Oldenburg Discussion Papers in Economics

Measuring Nuclear Power Plant Externalities Using Life Satisfaction Data:

A Spatial Analysis for Switzerland

Heinz Welsch

Philipp Biermann

V – 375– 15

January 2015

Department of Economics
University of Oldenburg, D-26111 Oldenburg

Measuring Nuclear Power Plant Externalities Using Life Satisfaction Data: A Spatial Analysis for Switzerland

Heinz Welsch

Philipp Biermann

Department of Economics

University of Oldenburg

26111 Oldenburg, Germany

Abstract

Conceptualizing externalities from perceived nuclear risk as being related to distance from nuclear facilities, we estimate the relationship between Swiss citizens' life satisfaction (understood as a proxy of utility) and the distance of their place of residence from the nearest nuclear power plant. Controlling for a rich set of life satisfaction factors, we find a statistically and economically significant satisfaction-distance gradient, whose monetary value amounts to CHF 291 per kilometer of distance, on average. The gradient is smaller for those who may feel protected by wind direction and topographical conditions, and it differs by age, sex, and the level of education. The satisfaction-distance gradient has changed significantly after the nuclear disaster at Fukushima, Japan, indicating a reassessment of distance-dependent nuclear risk. We find no evidence of hedonic locational equilibrium with respect to nuclear risk.

Keywords: nuclear risk; life satisfaction; non-market valuation; spatial equilibrium; Fukushima

JEL Codes: Q48; Q51; I31; Q54; R53

1. Introduction

The future role of nuclear power is high on the agenda in many countries around the world, in particular in the aftermath of the Fukushima-Daiichi nuclear meltdown in March 2011. While the governments of France, the UK and Australia adhere to nuclear power or plan to expand it, Germany, Italy and Switzerland announced to phase out their nuclear power plants, and the Chinese government decided to postpone approvals for new nuclear reactors (Davis 2012).

Similar as other electricity generation technologies, nuclear power has its specific advantages and disadvantages. Advantages typically invoked in public debates on nuclear power are low costs, security of supply, and the absence of air pollution and greenhouse gas emissions. On the downside, there is the risk of nuclear accidents, as well as the issue of nuclear waste disposal.

While the advantages of nuclear power tend to benefit citizens regardless of their location, the damage expected to arise from a nuclear accident has an explicit spatial dimension. Specifically, damage can be expected to increase with proximity to nuclear plants. This suggests that ceteris paribus people prefer more distant places to less distant ones. Nuclear risk, however, is not the only factor in people's locational preference function. Important other factors are wages (incomes) and housing costs, and these may vary with location. Hedonic spatial equilibrium theory suggests that people sort across locations according to location-specific (perceived) nuclear risk, wages and housing costs, and, as a consequence of locational choice, wages and housing costs adjust such as to capitalize the externality from nuclear risk and to eliminate any location-dependent differences in utility.

This paper studies nuclear risk as an externality in Swiss citizens' utility function using reported life satisfaction as a proxy for utility. Conceptualizing externalities from perceived nuclear risk as being related to distance from nuclear facilities, we estimate the relationship between Swiss citizens' life satisfaction and the distance of their place of residence from the nearest nuclear power plant (NPP). Framing our analysis within a model of locational choice, we investigate the following questions: (1) Does citizens' life satisfaction vary with distance to NPPs ceteris paribus, that is, when income and housing costs are kept fixed? (2) Does citizens' life satisfaction vary with distance if income and housing costs are allowed to vary with distance? (3) Did the relationship between life satisfaction and distance change after the Fukushima nuclear disaster? As it will be explained in section 2, an increase of life satisfaction with distance when income and housing costs are included in the regression will be interpreted as a measure of the NPP externality, whereas a variation of life satisfaction with distance when those factors are allowed to vary with distance will be taken to suggest an absence of locational equilibrium. A change in the satisfaction-distance relationship after the Fukushima disaster will be taken to represent a reassessment of nuclear risk triggered by an information shock.

Using several parametric and non-parametric specifications for the distance variable and controlling for a rich set of life satisfaction factors, we find a statistically and economically significant satisfaction-distance gradient at fixed income and housing costs, whose monetary value amounts to CHF 291 per kilometer of distance, on average. The gradient is smaller for those who may feel protected by wind direction and topographical conditions, and it differs by age, sex, and the level of education. These findings suggest the existence of significant nuclear power plant externalities in Switzerland. The satisfaction-distance relationships remain significant when incomes and housing costs are omitted from the regressions, indicating a violation of the condition for locational equilibrium. Finally, the satisfaction-distance gradient has changed significantly after the nuclear disaster at Fukushima, Japan, suggesting a reassessment of distance-dependent nuclear risk.

