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Environment, Well-Being, and Experienced Preference

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Environment, Well-Being, and Experienced Preference

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Recent years have seen a sharp increase in the use of subjective well-being data in environmental economics. This article discusses the conceptual underpinnings of using such data as a tool for preference elicitation and non-market valuation. Given the connection of those data to the notion of experienced utility, we refer to this approach as the experienced preference method and discuss recent methodological advances and applications of the approach to subject areas not previously reviewed. In addition, we discuss insights concerning environmental behavior that can be gained with the help of subjective well-being data.

1. Introduction

In recent years economists have increasingly used data on subjective well-being to study the consequences for human welfare of economic and social phenomena. As noted by Levinson (2013), the number of peer-reviewed economics articles referencing well-being, happiness or life satisfaction quadrupled from 153 to 651 in 2001-2011, and the proportion in the total number of articles indexed by EconLit doubled.

While large portions of this literature are concerned with economic variables in the narrow sense – such as income and unemployment – institutions and public goods or bads have also received considerable attention in these works. In particular, environmental quality and environment-related events have been matters of concern, and the relevant literature, though small, has seen an even more rapid expansion than the economic well-being literature overall. While 4 papers were published in journals indexed by the ISI Web of Science Journal Citation Reports in 2002- 2005, the number increased to 13 in 2006-2009, and 22 in 2010-2013.[1]

Explicitly or implicitly, an aim of practically all of those papers has been the elicitation of environmental preferences and the monetary valuation of environmental goods. As it will be discussed below, the conceptual underpinnings of this method of preference elicitation rest on the notion of "experienced utility", whereas the more conventional revealed and stated preference methods are closely connected to "decision utility". To highlight this

[1] A subset of those articles is indexed by EconLit. The corresponding numbers are 3 in 2002-2005 and 16 in 2010-2013.

distinguishing feature of preference elicitation by means of happiness or life satisfaction data, we will refer to this approach as the *experienced preference method* (EPM).[2]

The literature that we discuss is concerned with global self-reports of subjective well-being (SWB), as opposed to well-being in specific life domains (e.g. financial well-being). The concept of SWB encompasses both happiness and life satisfaction, where the former primarily refers to the affective and the latter to the evaluative aspect of SWB. Happiness data and life satisfaction data are usually highly correlated with each other, and using one or the other in economic analysis typically yields the same qualitative insights (see, e.g., Frey and Stutzer 2002). Economists mostly use the terms SWB, happiness, and life satisfaction interchangeably, and we follow this practice unless stated otherwise.

Though the use of subjective well-being data in environmental economics is a relatively new area of research, there exist at least three previous survey papers on this subject (Welsch and Kühling 2009, Frey et al. 2010, MacKerron 2012). In addition, important methodological aspects were discussed in Ferreira and Moro (2010) and Levinson (2013), whereas Smith (2008) offers a critical view on this literature. Against this background, this paper contributes in the following ways. First, we offer a discussion of the theoretical underpinnings of this new method of preference elicitation and its conceptual relation to other approaches. Specifically, we introduce a general utility-theoretic framework for non-market valuation which allows us to put the EPM in perspective and to compare it with other preference elicitation methods (Section 2). Second, we discuss advances and extensions of the empirical methodology used. We describe how recent EPM studies have improved over early studies by refining the spatial and temporal matching of environmental conditions to well-being data at the level of the

[2] The terminology up to this point has been inconsistent, referring to the happiness approach (Welsch and Kühling 2009), or the life satisfaction approach (Luechinger 2009, Luechinger and Raschky 2009, Frey et al. 2010).

individual (Section 3). Third, we describe applications to subject areas not previously surveyed. These include land use, energy supply systems, and natural disasters (Section 4). Fourth we discuss lessons from well-being research concerning environmental behavior. These refer to the hedonic spatial equilibrium model and the hypothesis of utility-maximizing environmental consumer choice (Section 5). We conclude by indicating directions for future research (Section 6).

2. Non-Market Valuation

In contrast to marketable goods, whose value can be inferred from observed market data under some mild assumptions, the public-good characteristics of many environmental goods prevent their value from being identified directly from observation. Since environmental valuation constitutes a basic ingredient to the benefit-cost analysis of environmental policy, researchers and environmental agencies use a number of standard tools for non-market valuation. In this section, we discuss the conceptual underpinnings of non-market valuation and the relationship between the various methods employed.

2.1 Experienced Utility as a Standard of Valuation

In an influential paper entitled "Back to Bentham?" Kahneman et al. (1997) introduced the distinction between decision utility and experienced utility, which will be important for putting non-market valuation techniques in perspective. These concepts can be defined as follows.

Definition 1. Experienced utility is the ex post hedonic quality associated with an (economic) outcome. Decision utility describes the ex ante expectation of experienced utility.

Experienced utility thus entails a retrospective (or contemporaneous) assessment of outcomes whereas decision utility involves a prospective assessment. Ideally, decision utility and experienced utility would coincide, but evidence from behavioral economics casts doubt on the general validity of their equivalence. Specifically, deviations between decision utility and experienced utility (and the associated decision errors) may arise because of failures in affective forecasting, that is, in figuring out the utility consequences of one's choices (Loewenstein and Adler 1995, Loewenstein and Schkade 1999, Loewenstein et al. 2003, Wilson and Gilbert 2003).[3]

Based on the concepts of decision utility and experienced utility, a natural definition of economic value follows.

Definition 2. The value of a good is its contribution to experienced utility.[4]

Different non-market valuation methods capture the value of environmental goods in different ways. Revealed and stated preference methods generically refer to decision utility. For instance, people's willingness to pay for a given house – which reveals their valuation of the associated environmental amenities – depends on their expectations as to how those amenities will affect their utility. Likewise, people's stated willingness to pay for a hypothetical improvement in environmental conditions depends on their expectations of the

[3] From the point of view of standard economics, an additional reason for decision utility to deviate from experienced utility is that at the time a decision is taken individuals may be imperfectly informed about the (objective) characteristics of the choice alternatives (goods). Implications of utility misprediction with regard to environmental behavior will be discussed in subsection 5.2.

[4] Kahneman and Sugden (2005) argue that goods have value by virtue of their capacity to create pleasurable affect states. This view is consistent with the subjective theory of value of, e.g., Jevons and Menger, which implies that the value of a thing reflects the utility or enjoyment experienced by the individual. While this assumption may be questionable in some cases of pure existence value, experienced utility can be considered a source of value for most environmental goods.

utility consequences of that improvement. To capture the value of non-market goods, both revealed and stated preference methods thus require that individuals are able to accurately predict the utility implications of (actual or hypothetical) choices.

