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ABSTRACT

The Life Satisfaction Approach to Environmental Valuation

In many countries environmental policies and regulations are implemented to improve environmental quality and thus individuals' well-being. However, how do individuals value the environment? In this paper, we review the Life Satisfaction Approach (LSA) representing a new non-market valuation technique. The LSA builds on the recent development of subjective well-being research in economics and takes measures of reported life satisfaction as an empirical approximation to individual welfare. Micro-econometric life satisfaction functions are estimated taking into account environmental conditions along with income and other covariates. The estimated coefficients for the environmental good and income can then be used to calculate the implicit willingness-to-pay for the environmental good.

JEL Classification: Q51, I31, D61, Q53

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1. Introduction

Environmental quality is an important determinant of individuals' well-being and an important policy issue. In response to poor environmental conditions, in many countries environmental policies and regulations are implemented to improve them. However, how do individuals value the effects on the environment?

In this paper, we review the Life Satisfaction Approach (LSA) representing a new non-market valuation technique. The LSA builds on the recent development of subjective well-being research in economics. A common understanding in this field is that subjective well-being can serve as an empirical approximation to individual welfare. If this interpretation of subjective well-being measures is accepted, it becomes straightforward to value environmental goods: Environmental conditions can be taken into account in micro-econometric life satisfaction functions along with income and other covariates. The estimated coefficient for the environmental good offers, first, a direct valuation in terms of subjective well-being. Second, the estimated coefficients for the environmental good and income can be used to calculate the implicit willingness-to-pay (WTP) for the environmental good or constant trade-off ratios between the environmental good and income. In other words, the increase in income can be calculated that would be necessary to compensate an individual for a given decrement in environmental conditions.

This newly emerged approach stands in a long tradition and debate of research trying to measure individual welfare. Classical economists such as Bentham and Edgeworth believed that measurement of utility is not only possible but also that it could be used to improve the rationality of policy decisions. In contrast, today's mainstream economics completely abandoned this idea. Preferences are inferred from behavior, above all, from market behavior. This poses obvious problems for environmental goods and other public goods for which no markets exist and for which individuals have limited incentive to disclose their true demand. Therefore, for a long time, economists have been very pessimistic as to whether it is possible to assess people's preferences for public goods: "[T]he very essence of the public goods problem is that there is no way these preferences can be determined" (Due and Friedlaender 1973, p. 53).

In defiance of this negative view, economists developed ingenious ways to value environmental and other public goods. Essentially, two avenues have been pursued: Either

people are asked to state their preferences in hypothetical contingent markets or the preferences are inferred from behavior as they are revealed in markets for private goods that are complements or substitutes of the environmental good. Stated preference methods such as the contingent valuation method (CVM) and revealed preference methods such as the hedonic method (HM) have been widely used in practice, both in the regulatory process and in litigation (Palmquist and Smith 2002; Carson et al. 2003). However, these methods suffer from well-known problems. The hypothetical nature of CVM surveys is likely to entail superficial answers and strategic behavior. The HM, on the other hand, yields biased results if housing markets are not in equilibrium because, for example, people are not fully informed or mobility is not costless.

The LSA aims at obviating several of these problems inherent in the standard methods or at least at offering a complementary approach. Importantly, the approach does not rely on an equilibrium assumption. Further, individuals are not asked to value the environmental good directly, but to evaluate their general life satisfaction. This is presumably a cognitively less demanding task and there is no reason to expect strategic behavior. While the LSA avoids some of the difficulties with previous valuation approaches, it depends on its own preconditions for a successful application. In particular, the validity of measures of subjective well-being, their inclusiveness and their reference to the present situation are important. Moreover, reports of life satisfaction should have small measurement errors, be interpersonally comparable and be available at a sufficiently large scale (at a sufficiently low cost).

The remainder of this review is organized in four sections. Section 2 introduces the basics of the LSA. Section 3 compares the LSA to the most prominent standard non-market valuation methods, the CVM and the HM. Section 4 provides a review of applications of the LSA. The focus is on studies valuing air quality. Section 5 offers concluding remarks.

2. The Basic Concept

The measurement of individual welfare, using data on reported subjective well-being, has made great progress and lead to a new field of subjective well-being research in economics.¹

¹ For surveys on the study of subjective well-being in economics, see Frey and Stutzer (2002b; a), Layard (2005), Di Tella and MacCulloch (2006), Clark et al. (2008) and van Praag and Ferrer-i-Carbonell (2008).

The LSA rests upon this new field of research and starts to build an important pillar of its fruitful policy relevant application.²

First, we discuss measures of subjective well-being as an approximation of individual welfare. Second, the valuation procedure as proposed by the LSA is outlined. In a third subsection, the prerequisites for a successful application of the approach are explained.

Measuring individual welfare

In received economics, utility is what is maximized in consistent choice, a representation of preferences which are simply choice-connected rankings of outcomes. According to the axiomatic approach, individuals' choices provide all the information required to infer the utility of outcomes. Subjectivist experience captured by surveys is rejected as being not objectively observable and unscientific. However, this position restricts the questions that can be addressed. Most importantly, conceptions about individuals' preferences or utility functions remain vague and the valuation of public goods is hampered. Revealed preference methods cannot be applied in all cases of interest and non-use values leave no behavioral trace. It is, therefore, no coincidence that non-market valuation is a field in economics where surveys have been widely used.

In recent economic research, new ways are proved to approach individual welfare. Utility is again related to the original, Benthamite meaning of utility as the hedonic quality of experience, broadly construed to include satisfaction as well as pleasure. In many situations the choice-based and the experience-based concept of utility coincide but there is also evidence indicating that they may systematically diverge in some situations (Kahneman et al. 1997). Empirically, utility based on judgments of satisfaction and pleasure can be captured by measures of subjective well-being.³

Subjective well-being is the umbrella term for different measures that can be distinguished along two dimensions. Regarding the first dimension, a common distinction is between cognition, the cognitive, evaluative or judgmental component of well-being (usually assessed

² For a general discussion on the use of research on subjective well-being in public policy see Adler and Posner (2008) and Frey and Stutzer (2010).