The extant literature on preference for distance to NPPs mainly comprises revealed preference (property value) studies and to a smaller extent stated preference (stated choice) studies. Nelson (1981), Gamble and Downing (1982), Clark et al. (1997), and Folland and

Hough (2000) find no or ambiguous effects of distance on property values in the US, whereas Farber (1998) reports a positive relationship between property values and the distance from NPPs. Clark and Allison (1999) find that the distance effect weakens over time, possibly due to relocation, or to preference adaptation attenuating initial price decreases.[1] Yamane et al. (2013), Fink and Stratmann (2013) and Bauer et al. (2013) studied property price changes in Japan, the US and in Germany, respectively, after the Fukushima disaster. Yamane et al. (2013) found that property values around the Fukushima-Daiichi plant decreased with increasing levels of local nuclear contamination, but not with proximity to the plant. Fink and Stratmann (2013) found no change of property prices in the proximity of NPPs in the US, whereas Bauer et al. (2013) found that house prices near NPPs in Germany dropped by up to 11 percent. Schneider and Zweifel (2013) report the results of a stated choice experiment conducted in Switzerland in 2001. Their main result is that stated willingness to pay for increased insurance coverage against nuclear accidents decreases with distance from plant once attitudes influencing choice of residential location are controlled for.

Our paper belongs to the rapidly expanding field of studies of experienced preference (Welsch and Ferreira 2014) for non-market-goods (also referred to as the life satisfaction or happiness approach). This method of preference elicitation uses people's reported life satisfaction as a proxy for utility. It estimates the statistical association between life satisfaction and the non-market good in question as well as people's income. The implied utility-constant tradeoff of income for the good is then used as a measure of the monetary value of the latter.

[1] Folland and Hough (2000) and Davis (2011) document that at the time of installation, as well as following the installation, land prices in the proximity of NPPs fell.

Life satisfaction data have been used in environmental economics (for surveys see Welsch and Kühling 2009, Frey et al. 2010, MacKerron 2012, and Welsch and Ferreira 2014) and, to a smaller extent, with respect to energy issues. In environment-related studies the spatial resolution ranges from whole nations (Welsch 2002) to GPS coordinates (MacKerron and Mourato 2014). Ferreira and Moro (2010) used spatially explicit life satisfaction data from Ireland to test the existence of hedonic spatial equilibrium.

With respect to energy, Welsch and Biermann (2014a) used life satisfaction data to study European citizens' preferences for alternative structures of their national electricity supply system. A number of life satisfaction studies considered the Fukushima nuclear disaster and found that it caused mental distress not only among people directly affected (Ohtake and Yamada 2013, Rehdanz et al. 2013) but, due to media coverage, in people thousands of miles away from the place of the event. Goebel et al. (2013) found an increase in environmental concern in Germany after the Fukushima nuclear disaster, but no change in life satisfaction.[2] Welsch and Biermann (2014b) found a change in the relationship between European citizens' life satisfaction and their countries' nuclear electricity share. Out of the energy-related life satisfaction studies, only Rehdanz et al. (2013) and Goebel et al. (2013) incorporated measures of distance from power plants.

The present paper is the first to use life satisfaction data to measure nuclear power plant externalities within an explicit locational choice framework. It is organized as follows. Section 2 presents the conceptual and empirical background. Section 3 describes the methodology. Section 4 reports and section 5 discusses the results. Section 6 concludes.

[2] Similarly, an increase in German people's concern about the environment but no change in life satisfaction was found after the Chernobyl nuclear accident in 1986 (Berger 2010).

2. Conceptual and Empirical Background

2.1 Conceptual Model and Hypotheses

We consider an economy with two marketable goods: housing and a numeraire. An individual derives utility from these goods and disutility from (perceived) nuclear risk. Her indirect utility function specifies the maximum utility she can attain by allocating income optimally to the marketable goods at a given housing price and a given level of nuclear risk. The indirect utility function of an individual with personal characteristics θ, takes the following form:

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

where p, y and R denote the price of housing, income, and nuclear risk, respectively. The indirect utility function is decreasing in the first and third argument and increasing in the second argument.