Non-market valuation using SWB data, conversely, does not rely on choices, but on the statistical association between individuals' SWB and indicators of environmental quality. Provided that reports of SWB are good proxies for experienced utility (see subsection 2.3), we propose to refer to non-market valuation using well-being data as the *experienced preference method* (EPM).

The immediate *conceptual* conformity to Definition 2 should, of course, not be construed to imply *practical* superiority of the EPM. Practical strengths and weaknesses of the main revealed and stated preference methods and the EPM will be discussed in subsection 2.4.

2.2 A Framework for Non-Market Valuation

In this subsection we present a general framework for non-market valuation. Since this framework is intended to formally encompass several particular valuation methods, for simplicity it disregards the possibility that decision utility deviates from experienced utility.

Consider an economy with one environmental good and two marketable goods, housing and a numeraire. An individual derives utility from those three goods. Her indirect utility function specifies the maximum utility she can attain by allocating income optimally to the marketable goods at a given housing price. The indirect utility function takes the following form:

$$u = v(p, y, q), \qquad (1)$$

where p, y and q denote the price of housing, income, and the quantity of the environmental good (level of environmental quality), respectively. The indirect utility function is decreasing in the first and increasing in the second and third argument.

The hedonic model assumes that houses are heterogeneous in terms of the environmental quality prevailing in the places where they are located and that the price of housing is an increasing function of environmental quality: $p = p(q)$. It also assumes that wages (and thus income) decrease in environmental quality: $y = y(q)$. Substituting these relationships in (1) gives

$$u = v(p(q), y(p), q)\,. \tag{2}$$

In addition, the hedonic model assumes that people choose their location in such a way as to balance the benefit from better environmental quality against the cost of more expensive housing and lower income. Under the appropriate concavity conditions this implies the spatial equilibrium condition

$$\frac{dv}{dq} = \frac{\partial v}{\partial p}\frac{dp}{dq} + \frac{\partial v}{\partial y}\frac{dy}{dq} + \frac{\partial v}{\partial q} = 0 \tag{3}$$

The hedonic model thus predicts that in spatial equilibrium the net marginal utility of environmental quality, dv/dq, is zero. Net marginal utility of environmental quality is composed of gross marginal utility, $\partial v/\partial q$, plus the marginal disutility from higher housing prices in cleaner places, $(\partial v/\partial p)*(dp/dq)$, and the marginal disutility from lower income, $(\partial v/\partial y)*(dy/dq)$. In spatial equilibrium, the latter two exactly offset the former.

An important message from this discussion is that the EPM and the hedonic model are conceptually consistent with each other. While the latter attempts to measure the value of environmental amenities in an indirect way, through the disutility from higher housing prices and lower wages, the former aims at a direct measurement of the utility from environmental quality. In spatial hedonic equilibrium, both can yield the same result: $\frac{\partial v}{\partial q} = -\frac{\partial v}{\partial p}\frac{dp}{dq} - \frac{\partial v}{\partial y}\frac{dy}{dq}$. If, however, the spatial equilibrium condition fails to be satisfied, results may differ. Specifically, environmental quality may be incompletely capitalized in housing or labor markets. In that case, results from hedonic pricing studies may be inappropriate as standards against which to assess the "plausibility" of EPM results.[5]

As regards stated preference methods, their conceptual background may be considered to be the same as in equation (1), but the practical way of eliciting the (monetized) utility of non-market goods is different (see subsection 2.4).

The discussion up to this point has been in terms of utility. To convert the marginal utility-value of the environmental good into monetary units, it must be divided by the marginal utility of income. This yields the marginal utility-constant monetary value of the environmental good, that is, the marginal rate of substitution (MRS) of income for the environmental good:

$$MRS = \frac{\partial v / \partial q}{\partial v / \partial y}. \qquad (4)$$

[5] By using SWB data as a proxy for utility, in principle, it is possible to check the spatial equilibrium condition $dv/dq = 0$ or its analog for non-marginal instead of marginal differences in environmental quality, $\Delta v / \Delta q = 0$, that is, the proposition of equality of utility across locations in spite of differences in environmental quality (see subsection 5.1 below).

The MRS represents the amount of income necessary to compensate people for a marginal increase in environmental quality while keeping utility constant. Diagrammatically, the MRS is the slope of an indifference curve at a given (y, q) configuration, as illustrated in Figure 1. With strictly convex indifference curves, the MRS depends on the point of measurement and can be large at large values of y / q (see, e.g., point D in Figure 1).

If non-marginal changes in environmental quality are to be valued, the compensating variation *CV* and the equivalent variation *EV* can be used. The compensating variation is the amount by which – *ex post* of an environmental improvement – income would need to be reduced to fix utility at its *ex ante* level, that is $v(p, y, q) = v(p, y - CV, q + \Delta q)$. The equivalent variation is the amount by which income would need to be raised to attain the level of utility *ex post* of an environmental improvement – did the improvement not take place: $v(p, y, q + \Delta q) = v(p, y + EV, q)$.

CV and *EV* are illustrated in Figure 1. For an environmental improvement that takes the individual from point A to B, we have *CV* = F – E and *EV* = G – F. As shown by, e.g., Johansson (1987) and illustrated in Figure 1, strictly concave indifference curves imply *EV* > *CV*, and *EV* is theoretically unbounded.[6]

2.3 The Experienced Preference Method

Application of the EPM involves using survey data on SWB as a proxy for the right-hand side variable in equation (1), that is, for experienced utility *u*, and specifying and estimating the indirect utility function *v*(.).

The survey questions pertaining to SWB may refer to "happiness" or to "life satisfaction", and the categories may be purely verbal or may combine verbal with numerical features. For

[6] The concepts of *CV* and *EV* can likewise be applied to environmental deteriorations. In this case, the *CV* is unbounded.

instance, the *General Social Surveys* use a three-point verbal happiness scale. It asks the question: "Taken all together, how would you say things are these days – would you say that you are very happy, pretty happy, or not too happy?" In the *World Values Surveys*, people are offered a scale from 1 (dissatisfied) to 10 (satisfied) to respond to the question: "All things considered, how satisfied are you with your life as a whole these days?"