³ The empirical study of subjective well-being used to be the province of hedonic psychology (for reviews, see Diener et al. 1999; Kahneman et al. 1999a).

with life satisfaction), and affect, the pleasure-pain component of well-being (Diener 1984). With regard to affect, two independent components of positive and negative affect are differentiated. The discriminant validity of the three components is analyzed in Arthaud-Day et al. (2005). The second dimension distinguishes between measures that capture a person's level of subjective well-being and the duration in the one rather than another mental state. Because life satisfaction is a relatively stable construct, duration measures usually refer to affect. A primary example of a duration measure is the U-index which measures the proportion of time an individual spends in an unpleasant state. Thus, the combination of the dimensions entails four typical measures: the level of life satisfaction, the level of positive affect, the level of negative affect (or the difference between the two affective levels) and the duration in one affective state.

The measures are elicited with global self-reports in surveys, the Experience Sampling Method (ESM), which collects information on individuals' actual experiences in real time in their natural environments, and the Day Reconstruction Method (DRM), which asks people to reflect on how satisfied they felt at various times during the day (on the latter two techniques, see Stone et al. 1999; Kahneman et al. 2004). Measures and measurement techniques are not independent of each other. For example, measures with an inherent time component are best captured by the ESM or DRM. Further, neurophysiological correlates of subjective well-being have been found with electro-encephalography (EEG) and neuroimaging techniques (Urry et al. 2004). On the one hand, these correlates validate survey measures; on the other hand they can be used as independent measures of subjective well-being.

The various measures capture different aspects of individual well-being and thus different concepts of individual welfare. For a measure of reported subjective well-being to serve as a proxy for individual welfare, an important assumption is necessary: The standards underlying people's judgments are those the individual would like to pursue in realizing his or her ideal of the good life. People's judgments about their life can then serve as a proxy for their individual welfare. People are assumed to pursue individual welfare based on some stable evaluation standards. Moreover, the extent to which individual welfare is identified depends on whether the evaluation metric fits people's judgments about their life.

The normative basis of this approach goes beyond assuming the pursuit of happiness, and also involves choosing the concrete evaluation metric to elicit people's judgments.⁴ Thus, ambiguities remain when selecting the empirical concept in order to measure individual welfare.

Some people might favor a distant look reflecting on one's life after the fact, while others favor the reasoned ex ante evaluations as their standards. Still others might give priority to how they felt when experiencing the course of life.

Imagine those people who see high individual welfare as something like the "positive, persistent attitude towards both particular experiences and life experience more generally that a person feels upon repeated reflection" (Kelman 2005, pp. 408-409). For them, general evaluations of their satisfaction with life as a whole might be an appropriate metric to capture judgments about individual welfare. For those people who equate individual welfare with moment-to-moment affect, individual welfare might be best measured by such approaches as the ESM or the DRM. When looking for an empirical tool to collect information about people's judgments, it is thus important to reveal the concrete metric.

Most of the empirical work undertaken so far on subjective well-being research in economics has been based on representative, large-scale sampling of individual global evaluations of life satisfaction. Given the state of research, we favor these measures of life satisfaction to value people's living conditions (and this also explains the name of the approach) as they offer a blend of cognitive judgment and affective state. Moreover, this kind of "affect-contaminated" cognition corresponds to what has been considered the best theory on the nature of welfare in philosophy (Sumner 1996, pp. 140-156).

The valuation procedure

Granted that reported subjective well-being can serve as an empirically adequate and valid approximation for individual welfare, it is an obvious and straightforward strategy to directly evaluate public goods in welfare terms. Moreover, by measuring the marginal utility of a public good or the marginal disutility of a public bad, as well as the marginal utility of income, the trade-off ratio between income and the public good can be calculated.

⁴ An excellent account of the ambiguities of welfare in the context of economics and hedonic psychology is provided in Kelman (2005).

The respective relationship can be stated in a simple subjective well-being function:

$$SWB = f(x, y, \theta'z) \quad 1.$$

Individual welfare in terms of subjective well-being depends on some good x , i.e. the environmental condition to be valued, income y and a set $\theta'z$ of other individual-level and macro-level determinants of subjective well-being.

Roughly speaking, a change in the non-market good of Δx is valued by Δy (corresponding to an implicit WTP) if this holds individual well-being constant. For a marginal change of x , the marginal WTP (MWTP) can be derived from totally differentiating function (1) and setting $dSWB=0$:

$$MWTP = -dy/dx = (\delta f / \delta x) / (\delta f / \delta y) \quad 2.$$

MWTP is invariant to any monotonic transformation of the subjective well-being function, i.e. no cardinal utility function is required.

For the valuation of infra-marginal changes of non-market good x two measures exist: First, the compensating variation is the amount of income necessary to keep the individual at the original or ex ante level of subjective well-being when a change in environmental conditions occurred. Second, the equivalent variation is the change in income necessary to attain the level of subjective well-being as if a change in environmental conditions occurred, i.e. the ex post level for a hypothetical change in environmental quality.

In order to calculate the relevant welfare measures, a subjective well-being function such as (1) can be estimated as an ordered discrete choice model applying ordered logit or ordered probit regressions. While the estimated coefficients from these models have no meaningful interpretation (as they refer to an underlying latent variable), ratios between any two coefficients can be interpreted. Therefore, the coefficients for the non-market good x and income y can be employed to calculate the marginal rate of substitution or the MWTP and welfare measures for infra-marginal changes. Thus, it is not necessary to assume cardinality.

For applications with individual panel data, OLS estimations are attractive that allow to control for individual-fixed effects. There is some evidence that assuming cardinality and using OLS makes little difference to estimating ratios between coefficients (while taking into

account individual heterogeneity makes a large difference) (Ferrer-i-Carbonell and Frijters 2004).