Perceived nuclear risk is conceptualized as the expected value of damage from a nuclear accident: $R = \pi * D$, where π denotes the subjective probability of an accident and D the subjective expected damage associated with an accident. Expected damage, in turn, is assumed to be decreasing in distance to the nearest NPP: $D = D(dist)$. We thus have $R = \pi * D(dist))$, which entails a downward-sloping relationship between perceived nuclear risk and distance. Using this relationship in equation (1), the latter can be rewritten as follows:

$$u = V(p, y, \pi, dist, \theta)\,. \qquad (1')$$

In this formulation, the derivative of *V* with respect to *dist* captures the (negative) nuclear power plant externality. We expect this derivative to be positive: controlling for housing costs and income, utility increases with distance due to the distance-dependent NPP externality.

The standard hedonic model suggests extending the above framework by assuming that the willingness to pay and, hence, the price of housing is a decreasing function of the nuclear risk in the places where houses are located: $p = p\ (R)$. It also suggests that local wages (and thus income) increase in nuclear risk: $y = y\ (R)$. Substituting these relationships in (1) gives

$$u = v(p(R), y(R), R, \theta)\ . \qquad (2)$$

In a simple model of residential locational choice, people choose their location in such a way as to balance the disutility from nuclear risk against the utility from less expensive housing and higher income so that the utility in different locations is equalized. Otherwise individuals would have an incentive to move. Under the appropriate concavity conditions this locational equilibrium condition can be expressed as follows:

$$\frac{dv}{dR} = \frac{\partial v}{\partial p}\frac{dp}{dR} + \frac{\partial v}{\partial y}\frac{dy}{dR} + \frac{\partial v}{\partial R} = 0 \qquad (3)$$

The hedonic model thus predicts that in locational equilibrium dv / dR is zero: Nuclear risk is capitalized in housing prices and income such that the marginal disutility from risk, $\partial v / \partial R$, is just offset by the marginal utility from lower housing prices in riskier places, $(\partial v / \partial p) * (dp / dR)$, and the marginal utility from higher income, $(\partial v / \partial y) * (dy / dR)$.

When we use $R = \pi * D(dist))$ in equation (2) we obtain

$$u = W(\pi, dist, \theta)\ . \qquad (2')$$

Consistent with equation (3), locational equilibrium implies that the derivative of *W* with respect to *dist* be zero:

$$\frac{\partial W}{\partial dist} = 0 \qquad (3')$$

Locational equilibrium thus implies that the derivative of utility with respect to distance be zero when removing housing costs and income from the indirect utility function.

In addition, similar as Bauer et al. (2013) and Fink and Stratmann (2013) in their property value studies, we investigate whether the Fukushima nuclear disaster may have acted as an information shock that altered people's assessment of nuclear risk even in places not physically affected by the disaster.[3] Specifically, in the above framework information on the accident and its consequences may have altered any or all of the following: (i) the expected accident probability π, (ii) the assumed relationship between expected damage and distance, $D(dist)$, and (iii) the weight placed on nuclear risk, $\partial v / \partial R$. Any of these changes translates into changes in the relationship $V(p, y, \pi, dist)$, specifically into changes in the marginal utility from distance.

Below, we report results from estimating empirical analogs to equations (1') and (2') for Switzerland, using reported life satisfaction as a proxy for utility. The results concerning equation (1') will be taken as evidence of the well-being externalities from perceived nuclear risk whereas the results concerning equation (2') will be taken as evidence on the presence or absence of locational equilibrium with respect to such risk. In addition, we investigate

[3] Fink and Stratmann (2013) model individuals' risk perception of nuclear power plant sites as a learning process, in which the Fukushima disaster constitutes an information shock.

whether those relationships are different before and after the Fukushima nuclear disaster, as hypothesized.

2.2 Data and Empirical Background

Our data comes from the Swiss *Statistics on Income and Living Conditions* (SILC). SILC is a representative large scale social survey that is fielded annually. The data base that we actually used was created and supplied on purpose by the Swiss Federal Statistical Office and refers to 2011. The distribution of the number of interviews across calendar dates is shown in Figure 1. As seen, a comparable number of interviews were conducted before and after the Fukushima disaster.

In contrast to the publicly available SILC data, our data base contains information on the distance between respondents' place of residence and the nearest domestic NPP in steps of 5 km. As a downside of this useful feature, person identifiers and several other variables were removed from this data base for purposes of data protection (anonymity). In particular, no information on the place of residence is available other than the distance to the nearest NPP and the language group to which a person belongs (French, Italian, and German).