In using SWB data for econometric analysis, some important assumptions have to be imposed on the information content of those data. As discussed by Ferrer-i-Carbonell and Frijters (2004), necessary assumptions are (a) a positive monotonic relationship between SWB and the underlying true utility u (if $SWB_{it} > SWB_{is}$, then $u_{it} > u_{is}$ for individual i at times t and s) and (b) ordinal interpersonal comparability (if $SWB_{it} > SWB_{jt}$, then $u_{it} > u_{jt}$ for individuals i and j). Validation research has produced a variety of supporting evidence of those assumptions (see Diener et al. 1999, Frey and Stutzer 2002, Ferrer-i-Carbonell and Frijters 2004).

Under ordinal comparability an ordered discrete choice model of the following form can be estimated:

$$u_{ilt} = \alpha \ln y_{ilt} + \beta q_{lt} + x_{ilt}'\gamma + \varepsilon_{ilt} \qquad (5)$$

$$SWB_{ilt} = 1 \Leftrightarrow u_{ilt} < \theta_1, \quad SWB_{ilt} = 2 \Leftrightarrow \theta_1 \leq u_{ilt} < \theta_2, \quad \ldots \quad , \quad SWB_{ilt} = K \Leftrightarrow \theta_{K-1} < u_{ilt} \qquad (6)$$

In equation (5), u_{ilt} is unobserved true utility of individual i at location l surveyed on date t. The variables y_{ilt} and q_{lt} are income and environmental quality (at location l and date t), respectively. The vector x_{ilt} comprises the individual's socio-economic characteristics, and possibly location and time fixed effects, and ε_{ilt} is a disturbance term. Equation (6) establishes the association between true utility and SWB. It states that the SWB scores take values 2, …, K (rather than 1) if utility exceeds certain thresholds θ_k, k = 1, …, K-1. The parameters in (5) and the thresholds in (6) are estimated simultaneously.

If, more restrictively than ordinal comparability, it is assumed that $SWB_{it} - SWB_{jt}$ is proportional to $u_{it} - u_{jt}$, SWB can be treated as a cardinal variable.[7] In this case, least squares can be applied to equation (5) with u on the left-hand side being replaced with the respective SWB scores. Ferrer-i-Carbonell and Frijters (2004) and many others found that assuming the data to be ordinal or cardinal and applying the corresponding estimation methods has little effect on qualitative results. In particular, the ratios of coefficients are similar, which is important for monetary valuation. Importantly, individual fixed effects can be included in this case if data availability allows doing so.

Another issue with SWB data is that they are bounded from below and from above. This implies that one can neither observe a decline in SWB if it was in the lowest category in the preceding period, nor an increase if it was in the highest category. A way of addressing this problem is by collapsing the information of SWB variables in two categories (high/low) and applying a binary choice model.

In applications of the EPM it has sometimes been observed that the valuations obtained, that is, the MRS of income for the public good under study, are “too high” (e.g. Frey et al. 2007, Ferreira and Moro 2010), in particular in comparison with results from hedonic pricing studies. As discussed in the preceding subsection, however, hedonic pricing need not capture the full value of environmental quality. In addition, as we also discussed above, being the slope of an indifference curve, the MRS can be large at the point of measurement if the indifference curve is sufficiently convex. A “high” MRS of income for environmental quality can thus arise when environmental quality is poor and should not per se be dismissed as

[7] Cardinality amounts to assuming that the difference between an SWB score of, say, 8 and 9 is the same as the difference between a 4 and a 5 (Ng 1997).

“implausible”. Similar considerations apply to the equivalent variation of an environmental improvement and the compensating variation of an environmental deterioration.

Though expectations as to “reasonable” magnitudes for the value of environmental quality may be misleading, a bias can nevertheless arise from a biased estimate of the marginal utility of income, the denominator of the MRS formula (4). One source of bias can be that income is endogenous and measured with error. In addressing this issue, Powdthavee (2009) finds that the income coefficient in an instrumental-variables specification of the well-being regression is larger than in a least-squares specification, suggesting that equation (4) would otherwise overstate the MRS of income for the environmental good.

In addition to issues of endogeneity and measurement error, it is important to be clear about exactly how to include income and what that implies for the interpretation of results. One important point is that specifications of well-being regressions often fail to control for the disutility from income generation (working hours, commuting and stress) and thus tend to deliver less than the “full” marginal utility of income (Luechinnger 2009).[8] Another relates to relative income effects. Specifically, there exists a large literature which finds that, due to habituation and social comparison, it is income relative to one’s past income and the income of others rather than absolute income which matters for well-being (see Clark et al 2008 for a review).

The findings on relative income effects might suggest to include in the well-being regression not only current own income but also lagged own income and the income of others. Because lagged own income and the income of others affect well-being negatively but are likely to be positively correlated with current own income, omission of those controls is expected to lead to a smaller coefficient on current own income than their inclusion. It is however open to debate whether this constitutes a bias or whether both specifications yield

[8] However, instrumenting income helps address this concern.

meaningful, though different insights: When lagged own income and the income of others are controlled for, the coefficient on current own income captures the short-term private marginal utility of income. When they are omitted, the coefficient on current own income incorporates the negative "internality" of past income and the negative externality of others' income. The coefficient can thus be interpreted as capturing the long-term social marginal utility of income, which is less than the short-term private marginal utility of income (Layard 2006).

Following this reasoning, standard EPM studies, which include only current own income, should be taken as delivering the value of environmental quality in terms of the long-term social value of income, which may be larger than its counterpart in terms of the short-term private value of income.[9] To the extent that individuals fail to account for negative consumption (income) "internalities" and externalities in making (actual or hypothetical) choices (as argued, e.g., by Frank 1985), conventional revealed and stated valuation approaches may be thought of as relying on the short-term private value of income.

2.4 Comparison of Valuation Methods

As discussed in subsection 2.1, the main *conceptual* difference between the standard revealed and stated preference methods and the experienced preference method is that the former relate to decision utility whereas the latter aims at a direct measurement of environmental goods' contribution to experienced utility. In addition, they differ at a *practical* level, and these differences constitute their respective strengths and weaknesses. Since these strengths and weaknesses have been discussed in previous review papers (Welsch and Kühling 2009, Frey

[9] Regarding habituation, Menz and Welsch (2010) experiment with including lagged income and find it to enter negatively and to considerably raise the coefficient on current income. Habituation could, however, affect not only income but also environmental quality, see subsection 3.3.

and Stutzer 2010, MacKerron 2012), we give only a brief account and limit ourselves to the hedonic pricing method and the contingent valuation method as the most important varieties of revealed and stated preference approaches, respectively.

