	-0.400321**	-2.23
	Air pollution (within local authority)	-0.039829*	-1.89

Note: In parenthesis, the reference group for dummy variables and the ED's proximity to the location-specific factors

***, **, and * denote significance at the 1% 5%, and 10% levels, respectively.