The variable used to capture utility is life satisfaction. It is based on the answers to a question whose English translation reads as follows: "All things considered, how satisfied are you with your life as a whole nowadays?" Response options range from 0 = 'extremely dissatisfied' to 10 = 'extremely satisfied', and we used the answers on the 11-point scale as our dependent variable. As explanatory variables we used the distance to the nearest NPP, the equivalized disposable household income, housing costs per household member, and the socio-demographic characteristics usually included in life satisfaction regressions (age, age-squared, sex, education level, employment status, civil status, and self-reported health status). The variable descriptions and summary statistics are presented in Table A1 in the Appendix.

Switzerland has five NPPs (Beznau 1, Beznau 2, Gösgen, Leibstadt, and Mühleberg). The last NPP was built in 1984. As shown in Figure 2, the NPPs are located in the north-western, German speaking part of the country. It is important to note that the Italian speaking citizens of Switzerland live south from the Alps, which can be considered to constitute a shelter from any radioactivity from NPPs. Similarly, the French speaking citizens of Switzerland live west from the NPPs. For them, the prevalence of westerly winds at most of the time constitutes some protection from radioactive fallout. Since nuclear power has been much debated in Switzerland, in particular in the context of public debates on Switzerland's future energy strategy (*Energiestrategie 2050*) people are well informed about the location of NPPs and the topographical and meteorological conditions mentioned above. It can therefore be expected that any relationship between perceived nuclear risk and distance from NPPs is more salient in the German speaking part of the country than in the Italian and French speaking regions.

With respect to German speaking Switzerland, we ran some explorative regressions on the relationship of income and housing costs to distance from NPPs (see Table 1). A simple linear specification (column A) suggests that income decreases with distance. When we use discrete distance categories (column B) we find that income is not statistically different at distance 40-85 km than at distance <40 km, but significantly lower at distance >85 km than at distance <40 km. Housing costs per household member decrease with distance according to simple linear specifications (columns C and E). Using discrete distance categories (columns D and F), housing costs are not statistically different at distance 40-85 km than at distance <40 km, but they are significantly lower at distance >85 km than at distance <40 km. These results for housing costs are valid regardless of whether or not the regression controls for income.

While the lower income at distance > 85 km than at distance <40 km is in broad agreement with hedonic theory, less expensive housing at distance >85 km than at distance <40 is in gross violation of less perceived nuclear risk at more distant places being capitalized in housing costs. Also, hedonic locational theory would predict that incomes and housing costs at distances <40 km and 40-85 km are different, contrary to what we find. Overall, it is thus ambiguous whether incomes and housing costs can be taken to reflect distance-dependent differences in perceived nuclear risk. In particular, the findings concerning (low) income and (inexpensive) housing at distance >85 may instead be related to these areas being less urbanized and more remote from the centers of economic activity (see Figure 2). For these reasons we will test our main results for robustness to omitting observations from the distance category >85 km. We will also use alternative categorizations of distance.

3. Method

3.1 Discussion of Subjective Well-Being Data

Our approach to measuring the externalities from NPPs involves approximating utility by data on subjective well-being, specifically, life satisfaction. Based on the notion of life satisfaction being a measure of experienced utility (Kahneman et al. 1997), preference elicitation using life satisfaction data has been dubbed the experienced preference method (Welsch and Ferreira 2014). The advantages and disadvantages of this method (also called the life satisfaction or happiness approach) have been discussed in several surveys (Welsch and Kühling 2009, Frey et al. 2010, MacKerron 2012, Welsch and Ferreira 2014). Though the experienced preference method relies on subjective data, a major feature of this method is that it does not rely on people's stated attitude towards or stated evaluation of the issues under study. Instead, life satisfaction data are being elicited independently of those issues, and it is the purely statistical association between life satisfaction and the independently measured variables of interest that is taken as a measure of preference.

In using life satisfaction data in economic analysis it is important to understand the assumptions 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 life satisfaction and the underlying true utility u (if $life\ satisfaction_{it}$ > *life* *satisfaction*$_{is}$, then $u_{it} > u_{is}$ for individual i at times t and s) and (b) ordinal interpersonal comparability (if *life satisfaction*$_{it}$ > *life satisfaction*$_{jt}$, 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 interpersonal comparability life satisfaction can be treated as an ordinal variable. If, more restrictively, cardinal interpersonal comparability is assumed (*life satisfaction*$_{it}$ – *life satisfaction*$_{jt}$ is proportional to $u_{it} - u_{jt}$), life satisfaction can be treated as a cardinal variable. 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 (see section 4.4).