From a methodological point of view, the strength of the hedonic pricing method (HPM) is that it relies on observations of objective data, such as housing prices and wages. In terms of scope, it can potentially capture all effects of environmental conditions that are linked to the location and that are capitalized in housing or labor markets. It is problematic, however, as it relies on assuming equilibrium (optimal) adjustment of market behavior to environmental conditions. The method thus neglects information asymmetries as well as transaction and moving costs which may prevent optimal adjustment.[10] It also presumes perfect functioning of markets, especially the absence of regulation, while in fact regulation is a characteristic of housing and labor markets in many countries. Finally, the hedonic method may be subject to sorting bias, as people most averse to poor environmental conditions choose to live in more favorable locales.[11] A test of the HPM by Ferreira and Moro (2010) finds that the predictions of the HPM are not satisfied in data from Ireland (see subsection 5.1).

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[10] Bayer et al. (2009) show that when moving is costly, the variation in housing prices and wages across locations may no longer reflect the value of differences in local amenities. Controlling for impediments to moving raises their HPM valuation results for particulate matter considerably.

[11] Over the past decade, a new "equilibrium sorting" framework has developed to characterize preference heterogeneity (Kuminoff et al. 2013). In their equilibrium sorting model, Bayer and McMillan (2012) show that as distance to work matters relatively less than other considerations in the household location choice, neighborhood stratification on the basis of local public goods consumption increases.

The contingent valuation method (CVM) rests on subjective data as to the stated willingness to pay (WTP) for or willingness to accept (WTA) for changes in environmental conditions. Its strength is that, in principle, it can be applied to all kinds of environmental conditions and can capture both use and existence values. In practice, however, several issues need careful consideration. In the first place, contingent valuation is concerned with hypothetical changes in environmental conditions. To place a monetary value on such changes presents people with an unfamiliar and cognitively complicated task of affective forecasting which may result in elicitation of attitudes rather than preferences (Kahneman and Sugden 2005). Contingent valuation is subject to framing effects and context effects In particular, it matters whether valuation questions are formulated in terms of WTP for gains or WTA for losses. While the difference should be small according to standard models of consumer choice, behavioral economics has consistently shown that, due to the so-called endowment effect, the valuation of losses is systematically larger than the valuation of gains (Knetsch 2005). Moreover, strategic responses may further widen the gap. Hausman (2012) provides a recent critical discussion of the CVM.

Similar as the CVM, the EPM rests on subjective data, but is cognitively less demanding than the CVM because individuals are not requested to place monetary values on hypothetical environmental conditions. In addition, less knowledge on the physical effects of those conditions is required than in both the HPM and CVM. In fact, the EPM is able to capture all effects of environmental conditions (ranging from non-monetized health to aesthetic values, ecological effects, altruism, consequences of correlated pollutants, and income losses), even though the individual may not be consciously aware of them. For instance, exposure to nuclear radiation can damage health through a process unnoticed by the people, but which nevertheless affects subjective well-being. The main weakness of the EPM is the assumption of (ordinal) interpersonal comparability of utility, as discussed above. In addition, the measurement of utility using reported well-being involves measurement error. Identification of the relationship between utility and environmental conditions may be biased if measurement error is correlated with those conditions (Bertrand and Mullainathan 2001). Similar to the HPM, the EPM may be subject to sorting bias as individuals can move according to their environmental preferences; and similar to the CVM it may be subject to framing and context effects as SWB data are gathered in surveys. Smith (2008) provides a critical discussion of the EPM.

3. **Methodological Advances**

In relation to studies reviewed in earlier survey articles on the EPM, there have been advances with respect to methodology, and growth in the areas of application. This section is concerned with methodological advances. They mainly refer to the spatial and temporal resolution of the data and the matching between the well-being and environmental quality data.

3.1 First-Generation Studies

We start with a brief account of some early EPM studies. They are characterized by using indicators of environmental quality and SWB at the country or country-year level. Using average SWB (by country or country-year) as the dependent variable implies assuming cardinality of the underlying individual-level well-being data. An advantage of this approach is that averaging SWB eliminates the problem of unobserved heterogeneity of individuals within countries or country-years. Unobserved heterogeneity between countries and years can be captured by country and year fixed effects. Country fixed effects control for unobserved between-country heterogeneity, while year fixed effects control for year-to-year heterogeneity. The main disadvantage of this approach is that the way environmental conditions are captured is crude: Only their cross-country and year-to-year variation is used as a source of identification; any regional, within-country variation is neglected.

An early EPM paper by Welsch (2002) studies the impact of air pollution (average levels of ambient sulfur dioxide, nitrogen dioxide, and total suspended particles) on country-average happiness for a cross-section of 54 countries around 2000. He finds that larger nitrogen dioxide concentrations are statistically associated with lower average happiness and translate into considerable monetary values.[12] Welsch (2006) addresses the problem of unobserved between-country heterogeneity by using country and year fixed effects in a panel comprising annual data (1990-1997) for 10 European countries. He finds that nitrogen dioxide and lead are both negatively and significantly related to average life satisfaction.

Rehdanz and Maddison (2005) study the relationship between SWB and climate for a panel of 67 countries in the 1990s. They control for between-country heterogeneity by means of social and macroeconomic indicators (such as life expectancy, literacy rate, religion, unemployment, inflation etc.) but do not include country or year FE in their regressions. They find that a country's average happiness is significantly raised by higher minimum temperatures and reduced by higher maximum temperatures as well as by an increased frequency of dry conditions.

3.2 Spatial Resolution

As noted above, using mean SWB and mean environmental quality indicators at the country level has the advantage that unobserved heterogeneity across individuals is evened out. However, SWB and environmental quality levels are assessed only on an aggregated scale. Ideally, data on environmental conditions would be matched to happiness data at the spatial level of disaggregation at which individuals actually experience their surroundings. This can

[12] We abstain from reporting and commenting on monetary values of environmental conditions if previous review papers (Welsch and Kühling 2009, Frey et al. 2010, MacKerron 2012) have already done so.

be facilitated by the use of geographical information systems (GIS), for example to define buffers around point data or to measure distances between points. In the case of climate or pollution data, in order to match the readings from a limited number of monitoring stations to individual SWB data, spatial interpolation techniques (such as kriging or inverse distance weighting) can be applied to the available data to provide climate or environmental quality information between monitoring stations. Alternatively, when possible, air pollution models can be used to model the dispersion of pollutants.