A common specification of an empirical subjective well-being function is the following:

$$LS_{i,j,t} = \beta_0 + \beta_1 x_{j,t} + \beta_2 \log(y_{i,t}) + \beta' z_{i,j,t} + \rho_j + \tau_t + \iota_i + \varepsilon_{i,j,t}. \quad 3.$$

In this specification, $LS_{i,j,t}$ stands for reported life satisfaction as a specific measure of subjective well-being of individual i in location j in time t . Specification (3) is a linearized version of equation (1) up to the log of income term $\ln(y_{i,t})$. A log of income specification presumes that the monetary value of change in environmental conditions is measured as a fraction of an individual's income. This implies that people with a higher income are prepared to give up more income in absolute terms for some improvement in environmental quality. This is equivalent to imposing decreasing marginal utility of income. Vector z again captures other individual-level and macro-level determinants. Finally, ρ_i is a set of region or location-fixed effects taking into account unobserved time-invariant factors, τ_t a set of time-fixed effects capturing unobserved location-invariant factors, ι_i are individual-fixed effects and $\varepsilon_{i,j,t}$ an error term.

So far, the LSA is presented without any interaction between the quality of the environment and other determinants of subjective well-being that are taken into account in the empirical analysis. In particular, market forces are expected to lead to upward wage pressure and a downward pressure on rents for housing in locations where the environmental quality is bad. These are the two most fundamental channels through which people are compensated for adverse environmental conditions. Accordingly, equation (1) would need to be extended to include income as a function of x , i.e., $y(x)$, and rents as one of many other factors in z to depend on x , i.e., $z(x)$. Obviously the aspect of (partial) compensation is relevant for the interpretation of measured partial correlations between environmental conditions and subjective well-being. We discuss this aspect in Section 4 after an exposition of HM which values non-market goods under the presumption of compensation of amenities and disamenities on the market. We emphasize the links between LSA and HM and outline under what conditions they can serve as complementary approaches.

There are, of course, the standard identification issues in empirical analyses that also apply to the LSA. We do not discuss them here in abstract but in relation to specific applications in Section 5.

Premises for the application of the LSA

The different measurement techniques and their corresponding measures all have their strengths and weaknesses. Which measure and measurement technique is to be preferred depends ultimately on its intended use. In the following, we list six premises that are relevant for the evaluation of public goods. The measures of subjective well-being should (i) be valid measures of individual welfare, (ii) be broad and inclusive, (iii) refer to respondents' present situation, (iv) have small measurement errors, and no systematic ones (v) be interpersonally comparable, and (vi) be available at a sufficiently large scale (at a sufficiently low cost).

Validity. While we claimed the validity of subjective well-being measures at the outset of this review, we present here some specific evidence for reported satisfaction with life. Respondents who are satisfied with their lives are also rated as satisfied by family members, friends and experts (Sandvik et al. 1993). Life satisfaction scores correlate with other variables that can be plausibly claimed to be associated with true individual well-being (Di Tella and MacCulloch 2006). In two 20-year follow-up studies, low levels of reported life satisfaction predicted all-cause, disease and injury mortality, especially for male respondents (Koivumaa-Honkanen et al. 2000) and suicide (Koivumaa-Honkanen et al. 2001). Satisfied individuals are less likely to suffer from hypertension, a relationship that even translates into a correlation between hypertension and satisfaction at the national level (Blanchflower and Oswald 2007). Finally, life satisfaction predicts both, future marriage (Stutzer and Frey 2006) and future marital break-up (Gardner and Oswald 2006).

Inclusiveness. Essentially, this criterion approaches the validity issue from a second angle. Subjective well-being is an appropriate empirical approximation of individual welfare if it is broad and all inclusive. We think that the current evidence supports this position. However, critics claim that subjective well-being is extremely narrow and constitutes only one of many components of individual welfare (Adler and Posner 2006, p. 77), one sub-utility function among others (Kimball and Willis 2006). This debate parallels the normative question of the nature of welfare with the "objectivist" ascribing various goods intrinsic importance and "subjectivists" conceding other goods only instrumental importance insofar as they contribute

to well-being. The positive question asks whether other “higher order” goods are sub-utility functions of equal standing with subjective well-being or whether these goods are arguments in the subjective well-being function with no independent effect on individual utility. Data on subjective well-being can only be used to evaluate policies if subjective well-being is a broad and (all-)inclusive concept.

The strategy of the critics is to equate subjective well-being with pleasure and pain and declare the ESM or DRM as the gold standard of measurement techniques. They then reject the view that subjective well-being thus understood is a meaningful measure of overall utility and extend the conclusions beyond the narrower measures to subjective well-being research as such. This victory over measures of subjective well-being is cheap and hollow. As we have mentioned, there is a wide array of measures and measurement techniques.

Reference to presence. Measures of subjective well-being should refer to the respondents’ present lives and represent their period- or flow-utility. If scores of subjective well-being reflected discounted expected future utility, it would become difficult to relate changes in objective circumstances to changes in subjective well-being. In measures of global self-reports, the focus on the present situation is often indicated by means of the wording of the question. Often the questions have extensions such as “these days”, “now”, “nowadays” or “at present”.

Measurement errors. The major concern in the discussion on the degree of inclusiveness was that measures of subjective well-being may exclude important aspects of utility. The converse concern is that measures of subjective well-being include a lot of noise and are contaminated by confounding factors. Most research on this problem has focused on global self-reports.

Normally, the global judgments are only construed when asked. Answering the question involves cognitive (memory and aggregation) and communicative processes. At the level of the cognitive processes, concerns may arise that respondents may make little mental effort and instead rely on easily accessible information. Experimental research shows that self-reports can be influenced by the immediate context as well as by artificially induced intra- and interpersonal comparisons and temporal mood states (Schwarz and Strack 1991). At the level of the communicative process, issues of communicative norms, self-representation and social desirability become important (Larsen and Frederickson 1999; Schwarz and Strack 1999).