3.2 Empirical Strategy

We estimated micro-econometric life satisfaction functions in which the self-reported life satisfaction (*LS*) of individual *i* depends on her equivalized disposable income, housing costs per capita, her distance from the nearest NPP and a standard set of socio-demographic controls (age, age-squared, sex, education level, employment status, civil status, and self-reported health status). The estimating equation can be stated as follows:

$$LS_i = const + \alpha * \ln(income_i) + \beta * housing_i + \gamma * distance_i + \delta' \mathbf{controls_i} + \varepsilon_i \qquad (4)$$

where ε_i denotes the error term. This equation is the empirical analog to equation (1’), where the vector of controls corresponds to the personal characteristics θ from the conceptual model. As is common in this literature, income is included in logarithmic form to account for decreasing marginal utility.

For *distance* we will use several alternative specifications, including those that involve functional form and others that involve dummy sets of distance categories. Specifically, we consider the distance categories <40km (Ring 1), 40-85km (Ring 2) and >85km (Ring 3), but also report results for alternative distance categories. To account for the topographical and meteorological circumstances discussed in subsection 2.2, our main analysis focuses on German speaking Switzerland. We will, however, extend this to the overall country in order to see if results change and, if so, whether they change in a plausible way.

Though specification (4) is to be understood as the empirical analog to equation (1') from the conceptual model, it is lacking an indicator of the subjective probability of a nuclear accident, which may differ across individuals. Since the subjective accident probability enters our conceptualization of nuclear risk in a multiplicative fashion ($R = \pi * D(distance)$), the parameter γ in specification (4) may differ across people with different subjective probabilities. As reported by Schneider and Zweifel (2013) in their stated choice study, for instance, women in Switzerland are more concerned about nuclear risk than are men. We will therefore estimate extended versions of specification (4) that include interactions of *distance* with a *female* dummy, but also with age and the education level.[4]

In order to check the validity of the locational equilibrium condition (equations (2') and (3')), we estimate versions of specification (4) which omit income and housing costs. Statistical significance of the parameter on *distance* in these specifications will be taken to be a violation of the locational equilibrium condition. It will indicate that perceived nuclear risk is not or incompletely capitalized in income and rents.

To investigate whether the relationship between life satisfaction and distance to NPPs has changed after the Fukushima event, we created a dummy variable *postevent* that takes the

[4] It would be desirable to consider an interaction with environmental attitude, but such data are not available in our data base.

value 1 if a person was interviewed after the event and zero otherwise. We included this variable in the following extension of specification (4):

$$LS_i = const + \alpha^*\ln(income_i) + \beta^*housing_i + \gamma_1^*distance_i + \gamma_2^*postevent_i + \gamma_3^*postevent_i^*distance_i + \delta'\mathbf{controls_i} + \varepsilon_i \quad (5)$$

In this formulation, the coefficient on *distance* measures the LS-distance relationship before the event whereas the coefficient on the *postevent*distance* interaction measures a change in that relationship, if any.

In our main analysis, we treat the dependent variable, 11-point life satisfaction, as a cardinal variable and estimate equation (4) and variants thereof using least squares. We checked that the qualitative findings reported below (signs and significance of coefficients) are robust to using an estimator for ordered choice variables. We report robust standard errors.

4. Results

4.1 Main Results

Table 2 reports estimation results for German speaking Switzerland focusing on the main variables of interest, whereas Table A2 in the Appendix presents more detailed results for the socio-demographic control variables. With respect to the latter, we notice that they correspond to those typically found in data for developed countries (see Dolan et al. 2008).[5]

Column A of Table 2 captures distance to the nearest NPP as an integer variable with values 1 = 5 km, 2 = 10 km, …, 20 = 100 km, 21 = 100+ km, whereas column B includes a

[5] Specifically, life satisfaction decreases in age, increases in age-squared, is greater for women than for men, positively related to being married and to health, and negatively related to unemployed status.

set of dummy variables for distance categories <40 km (Ring 1), 40-85 km (Ring 2) and > 85 km (Ring 3). As seen in columns A and B, life satisfaction (LS) is statistically positively related to income and statistically negatively related to housing costs per household member. According to column A, LS increases statistically significantly in distance to the nearest NPP. Quantitatively, a 5-km increase in distance is associated with an increase in LS by 0.0065 points on the 11-point scale. According to column B LS is significantly greater in Ring 2 and weakly significantly greater in Ring 3 than in Ring 1, the difference amounting to 0.1 LS points in both cases.