In one of the first applications of GIS analysis to happiness studies, Brereton et al. (2008) find that the explanatory power or their life-satisfaction regression for Ireland substantially improves after accounting for environmental amenities. By controlling for a broad range of spatial variables, they reduce the risk of omitted variable bias, present in studies that focus on only one amenity. The matching between individual happiness data and spatial amenities in their study is at the Irish electoral district level (ranging between 17 and 6,189 ha). A more precise matching of environmental amenities to individual data is done at the zip-code area level in Van Praag and Baarsma's (2005) study of aircraft noise around Amsterdam Schiphol airport. They find that although individuals' experienced noise nuisance is negatively related to SWB, direct noise measures are not significant.[13] MacKerron and Mourato (2009) also use the postcode to match annual average concentrations of nitrogen dioxide (which is found to have a large negative impact) and PM10 to individual life satisfaction in their convenience sample of Londoners.

Although data at the zip-code level are generally not available, practically all the recent (post 2008) studies that have analyzed the impact of environmental amenities on individual-level SWB have relied on sub-national (regional or local) data. For example, Smyth et al.

[13] Similarly, Weinhold (2013) finds *perceived* noise levels across Europe to be negatively associated with SWB.

(2008) link SO_2 emissions, environmental disasters, traffic congestion and access to parklands to SWB for 30 cities in China. Cuñado and Perez de Gracia (2012) study the impact of a wide range of regional amenities (NO_2, PM10 concentrations, CO_2 emissions, and indicators of precipitation and temperature) on SWB in Spain. Ferreira et al. (2013) find a negative and significant relationship between SO_2 concentrations at the regional level and life satisfaction in Europe. Murray et al. (2013) analyze the impact of regional climate variability in Europe. Ambrey et al. (2014) focus on PM10 concentrations at the collection-district level (similar to a US census block group) in South-East Queensland, Australia.

Luechinger (2009) also combines individual-level data with high resolution SO_2 data (at the county level for Germany). Unlike other studies, however, he is able to control for individual fixed effects as he uses data from the German Socio-Economic Panel Study (SOEP), a large panel survey. Moreover, he uses the estimated improvement in air quality caused by the mandated installation of scrubbers at power plants as a novel instrument for air pollution. In a subsequent study, Luechinger (2010) uses pollution from foreign sources as an instrument for mean annual SO_2 country-level concentrations across Europe. In both cases, instrumenting for pollution results in it having a larger impact on SWB.

3.3 Time Scale

In addition to the spatial dimension, an important issue is the temporal dimension of the link between well-being and environmental quality. While this is of less importance in the case of environmental amenities that do not change over a longer period of time, it may be highly relevant for flow pollutants, especially if their amounts are volatile.

Levinson (2012) merged data on local air quality and individual observations to estimate SWB as a function of air quality on the day the well-being question was asked.[14] He finds a statistically significant negative coefficient on the daily concentration of PM10, whereas the coefficient on the annual average concentration of the same pollutant is negative but statistically indistinguishable from zero. He concludes from these results that long-term average pollution levels may be of little importance for well-being, due to habituation.

Since several papers find significant effects of annual levels of other air pollutants, such as nitrogen dioxide, lead, and sulfur dioxide (Welsch 2002, 2007, Luechinger 2009, 2010), the general validity of this proposition is unclear. Moreover, by differentiating survey respondents by birth cohort, Menz and Welsch (2012) find the well-being effect of nitrogen dioxide to be greater in people who likely were exposed to high pollution loads in early childhood. This finding is consistent with epidemiological evidence of greater susceptibility to current air pollution in people whose lung functions were impaired by early exposure to that pollution. Moreover, even with respect to PM10, Menz (2011) finds the pollution levels of both the current year and the preceding year to have significant negative coefficients in life satisfaction regressions, which suggests the existence of long-term effects rather than habituation.

We conclude from these results that the dynamics of the relationship between pollution and well-being are likely to depend on specific aspects of the type of pollution and are an area for further investigation.

3.4 Instantaneous Well-Being

[14] He takes the population-weighted centroid of each GSS respondent's county and computes a weighted average of all the air quality and weather monitors within a 25-mile buffer zone around it, where the weights are equal to the inverse of the square root of their distance to the population-weighted centroids (p. 871).

All the studies reviewed so far relate indicators of environmental quality to global self-reports of subjective well-being (happiness or life satisfaction). Although the use of high resolution spatial data is expected to yield a better match between the survey respondent and the environmental conditions she experiences, the match between the two is done using the location of the residence. Even in Levinson's (2012) study in which air quality is measured at the day of the interview, the pollution concentrations might not reflect the individual's actual exposure to pollution on that day if, for example, the respondent spent most of the day indoors or at a different location (e.g. at work).

In a path breaking study, MacKerron and Mourato (2013) use an alternative approach to the measurement of the impact of environmental amenities on SWB. They develop and apply a smartphone app that signals participants at random moments during their daily lives and asks them to report the extent to which they are feeling "Happy". Although longitudinal study designs in which participants provide ongoing reports of their momentary, experienced SWB are not new, the novelty of their application of the Experience Sampling Method is the use of satellite positioning (Global Positioning System, GPS) to determine the precise geographical coordinates that then can be associated to objective spatial data. Three environmental indicators are collected: land cover type, weather conditions and daylight status. On average, study participants are significantly and substantially happier outdoors in natural habitat types than they are in urban environments.

4. Areas of Application

As seen in Table 1, the EPM has been applied to issues such as air pollution, noise, climate parameters, and the presence of local environmental (dis)amenities. Some more recent papers have dealt with land use, energy supply systems and environmental disasters. In addition, the EPM has been applied in the context of an explicit benefit-cost analysis of environmental policy. This section reviews some of the more recent applications.

4.1 Benefit-Cost Analysis

Though an important rationale for environmental valuation is benefit-cost analysis, the results from EPM studies have rarely been applied in such a context. An initial step in this direction was taken by Welsch (2002) by comparing the monetized benefit from air pollution abatement with estimates of marginal abatement costs from the literature. The result of this comparison was that the marginal benefit from abatement exceeds the corresponding marginal costs up to considerable degrees of abatement.

That analysis was extended by Welsch (2007). Using the same basic data set and happiness function as Welsch (2002), the model is augmented by a concave production function for per capita GNP. In the production function, air pollution plays the role of a quasi-input, other inputs being physical and human capital. In this set-up, the net marginal value of pollution, that is, the marginal product minus the monetized marginal disutility can be computed. The net marginal value at observed pollution levels is found to be negative for most countries included in the sample. By computing that level of pollution at which the marginal product and the marginal monetized disutility are equalized, optimal pollution reduction rates are determined. They are found to be substantial in the case of several less developed and transition economies with weak environmental regulation.