In order to assess the importance of these findings for the LSA, it is useful to integrate them into a measurement error framework (Bertrand and Mullainathan 2001). This allows us to distinguish two types of errors: White noise errors that are unrelated to right hand side variables on the one hand, and systematic errors that are correlated with the explanatory variables on the other hand. Mood variability and most context effects fall in the first category. Conceptually, errors of this sort pose no problem. They entail no systematic bias as the idiosyncratic effects cancel each other out. However, the random variation reduces the statistical fit. Therefore, the ratio of error variance to true variance has to be sufficiently low to make statistical work productive.

Measurement errors that fall into the second category pose a more serious problem. Two findings of the experimental research are of potential relevance for the LSA. First, other questions in the questionnaire and the order of the question can influence the reported subjective well-being. If the questionnaire includes questions referring to the public good to be evaluated and to income, these questions may systematically bias the results, especially if the questions precede the subjective well-being question. On the one hand, the questions increase the accessibility of information on the public good and income and heighten their awareness, thereby increasing the weight of these aspects in the global judgment. On the other hand, conversational norms of non-redundancy may decrease the weight of these aspects. The latter effect is to be expected if questions of satisfaction with the public good or satisfaction with income immediately precede the subjective well-being question. Both effects have been documented (Strack et al. 1988). Second, answers deemed to be socially desirable or serving self-representation purposes can also systematically influence the results. Thus, problems of the second category have important implications for the questionnaire design and survey mode as well as for the choice of existing data.

Interpersonal comparability. No doubt, it is in principle not possible to observe the level of an individual's utility and, therefore, compare utility levels of different persons (Robbins 1938). Individuals with identical preferences (as revealed through behavior) and with identical expressive reactions to any situation may nevertheless attach different utilities to identical situations. In the present context, the practical question thus are whether identical (verbal and physiological) expressions reflect similar mental states and what the consequences for empirical research are if they do not.

Kahneman (2000) suggests that there is evidence of considerable interpersonal convergence in ranking of pleasure and pain. In painful medical procedures, for example, the relationship between expressed pain and physiological reactions is similar across persons. Similarly, the correlations between self- and other-reports discussed above show that self-reports are not just artifacts of individual specific response behavior but are related to shared standards of evaluation. More importantly, for most empirical research (including research using the LSA), comparisons at the individual level are not necessary. Instead, empirical analysis is focusing on groups and compares the subjective well-being of individuals under different circumstances, e.g. the subjective well-being of groups of individuals exposed to different levels of a public good. By focusing on groups, personal peculiarities of individuals counterbalance one another.

In sum, Robbins' (1938) statement that utility cannot be interpersonally compared with standard scientific rigor still holds and pertains to all measures of subjective well-being. However, it is important to remember that without the assumption of interpersonal comparability of utility, cost benefit analyses and many other analyses in applied welfare economics are impossible.

Availability and costs. Most public goods can be expected to have relatively small effects on subjective well-being, in particular, smaller effects than personal characteristics. In order to statistically detect the effects, large sample sizes are required. Therefore, the cost component is another criterion for evaluating measures and measurement techniques. Beyond doubt, the least expensive measurement technique are surveys including global self-reports. The most expensive measurement techniques are probably the ESM and physiological techniques, the DRM falling between these two extremes.

4. Comparison with Standard Methods

In economics, environmental valuation is typically based on preferences stated in hypothetical contingent markets or on preferences revealed in the demand for marketed goods (e.g., Freeman 2003). In the following, we discuss the two most prominent methods – the CVM and the HM – and their inherent problems, in particular those which the life satisfaction obviates.

Stated preference methods: Contingent valuation (CVM)

The CVM is a survey based technique of non-market valuation. Respondents are asked directly what they would be willing to pay for a change in an environmental amenity. This is often an unfamiliar situation and gives rise to problems of strategic responses. Therefore, the credibility, validity and reliability of results based on the CVM are the subject of heated controversy in economics. Skepticism is largely based on the empirically observed “embedding effect” (Kahneman and Knetsch 1992) that refers to several interrelated regularities in CVM surveys, i.e. the insensitivity of expressed WTP to scale and scope of the public good, as well as sequencing and sub-additivity effects. Critics see the “embedding effect” as evidence for the non-existence of individual preferences for the public good; individuals receive positive feelings from expressing support for good causes and, accordingly, the survey process creates the values it seeks to reveal (Diamond and Hausman 1994). However, meta-analysis find significant sensitivity to scale and scope (Smith and Osborne 1996) and, according to proponents, the sequencing and the sub-additivity effect can be explained in terms of substitution effects and diminishing marginal rates of substitution (Hanemann 1994; Carson et al. 2001). Further, a number of guidelines have been developed to assure credibility, validity and reliability, most importantly the presentation of adequate information, the choice of a credible (hypothetical) method of public good provision and payment mechanism and the use of the referendum format (Arrow et al. 1993; Portney 1994).

Nevertheless, the two basic problems of the CVM are difficult to overcome. The hypothetical nature of the questions asked and the unfamiliarity of the task often entail superficial answers and symbolic valuation in the form of attitude expression (Kahneman et al. 1999b). Similarly, the problem of strategic behavior can only be addressed to a limited extent. The LSA is not affected by either of these problems. It does not rely on respondents’ ability to consider all relevant consequences of a change in the provision of a public good. In fact, people might not even consciously notice that there is a relationship between environmental conditions like fine particulate matter in an urban region and their subjective well-being. It suffices if they state their own life satisfaction with some degree of precision. This considerably reduces subjects’ cognitive burden and costs of information processing. Moreover, there is no reason to expect strategic behavior because the connection between life satisfaction and the environmental good is made ex post by the researcher. One might argue that a respondent exposed to a negative externality, anticipating that his or her reported life satisfaction is used

to value the externality, strategically reports an overly low life satisfaction. While theoretically possible, this problem is most likely to be of minor importance in practice. Life satisfaction data are usually collected for a multitude of purposes and the same data can be used to value a wide array of (environmental) goods. This effectively prevents strategic biases.