4.2 Land Use, Biodiversity, and Scenic Amenities

A number of recent studies use the EPM to provide insights on the value of natural environments or specific attributes associated with those natural environments (biodiversity and scenic amenity). As noted in MacKerron and Mourato (2013), there are at least three reasons for thinking that natural environments will have a positive impact on individual well-being. First, the biophilia hypothesis suggests that there is an instinctive bond between human beings and other living systems which is product of biological evolution (Wilson 1984).

Second, environmental quality may be higher in natural environments. Third, natural environments may encourage behaviors (such as exercise, recreation and social interaction) that are physically and psychologically beneficial.

Kopmann and Rehdanz (2013) relate regional land-use data to SWB in Europe, and find that natural land cover (encompassing both cultivated and natural varieties) has an effect on SWB, regardless of region, with higher values for scarce land categories (those with the lowest shares). Interestingly, artificial areas dedicated to mineral extraction, dumping and constrution sites also have a positive effect in some specifications. These findings seem to be at odds with those of MacKerron and Mourato (2013) who use a much higher level of dissagregation. Neither study, however, identifies what specific attributes of natural environments may have a positive impact on SWB.

Ambrey and Fleming (2011 and 2013) point at scenic amenity and biodiversity as potential channels, at least for the residents of South East Queensland (SEQ), Australia. They measure scenic amenity (in a 1-10 scale) by combining, at the Australian collection district level, scenic preference maps (based on surveys of public preferences for scenery) with maps showing the degree of landscape visibility in SEQ. Ecosystem biodiversity for the same region is measured at a similarly high spatial resolution via Simpson's (1949) diversity index. Both variables are found to have a large impact on the life satisfaction of SEQ residents.

4.3 Energy Supply Systems

A recent area of application of the EPM is the supply of energy, specifically the supply of electricity. Though electricity *per se* is a private, marketable good, different supply technologies differ in terms of attributes such as cost, environmental impacts, and safety and security of supply. Given those differences, the question arises as to people’s preferences over electricity supply systems and whether those differences manifest in a relationship between the energy mix and SWB.

This issue is studied by Welsch and Biermann (2013). They merged survey data for about 140,000 individuals in 25 European countries, 2002-2011, with the supply shares of nuclear power and several types of fossil-based and renewable power in the respective country-years. Controlling for the usual individual and macro-level factors as well as country and year fixed effects, they find that individuals' life satisfaction varies systematically and significantly with differences in the electricity mix across countries and across time. Among other results, they find that a greater share of solar and wind power relative to nuclear power is associated with greater life satisfaction. This relationship exists at all levels of income. Moreover, the respective coefficient has risen drastically after the Fukushima nuclear accident. Since a higher share of solar and wind power is associated with higher electricity prices, the authors interpret those results as evidence of a preference for a clean and safe electricity supply in spite of higher costs. In addition, the preference for oil-based electricity dropped at the time of political unrest in oil-exporting countries in North Africa ("Arab Spring"), which they take to indicate increased concern about supply security.

4.4 Environmental Disasters.

Natural disasters caused by *inter alia* earthquakes, volcanic eruptions, tsunamis, hurricanes, floods and droughts occur frequently across the world and can have profound environmental, political, and social consequences. The interest of economists in studying the impacts of natural disasters on human welfare is not new, but has intensified in recent years due to an increase in their incidence and damages. Some estimates put ex-post disaster relief spending between 2011 and 2013 as high as $40 to $50 billion per year only in the US (Weiss and Wideman 2013). Disasters can have an impact on life satisfaction through the financial losses associated with property damages and fiscal consequences of reconstruction. Moreover, they can cause stress and other psychic costs (grief for the bereaved, individual and collective traumas). It is not surprising then that a number of studies have used the EPM to assess the impact of disasters on SWB.

In one of the first studies linking global self-reports of SWB to natural disasters, Kimball et al. (2006) find that reported happiness dipped significantly after the seriousness of the damage done by hurricane Katrina along the US Gulf coast from central Florida to Texas, became clear. The impulse response of happiness is stronger in the South Central region, closest to the devastation of Katrina. Interestingly, a remote event (the October 2005 earthquake in Pakistan) is also found to affect happiness, albeit to a lesser extent. Subsequent studies have analyzed the impacts of flood disasters on the life satisfaction of Europeans (Luechinger and Raschky 2009) and of droughts on the life satisfaction of Australians (Carroll et al 2009). Both studies estimate a large willingness to pay to avoid hydrometeorological disasters: $6,505 to prevent a sure flood event, and A$18,000 for residents in rural areas to prevent a spring drought, respectively.

Kountouris and Remoundou (2011) estimate the impact of fire frequency and extent on the life satisfaction of residents of the European Mediterranean region (Italy, France, Spain and Portugal).[15] As expected, the negative impact of forests incidents is larger for larger-scale fires and more pronounced for rural residents, but even in this case, the WTP to prevent an additional forest fire incident is estimated at only €0.26.

[15] Because fires are correlated with pressures from local economic activity which are not included as regressors in the life satisfaction equation, they instrument their fire indicator with mean daily precipitation from April to September, which does not overlap with the period of survey fieldwork. Although this ensures that the instrument does not have a direct influence on SWB through weather conditions on the day of the interview, many studies (Rehdanz and Maddison 2005, Maddison and Rehdanz 2011, Murray et al. 2013) have shown that climate conditions do have an impact on SWB.

In the aftermath of the earthquake, tsunami and subsequent meltdown of the reactors of a nuclear plant in Fukushima, Japan on March 11, 2011, Chancellor Angela Merkel proclaimed an acceleration of the phase-out of nuclear power in Germany, a country more than 5,000 miles apart from Japan. Is it possible that the effects of a disaster in Japan reverberate on the German electorate? Kimball et al's results suggest that, yes, an environmental disaster can have impacts on the SWB of individuals far removed from the directly affected area. In addition, nuclear energy in Germany has been controversial for years (leading to a phase-out decision already in 1999 which was revised 10 years later). Using data from the German SOEP, Berger (2010) shows that a previous nuclear accident, at Chernobyl‘s nuclear power plant on April 26, 1986 boosted environmental concerns among the German population. However, she does not find evidence that the accident had a significant effect on general life satisfaction. Goebel et al. (2013) find similar results for the Fukushima accident, the meltdown significantly increased environmental concerns in Germany (by 20%), but did not have an effect on global reports of life satisfaction, only on an affective well-being measure: sadness.

The accident in Fukushima did have a marked impact on SWB in Japan. Rehdanz et al. (2013) find that after the disaster people living in a place affected by the tsunami or close to the Fukushima Dai-ichi power plant experienced a drop in life satisfaction (measured as "satisfaction with life in the previous year"), while the well-being effects declined with distance to the place of the event. The drop in life satisfaction in areas affected by the tsunami is equivalent to 72 percent of annual income and goes up to 110 percent in areas where fatalities were reported. However, in contrast to satisfaction with life in the previous year, no effect on people's satisfaction with their entire life can be found among those affected by the disaster. In addition, no change in well-being is detectable in people living close to nuclear facilities in general.

5. Well-Being and Environmental Behavior

In addition to offering a tool for environmental valuation, well-being data permit to test assumptions on environmental behavior made in mainstream economics. One such assumption refers to people's location choices in response to differences in environmental conditions which, according to the hedonic model, are expected to result in equalization of utility across locations. Another assumption is that individuals correctly anticipate the utility consequences of environmentally relevant consumption choices and balance the benefits and costs of those choices in such a way that utility is maximized.

5.1 Spatial Equilibrium and Hedonic Pricing

In a hedonic spatial equilibrium wages and rents must adjust to equalize utility across locations. Otherwise some individuals would have an incentive to move to locations where they could attain a higher utility. However this equilibrium relies on strong assumptions that are not likely to hold in practice. For example, hedonic models typically assume that people have perfect information and move freely among locations when they buy homes and choose jobs. Even in a country such as the US where costs to mobility are assumed to be low, Bayer et al. (2009) show that the great majority of household heads (from 58 to 79%) reside in the region of their birth.

Other than by observing violations of its implicit assumptions, a test of the hedonic spatial equilibrium requires a comparison of utility across locations. This is precisely the test that Ferreira and Moro (2010) propose. Using SWB as a proxy for utility, in statistical terms, the differences in reported SWB should not be significant across different locations. Assuming that personal traits are averaged out, they perform both parametric and non-parametric statistical tests and find that even in a small country such as Ireland, SWB varies across all the geographical levels considered (regions, local authorities and electoral divisions). In addition to the unconditional tests, they conduct another, conditional test to account for potential structural differences across locations that may lead to personal traits not averaging out. They run a SWB regression with region dummies controlling for individual characteristics and find that the regression-adjusted life satisfaction in different regions (the estimated location dummies) are also statistically different. They interpret these findings as evidence that the equilibrium condition required by the hedonic approach in Irish markets does not hold.

Moro et al. (2008) show that differences in utility across Irish regions are related to differences in their environmental amenities. They find that three alternative rankings of quality of life (QoL): the simple unconditional average of SWB across location, a conditional average that differs only in terms of the environmental amenities, and a QoL index that weights environmental amenities by their MRS with income, are highly correlated (r=0.61 to 0.98). This suggests that the spatial variation of SWB across locations is not random but driven by their endowments of amenities. Because hedonic price data on wages and rents in Ireland are not readily available, Moro et al. (2008) cannot compare their rankings with “objective” QoLs rankings (where the weights for environmental amenities are derived from hedonic regressions). Oswald and Wu (2010), using data for the US, do. They find a strong correlation (r=0.6) between the conditional average/regression adjusted life satisfaction and objective QoL rankings, which they take as an objective confirmation that subjective well-being measures are meaningful.

5.2 Environmental Behavior and Rational Choice

Consumer theory maintains that individuals make accurate forecasts as to the utility consequences of their choices (or, equivalently, that decision utility coincides with experienced utility) and make choices that maximize utility. This assumption has been called into question by behavioral economists (see subsection 2.1) but is impossible to test unless a measure of experienced utility is available. SWB data offer such a measure and have been used to test the assumption of utility-maximizing choice, in particular with regard to environmentally relevant choices.

One example of an environmentally relevant choice refers to commuting. Standard theory predicts that people balance the benefits from commuting in terms of higher income against the associated mental distress, loss of time available for social and family interactions, etc. At the optimum, the net marginal utility from time spent commuting should be zero. Stutzer and Frey (2010) use information on individuals' commuting time and subjective well-being to test whether the optimality condition is satisfied. They estimate a well-being regression that includes commuting time but not income. In such a set-up, a utility maximum would require that the coefficient on commuting time be indistinguishable from zero, but in fact it is found to be significantly negative. This suggests that people ex ante underrate the disutility from commuting relative to the utility from higher income and spend more time commuting than is utility maximizing.

A similar question arises with respect to pro-environmental behaviors, such as recycling, water saving, and the purchase of "green" products. These activities are supposed to yield utility (satisfaction) due to an intrinsic motivation to protect the environment, but also disutility due to inconvenience or high costs. Utility maximization would imply that the net marginal utility from these behaviors be zero.

This condition is tested and refuted by Welsch and Kühling (2010). In their life satisfaction regressions the coefficients indicating the net marginal utility from recycling, water saving and purchasing green products are found to be significantly positive. This suggests that people ex ante underrate the satisfaction from pro-environmental behavior relative to other forms of consumption and, consequently, could raise utility by behaving more environmentally friendly. These qualitative findings are confirmed by Welsch and Kühling (2011). In addition, they find that the decision error is smaller in people whose peers display more pro-environmental behavior and in people who have themselves displayed those behaviors for a longer period of time. One interpretation of these findings is that people learn to appreciate the satisfaction from those behaviors, such as to make smaller errors. Another would be in terms of social comparison and habituation effects diminishing the satisfaction from green behaviors.

Another example of an assumption rooted in economic analysis is that people care more about the environment as their income increases. While in principle, any valuation technique can be used to estimate whether the willingness-to-pay for environmental amenities varies with income, using SWB one can directly analyze whether the marginal utility of environmental amenities varies with income. Ferreira and Moro (2013) find little empirical support for the marginal effects of environmental amenities in Ireland being larger for the richest.

6. Conclusions

Recent years have seen a sharp increase in the use of subjective well-being data in economics in general and environmental economics in particular. This article has discussed the conceptual underpinnings of using such data as a tool for preference elicitation and non-market valuation. Given the connection of those data to the notion of experienced utility, we referred to this approach as the experienced preference method and discussed recent methodological advances and applications of the approach to subject areas not previously reviewed. In addition, we discussed insights concerning environmental behavior that can be gained with the help of subjective well-being data.