Revealed preference methods: Hedonic method (HM)

The HM invokes the assumption of weak complementarity between an environmental good and a private good such as housing and can be used if the former is a qualitative characteristic of the latter. In such a situation, the housing market functions as a market for the environmental good and information on environmental good demand is embedded in the prices and consumption level of housing. House price differentials between locations with different environmental conditions serve as implicit prices for the environmental good. In equilibrium they correspond to the individuals' MWTP for the environmental good (Rosen 1974; Roback 1982).

The main problems of the HM arise from its dependence on the equilibrium assumption. This assumption is only met if there is a sufficiently wide variety of houses, if prices adjust rapidly, if households have full information and if transaction and moving costs are zero.

These conditions are often violated and, consequently, WTP estimates biased. For example, if mobility is costly, the true value of a change in an environmental amenity is greater than the house price effects imply. Consider the case of an exogenous improvement in air quality in a particular region. The cleaner air attracts new residents and, as a consequence, costs of housing rise until a new equilibrium is reached. Without mobility costs, the change in the costs of housing fully reflects the value of cleaner air. However, if migration is costly, a person will only move to the region with improved air quality if the cleaner air compensates him or her for both the higher rents and the cost of moving. In order to estimate the full WTP in presence of migration costs, Bayer et al. (2009) develop an alternative discrete choice approach that models household decision directly and does not rely on the equilibrium condition. They use their approach to value air quality (total suspended particulate, TSP) in the U.S. metropolitan areas in 1990 and 2000. The estimated annual MWTP for the median

household income amounts to between \$309 and \$384 (in 2007 U.S. dollars).⁵ By comparison, the MWTP estimated with the conventional hedonic model is only \$114. Their results suggest, thus, that conventional hedonic models underestimate the WTP for clean air by a factor of around three. In contrast to the hedonic method, the LSA explicitly captures individual welfare in the absence of market equilibria. In the case of public goods for which it is useful to distinguish between expected benefits and materialized benefits and for which the effects on life satisfaction are identified on the basis of the latter, the LSA can recover the full utility consequences independent of the degree of capitalization in the housing and labor market. For all other public goods, compensating variation in the private markets has to be accounted for. If they are not, the LSA captures only the residual effect. These issues are discussed in more detail below. Anticipating one of the main conclusions, the discussion suggests that, if anything, the LSA works best if there is no market equilibrium.

As with mobility costs, incomplete information of households is likely to bias the hedonic estimates downwards. To correctly anticipate the effect of an environmental disamenity such as air pollution at a particular location, a prospective house buyer or renter requires adequate knowledge of pollution risks and adequate information about prevailing pollution levels. Distorted risk perceptions may bias hedonic estimates in either direction since people may underestimate or exaggerate the risk of pollution.⁶ In contrast, incomplete information about prevailing pollution levels invariably attenuates price gradients towards zero (Pope 2008b). Several studies suggest that individuals' information void on location specific amenity levels and the resulting downward bias in hedonic estimates may be large. Brookshire et al. (1985) and Troy and Romm (2004) find no price discounts for properties in areas with elevated risks of earthquakes and flooding before laws have been passed that require sellers of property to disclose information on earthquake and flood risks, but large and significant price discounts thereafter. Similarly, Pope (2008a) finds the introduction of mandatory disclosure requirements to increase the marginal valuation of airport noise by 37%.

Distorted perceptions are of particular importance for the capitalization of health effects. Smith and Huang (1995) provide evidence consistent with the notion of incomplete

⁵ Bayer et al. (2009) report their results in 1982-1984 U.S. dollars. The figures have been transformed to 2007 U.S. dollars using the CPI for all urban consumers (CPI-U) of the Bureau of Labor Statistics.

⁶ For example, McCluskey and Rausser (2001) show that risk perceptions and consequently hedonic price gradients are importantly influenced by newspaper coverage.

capitalization of health effects. Benefit estimates for improvements in air quality in selected US cities based on dose-response functions and value of statistical life estimates are at least four times higher than benefit estimates based on hedonic studies. Smith and Huang (1995, p. 223) conclude that “hedonic models are more likely to reflect aesthetics, materials and soiling effects, and, to some degree, perceived health effects, but the latter may well be incomplete.” Moreover, reduced mortality risk is only one benefit of clean air. Reduced risk of morbidity, both chronic diseases and minor symptomatic discomforts, reduced material damages and improved visibility are other benefits.

A conceptual problem of revealed preference methods is that individuals’ behavior in private markets always reflects expected future risks (even if expectations are based on current or past risks). In contrast, in most applications of the LSA, the welfare consequences of risks are primarily identified on the basis of actual events, i.e. when the risk materializes. The LSA is, therefore, less affected by distorted risk perceptions. As mentioned above, the LSA can also capture effects of externalities that affect individuals’ life satisfaction through a process unnoticed by the individuals themselves. For example, it can capture the welfare consequences of health effects even if individuals are ignorant about the causes. Moreover, most survey respondents are long-term residents in a particular location and they are arguably better informed about prevailing pollution levels than prospective house buyers and renters who consider moving to that location. This is not to say that perceptions are irrelevant for the LSA. To the extent that perceptions of local pollution levels as such enter individual welfare judgments, distorted risk perceptions affect life satisfaction estimates as well. However, the above discussion suggests that distorted perceptions are more important for the hedonic method than for the LSA.

Utility misprediction and valuation

The standard methods are also challenged by the systematic divergence of two basic concepts of utility. The traditional axiomatic approach in economics holds that the choices made by individuals provide all the information required to infer the utility of outcomes. People, on average, correctly predict how they value some outcome. This first concept of utility is the basis for the revealed preference methods for valuing the environment. The same presumption with regard to the accurate prediction of utility is also underlying stated preference methods. There is now more and more evidence in both, hypothetical and real markets, that individuals mispredict their future feelings (Kahneman and Thaler 2006; Frey

and Stutzer 2008). This undermines a tenet of the revealed preference approach. Utility misprediction is due to a combination of incorrect intuitive theories about the determinants of happiness, incorrect beliefs regarding the speed and degree of adaptation, a difference in saliency of various aspects between the moment of prediction and the moment of experience and a focusing illusion (for a discussion of these effects in the specific context of the CVM, see Loewenstein and Schkade 1999; Kahneman and Sugden 2005; Dolan and Kahneman 2008). Moreover, these deviations and discrepancies are most likely in complex decisions with long-term trade-offs (Camerer et al. 2005), i.e. nearly all decisions of policy relevance. Therefore, the second utility concept underlying the LSA emphasizes individuals' judgments of experiences *ex post* as for example reflected in measures of reported life satisfaction. With this concept, valuation of alternatives are expected to be less biased by systematic prediction errors.

Relationship between the HM and LSA

There is some disagreement in the literature about the relationship between the HM and the LSA and about what effects of environmental quality can be identified with the LSA. While some compare estimates based on the HM with estimates based on the LSA and, thus, implicitly or explicitly see the two methods as substitutes that measure the same thing (e.g., Dolan and Metcalfe 2008), others argue that the methods are complementary and the estimates from the two methods have to be combined (van Praag, Bernard M. S. and Baarsma 2005; Luechinger 2009b). The intuitive explanation underlying the second position is that – according to the premise of the hedonic method – people exposed to negative externalities are compensated in the housing market. The markets compensate people for the costs of self-protection measures, for the costs of locally financed public measures as well as for any direct utility costs associated with these measures, for higher risk premiums for insuring themselves against damages as well as for all non-insurable and non-avertable losses. Therefore, this compensating variation has a countervailing effect on individual welfare. In the market equilibrium, rents must adjust to equalize utility across locations. Otherwise, some individuals would have an incentive to move (Roback 1982). If the equilibrium assumption holds and people are fully compensated, we would find no effect of an environmental disamenity on life satisfaction in a life satisfaction regression with the environmental disamenity as an explanatory variable. However, as discussed above, migration costs and

informational asymmetries may prevent full capitalization in particular in the short run. It is these residual shadow costs of environmental conditions that are captured with the LSA.

So far, the discussion refers to cross-section analyses but the same argument can be made for panel analyses.⁷ Utility will be equalized across regions at every point in time but not necessarily across time. However, changes over time will usually be captured by time specific effects. Thus, also with panel data, only the residual effect can be captured. Of course, in a panel setting, the focus is on changes in environmental conditions. Compensation of these changes is likely to be less pronounced and the residual effect may capture a great part of the overall effect. Nevertheless, conceptually, it is still a residual effect and the two methods remain complements.

An exception are environmental conditions for which it is useful to distinguish between expected benefits or costs and materialized benefits or costs, i.e. environmental risks such as the risk of flooding. In the case of risks, compensating variation in the housing market is based on expected risks. If the underlying probabilities are stable, the compensating variation is captured by region-specific effects. By the same token, all utility costs of insurance, protection measures and self-protection measures are reflected in the fixed-effects. In applications of the LSA with panel data, the effect of risks is accordingly identified on the basis of actual events, i.e. if the risk materializes. Therefore, the full utility losses or, more precisely, the full non-insurable and non-avertable losses can be recovered. In this situation, the hedonic method and the LSA are substitutes.

5. Applications

The LSA can be used to value a wide range of different public goods and bads, negative and positive externalities. Not claiming comprehensiveness, the LSA has been used to value climatic conditions (Frijters and van Praag 1998; Rehdanz and Maddison 2005; Becchetti et al. 2007; Brereton et al. 2008), airport noise nuisance (van Praag, Bernard M. S. and Baarsma 2005), proximity to infrastructure (Brereton et al. 2008), urban regeneration schemes (Dolan and Metcalfe 2008), droughts (Carroll et al. 2009), floodings (Luechinger and Raschky

⁷ A complicating issue which is not considered here is that the standard hedonic theory describes the housing market equilibrium at a single point in time and is, thus, inherently cross-sectional. Panel analyses do not, in general, allow researchers to identify the MWTP (Kuminoff and Pope 2009).

2009), crime (Cohen 2008) and terrorism (Frey et al. 2009). However, as with the HM, the most widely studied environmental disamenity is air pollution.

Air pollution was the object of interest already in the first application of the HM to the valuation of a public goods (Ridker and Henning 1967). By the mid 1990s, the number of studies allowed for a meta-analysis: Smith and Huang (1995) identified 86 MWTP estimates for a reduction in TSP in 37 different studies (the median MWTP was \$46, the mean \$228 in 2007 U.S. dollars).⁸ Still today many methodological innovations are exemplified for the case of air pollution (Chay and Greenstone 2005; Bayer et al. 2009). This interest in air pollution is shared by the growing number of LSA studies. Up to date, at least seven studies focused on air pollution. This may be explained by the fact that air pollution belongs to the long-standing environmental concerns and was the focus of the earliest and most significant environmental regulations. While for some countries and air pollutants the situation improved, the situation in other countries, especially developing countries, and for other air pollutants deteriorates.

Table 1 summarizes the seven LSA studies on air pollution. It reports the source and structure of the survey data used, the spatial resolution, the time period, the included pollutants and main control variables along with MWTP estimates (all estimates are in 2007 U.S. dollars). Most studies report the results for several specifications. The table summarizes the results from the baseline regression. If several specifications are presented as baseline regressions, the results of the most complete or comprehensive model are presented in the table. Similarly, if studies contained baseline regressions with the pollutants included individually and baseline regressions with the pollutants included jointly, the reported estimates are based on the latter regressions. Further, only statistically significant estimates are shown. Despite their shared focus on air pollution, the diversity in terms of considered pollutants, countries or regions and time periods as well as methodology, renders futile any attempt to synthesize their results into a summary statistics. The review of the studies rather serves to exemplify methodological aspects that pertain to the LSA literature more generally.