The literature reviewed indicates that parameters such as air pollution, noise, climate, scenic amenities, biodiversity and natural disasters are correlated with subjective well-being. Though the relationships found are broadly plausible a priori, they largely have the character of reduced-form relationships in which the specific transmission channels at work remain in the background. For example, air pollution may affect people both aesthetically (through reduced visibility) and through its health impacts, but the extant literature has not assessed the relative importance of each of these mechanisms. In some other cases, the specific transmission channels are still highly hypothetical. For instance, the channels through which biodiversity impacts on well-being are as of yet more a matter of philosophical reasoning rather than empirical evidence.

A specific issue of which a better understanding is desirable is the role of habituation to environmental conditions. As it was discussed above, it is unclear what time scales are relevant in the relationship between air pollution and well-being and to what extent people habituate to air pollution. While impairment by poor visibility is probably a short-term phenomenon, some health effects may depend on long-term exposure. Combining subjective well-being research with epidemiological research might help shed more light on such questions. In addition, the use of complementary approaches (such as the Day Reconstruction Method and the Experience Sampling Method) and new technology (GPS, biophysical monitoring) may help disentangle the immediate and lasting impacts of pollution on mental and physical well-being.

As to geographical coverage, the literature to date has mostly focused on industrialized or emerging economies. To a great extent this is due to a lack of appropriately disaggregated environmental data for developing countries (although for an exception, see Alem and Colmer 2013). It is to be hoped that such data will be forthcoming with more resources and improved tools and technologies. This would then allow investigation of possible differences across development levels and cultures in the relationship between environment and well-being. In addition, geographically disaggregated data in a cross-national setting would facilitate the identification and further exploration of transboundary effects on well-being.

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Table 1: Articles on Environment and Subjective Well-Being by Year of Publication

Article	Environmental Variables	Geographical Area
Frijters and Van Praag (1998)	Climate	Russia
Welsch (2002)	Air pollution	54 countries
Van de Vliert et al. (2004)	Climate	71 countries
Rehdanz and Maddison (2005)	Climate	67 countries
Van Praag and Baarsma (2005)	Noise	Amsterdam
Venuri and Costanza (2006)	Natural capital	171 countries
Welsch (2006)	Air pollution	10 countries, 1990-1997
Welsch (2007)	Air pollution	54 countries
Brereton et al. (2008)	Environmental amenities	Ireland
Moro et al. (2008)	Environmental amenities	Ireland
Di Tella and MacCulloch (2008)	Air pollution	13 countries, 1975-1997
Rehdanz and Maddison (2008)	Air pollution, noise	Germany
Smyth et al. (2008)	Environmental Amenities	China
Carroll et al. (2009)	Drought	Australia
Engelbrecht (2009)	Natural Capital	58 countries
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Berger (2010)	Nuclear disaster	Germany
Ferreira and Moro (2010)	Environmental amenities	Ireland
Luechinger (2010)	Air pollution	13 countries, 1979-1994
Menz and Welsch (2010)	Air Pollution	25 countries, 1990-2004
Ambrey and Fleming (2011)	Scenic amenity	Australia
Fischer and Van de Vliert (2011)	Climate	58 countries
Kountouris and Remoundou (2011)	Forest fires	European regions
Maddison and Rehdanz (2011)	Climate	79 countries
Menz (2011)	Air pollution	48 countries, 1990-2006
Cuñado and Perez de Gracia (2012)	Air pollution, climate	Spain
Gandelman et al. (2012)	Air pollution, noise	Uruguay
Levinson (2012)	Air pollution	USA
Menz and Welsch (2012)	Air pollution	10 countries, 1990-1997
Ambrey and Fleming (2013)	Ecosystem diversity	Australia
Ferreira et al. (2013)	Air pollution	European regions
Ferreira and Moro (2013)	Environmental amenities	Ireland
Guardiola et al. (2013)	Water access	Mexico
Koopman and Rehdanz (2013)	Land Use	European regions
MacKerron and Mourato (2013)	Land Use	UK
Sekulova and van den Bergh (2013)	Climate	Barcelona
Urban and Maca (2013)	Noise	Czech Republic
Weinhold (2013)	Noise	28 European countries
Ambrey et al. (2014)	Air pollution	Australia
Li et al. (2014)	Air pollution	China

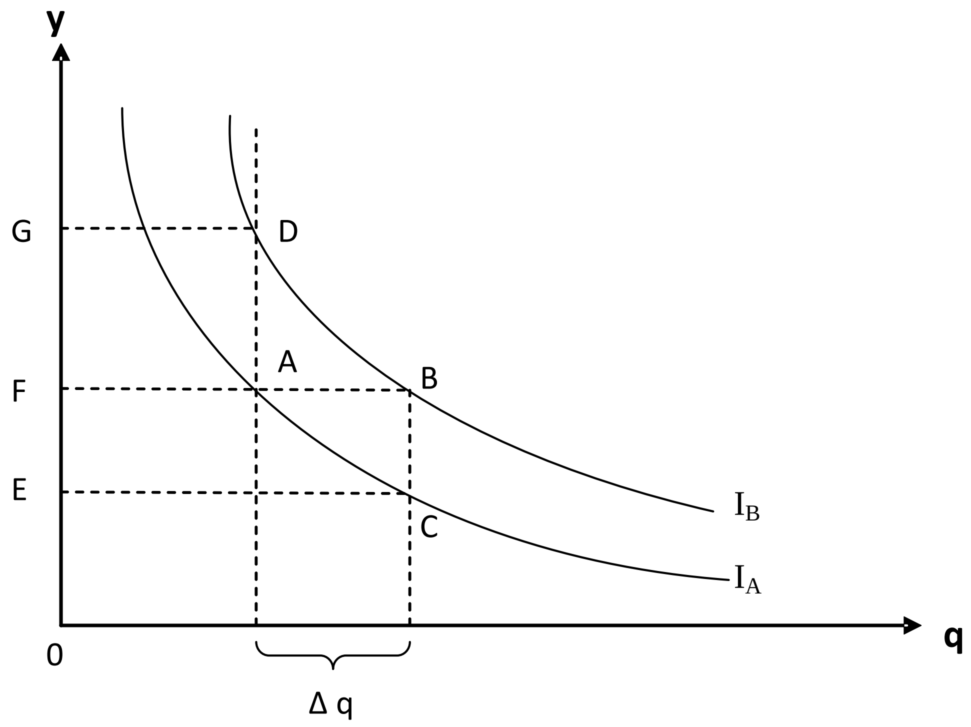

Figure 1: Trade-off between income and environmental quality. If an environmental improvement moves the individual from A on indifference curve I_A to B on indifference curve I_B , the associated equivalent and compensating variations are G – F and F – E, respectively.

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