The structure of the survey data is a first difference between the studies. While most studies use repeated cross-section data, two studies use cross-section data (Welsch 2002; MacKerron

⁸ Smith and Huang (1995) report their results in 1982-1984 U.S. dollars. The figures have been transformed to 2007 U.S. dollars using the CPI for all urban consumers (CPI-U) of the Bureau of Labor Statistics.

and Mourato 2009). It is clear that the inability to control for unobserved spatial heterogeneity that is correlated with air pollution makes cross-section estimates more prone to omitted variable bias and, most likely, more sensitive to changes in the specification. For example, in Welsch (2002), the effect of nitrogen dioxide (NO_2) falls below conventional levels of significance if the number of scientists is excluded from the set of controls. Only one study uses individual panel data (Luechinger 2009b). While controlling for individual heterogeneity may be less important to correctly estimate the effect of pollution, it has substantial effects on the estimates of the effect of personal characteristics such as income (Ferrer-i-Carbonell and Frijters 2004). This is important because the coefficient for income feeds in the calculation of the benefit estimates in monetary terms.

Another difference across studies is the spatial resolution at which the survey data and the pollution data are merged. Most studies use country or country-year averages of pollution levels (Welsch 2002; 2006; Di Tella and MacCulloch 2007; Luechinger 2009a). To the extent that the country averages do not well represent respondents' experienced degree of exposure to pollution where they live, the estimated effect of pollution on life satisfaction is attenuated towards zero.⁹ This problem can be addressed by using pollution data with a higher spatial resolution such as the county or ZIP-code level (Levinson 2009; Luechinger 2009b; MacKerron and Mourato 2009). The relevance of the attenuation bias is ultimately an empirical issue and will differ across settings. While for some pollutants and time periods the large cross-country and temporal variation may dwarf within country differences, for other settings the bias is likely to be more severe.

Levinson (2009) extends the logic of the argument above to the issue of temporal resolution. While in the spatial case a higher resolution is generally desirable, this may not be true in the temporal case. The appropriate degree of temporal resolution depends on the channels through which pollution is likely to affect life satisfaction. On the one hand, if air pollution affects subjective well-being mainly through adverse health consequences, material damages and the like, measures capturing longer term exposure are relevant and, thus, longer term measures such as annual mean concentrations are more appropriate than short term measures. On the other hand, if aesthetics effects such as reduced visibility are the most important

⁹ In the Di Tella and MacCulloch's (2007) study, this problem is aggravated by the fact that they use sulfur oxide (SO_x) emissions instead of sulfur dioxide (SO_2) concentration as measure of air pollution. Since a large part of SO_x pollution is transboundary, emission and pollution levels can differ greatly.

channel, short term measures may be better suited. Empirically, however, high peak concentrations and high annual mean concentrations will often go together and, hence, the choice of temporal resolution will be of minor importance.

Even if repeated cross-section and panel data allow researchers to control for time-invariant spatial heterogeneity, estimates of pollution benefits are still prone to severe omitted variable biases: Local air pollution is likely to be highly correlated with unobserved local economic activity. In their HM analysis on the costs of TSP pollution, Chay and Greenstone (2005) provide evidence that supports this conjecture. Conventional MWTP estimates often have a perverse positive sign or are at best economically small and statistically insignificant. In contrast, MWTP estimates based on IV regressions range between \$176 and \$315 (2007 U.S. dollars).¹⁰ In order to address this simultaneity problem, two of the studies in Table 1 use exogenous changes in air pollution to identify the effect of air pollution on life satisfaction. Luechinger (2009b) exploits the natural experiment created by the mandated scrubber installation at German power plants together with wind directions dividing counties into treatment and control groups. Luechinger (2009a) instruments a country's air pollution with the long-range transboundary air pollution caused by emissions in foreign countries. As can be seen from Table 1, MWTP estimates based on IV regressions are higher compared to the conventional estimates in both studies.

With the LSA it is straightforward to go beyond estimating average effects. Several studies report differentiated effects for different subgroups of the population such as predicted risk groups, the elderly or environmentalists (Levinson 2009; Luechinger 2009b; a). On the one hand, these differentiated effects can serve as a robustness and plausibility check. On the other hand, differentiated effects can provide valuable information for policy makers and can help to understand the intensity of support for public good provision in the political process.

6. Concluding remarks

Based on our review of the LSA, concluding remarks in three directions are drawn. First, we derive some implications for research on subjective well-being and non-market valuation in

¹⁰ Chay and Greenstone (2005) report their results in 1982-1984 U.S. dollars. The figures have been transformed to 2007 U.S. dollars using the CPI for all urban consumers (CPI-U) of the Bureau of Labor Statistics.

economics. Second, we raise the issue whether the effects of public goods on life satisfaction should be monetized. Finally, some proposals for future research are raised.

The LSA and economic research on subjective well-being

The LSA emphasizes public goods and externalities as determinants of individual welfare and thus complements our understanding of people's preferences as derived from research on subjective well-being in economics. For a further successful application, we discussed six requirements subjective well-being measures should meet. These requirements though are important for empirical happiness research in general as they are (i) validity, (ii) inclusiveness, (iii) reference to presence, (iv) sufficiently high signal-to-noise ratio, (v) interpersonal (or intergroup) comparability, and (vi) availability.

It was the aim of this review to convince the reader that subjective well-being data can be used to value public goods and, hence, that the LSA expands the economists' toolbox in the area of non-market valuation. This same approach also allows researchers to test the underlying assumptions of the standard non-market valuation techniques. For example, the negative relationship between life satisfaction and air pollution indicates that air pollution is incompletely capitalized. Thus, the hedonic method understates the value of clean air. However, the problem of undercapitalization is likely to be more severe for externalities which are rapidly changing and which have important indirect effects than for stable and salient risks.

Monetization?

Does the LSA overshoot when monetizing the value of environmental conditions? The standard argument for monetization of externalities and public goods is that money is a convenient measuring rod that allows decision makers to compare various benefits and costs. However, it has long been recognized that WTP for a change in public good provision is an imperfect approximation for the effects of the change of overall welfare because of the wealth effects and the variable marginal utility of income or, in other words, because of the diminishing marginal utility of income. Suppose, for example, that a public project benefits the poor but hurts the rich. Such a project may increase aggregate welfare even though the sum of individual WTP is negative. Further, if public goods are monetized with the LSA, estimates on the effect of income on life satisfaction play a crucial role. Unfortunately, estimating the effect of income on life satisfaction is associated with serious problems, most

importantly endogeneity and omitted variable problems (Clark et al. 2008). This may well speak in favor of subjective well-being scores as an alternative non-monetary scale.

However, several counterarguments speak in favor of monetization. First, many costs naturally accrue in monetary form, e.g. if compliance costs decrease firms' profits and increase consumer prices. Converting monetary figures into life satisfaction scores is associated with exactly the same potential problems as the reverse operation. Second, in many situations, the LSA is complementary to the standard techniques and captures the residual shadow benefits only. In these situations, WTP estimates based on different methods have to be summed up in order to calculate the total shadow benefits of a public good. Third, for some potential uses of the LSA, welfare effects ultimately have to be expressed in monetary terms. An example are tort cases. Fourth, a large body of literature exists that contains a wealth of information on people's WTP for public goods. For academic curiosity and for practical purposes, one might want to compare estimates based on the LSA to these WTP estimates.

We recommend that studies using the LSA offer both: effect sizes in terms of subjective well-being scores (together with exact information on the subjective well-being question, the mean response and the standard deviation in the sample) and in monetary terms. Effects in terms of subjective well-being can then later be combined with state of the art findings for the effects of monetary transfers on individual welfare.

Future research

We see two areas that warrant further research in the future. First, important insights will be gained by additional comparisons of the LSA with the standard methods. For example, subjective well-being data would allow us to test the crucial assumption of the travel cost approach that traveling to a recreational site provides no direct utility or disutility. Or, they could be used to quantify the non-pecuniary costs of defense and prevention behavior that is relevant for the defense expenditure approach. The second area for future research relates to improvements of the LSA. One major issue in this respect is a need for better estimates of the effect of income on life satisfaction. So far, estimates based on exogenous changes in income are rare. It has to be realized that many correlates in subjective well-being are actually choice variables and choices involve trade-offs. Thus, it should be no surprise if – at least at the margin – the raw effect of the choice variable on life satisfaction is small. Another issue

concerns the subjective well-being measures. We argued that existing measures of subjective well-being, particularly global self-reports of life satisfaction, are well suited for the purpose of valuing public goods. Yet there is still the concern that these measures and the estimates based thereon are systematically biased because of conceptual problems and contextual factors such as question order effects and the lack of intergroup comparability. The LSA would greatly benefit if these problems were taken seriously in the development of the next generation of subjective well-being measures.

In sum, there is still room for improvement and many of the questions raised in this review remain unanswered. However, if we convinced the reader that the LSA can be potentially used to value public goods and that it is worthwhile to address the open issues, we have achieved our aim.

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Table 1. Summary of LSA studies valuing air quality

Study	Data, structure, spatial resolution and period	Air pollution indicators	Controls	MWTP
Welsch 2002	Various sources, cross-section, 54 countries (dependent variable is country average of happiness), early and mid 1990s	TSP, SO ₂ and NO ₂	Water pollution and other economic and societal variables	NO ₂ : \$113
Welsch 2006	Eurobarometer, repeated cross-section, 10 European countries (dependent variable is country-year average of life satisfaction), 1990-1997	TSP, NO ₂ and Pb	GNP per capita as well as country and year effects	Pb: \$184
Di Tella and MacCulloch 2007	Eurobarometer and GSS, repeated cross-section, 12 OECD countries, 1975-1997	SO _x emissions per capita	Personal characteristics, life expectancy, crime rate and other economic and societal variables as well as country and year effects	SO _x : \$171
Levinson 2008	GSS, repeated cross-section, approx. 300 US counties, 1973-1996 (with gaps)	PM10; in separate regressions also SO ₂ and CO	Personal characteristics, temperature and precipitation, region, year and month effects	PM10: \$896
Luechinger 2009a	Eurobarometer, repeated cross-section, 13 European countries, 1979-1994	SO ₂ , conventional and IV-estimates	Personal characteristics, macro-economic variables as well as country and time effects	SO ₂ : \$157 SO _{2, IV} : \$324
Luechinger 2009b	GSOEP, individual level panel, approx. 450 German counties, 1985-2003	SO ₂ , conventional and IV-estimates	Personal characteristics, county characteristics, county, state specific time trends as well as time and individual effects	SO ₂ : \$200 SO _{2, IV} : \$340
MacKerron and Mourato 2009	Own web survey for London, cross-section, ZIP-codes of 400 respondents, 2007	NO ₂	Personal characteristics, attitudes and perceptions, distance from major road and city centre	NO ₂ : \$8,296

General notes: (1) Most studies present the results of different specifications. The table summarizes the results from the baseline regression. If several specifications are presented as baseline regressions, the results of the most complete or comprehensive model are presented in the table. (2) The results reported in the studies have been transformed to 2007 U.S. dollars with the CPI for all urban consumers (CPI-U) of the Bureau of Labor Statistics and annual exchange rates where necessary. (3) MWTP estimates refer to a reduction of 1 $\mu\text{g}/\text{m}^3$ of the respective pollutant. Exceptions are the MWTP estimates for lead (Pb) and sulfur oxide (SO_x) emissions. For Pb, the MWTP refers to a reduction of 0.01 $\mu\text{g}/\text{m}^3$ since Pb concentrations are around 100 times lower compared to the concentrations of other pollutants. For SO_x emissions MWTP refers to a reduction of 1 kg per capita.