Columns C and D are counterparts to columns 1 – 3, respectively, in which income and housing costs are omitted. As stated in equation (3’), hedonic locational equilibrium would imply that the coefficients on the distance variables become insignificant in such specifications. This is, however, not the case. Instead, the distance variables retain their significance, and their magnitudes are practically unchanged. These results suggest the absence of locational equilibrium, consistent with the relationships between distance and housing costs reported in Table 1.

Table 3 reports a series of robustness checks concerning the definition of distance categories and the sample considered. As can be seen, the qualitative results (signs and significance of coefficients) for income and housing costs are unaffected by these changes, as are those for the control variables (not shown). In column A, we employ alternative distance categories, namely <35 km, 35-65 km, and > 65 km. This leads to a more balanced distribution of observations across categories (4721, 2854 and 1479 instead of 5660, 2467 and 927). The coefficient on the intermediate distance category is now smaller than in column B of Table 2 and weakly significant only. This is intuitive, because about 20 percent (939/4721) of the individuals in the category 35-65 km come from the category <40 km which was found to be the least satisfied group according to column B in Table 2. The coefficient on the most outward category (>65 km) is significantly positive and greater than that on the intermediate category.

Column B reverts to the initial distance categorization but omits people at distance >85 km from the sample. Following up on the discussion in subsection 2.2, this modification serves to check whether the preceding results were driven by some unobserved characteristics of the area >85 km, in particular the presumably less urbanized character. As can be seen, individuals in Ring 2 continue to be significantly more satisfied than those in Ring 1, and the coefficient is very similar to that in the counterpart regression that contains people from all three distance categories (column B in Table 2).

Column C extends the sample from German speaking Switzerland to the entire country. We use language dummies for Italian and French as additional controls and find the corresponding coefficients to be negative (the one on French significantly so). The coefficient on the Ring 2 dummy remains significantly positive, but is smaller by 27 percent in comparison with the one for German speaking Switzerland (column B in Table 2). The coefficient for Ring 3 is insignificant. Both of these findings are intuitive, because, as seen in Figure 2, a larger fraction of Ring 2 inhabitants now live west from the NPPs (in the French speaking region) and a larger fraction of Ring 3 inhabitants live south from the Alps (in the Italian speaking region). Assuming that these people feel less vulnerable to radioactive fallout because of the meteorological and topographical conditions, the phenomenon of increasing life satisfaction with increasing distance from NPPs is less prominent or absent in these people.

We note that in view of the meteorological and topographical circumstances the differences between the results for German speaking Switzerland and the entire country are consistent with the idea that distance-related differences in life satisfaction represent the influence of perceived nuclear risk.[6]

Columns D - F of Table 3 are counterparts to columns A – C in which income and housing costs are omitted. Similar as in Table 2, we find little difference between specifications with and without income and housing prices. In particular, inconsistent with hedonic locational equilibrium, life satisfaction is positively related to distance from NPPs even when income and housing costs are allowed to reflect nuclear risk (rather than being fixed).

4.2 Heterogeneity

As was mentioned above, the relationship between utility (proxied by life satisfaction) and perceived nuclear risk may vary across subgroups of the population. Such heterogeneity may refer to the perceived relationship between expected damage from an accident and distance from NPPs, and to the subjective accident probability. Both types of heterogeneity will translate into heterogeneity in the relationship between life satisfaction and distance from NPPs.

The regressions reported in Table 4 represent heterogeneity by means of interactions of the distance variables and gender, the level of education, and age. The regressions refer to German speaking Switzerland.

---

[6] We repeat that people's language region, in addition to distance from NPPs, constitutes the only spatial information that we have. Though rationalizing our findings in terms of the relation between language regions and meteorological and topographical conditions seems plausible, we cannot rule out that culture-specific attitudes towards nuclear risk also contribute to those findings.

Column A reproduces the basic specification with undifferentiated effects (column B from Table 2). Column B focuses on possible heterogeneity between men and women. As seen, there is a significantly positive relationship between women’s life satisfaction and living in Ring 2 and 3 instead of Ring 1. While for Ring 2 the coefficient size is only slightly greater than in Table 2 (0.114 instead of 0.0998), the coefficient for Ring 3 is more than twice as large as in Table 2 (0.202 instead of 0.0996). In sharp contrast to these results, the coefficients on Ring 2 and Ring 3 are insignificant in the case of men.

Regarding the level of education (column C), we find significantly positive coefficients on the Ring 2 and 3 dummies for individuals with primary education, and their size is much greater than on average (2.2 times for Ring 2 and 3.5 times for Ring 3). Individuals with secondary education are weakly significantly more satisfied living in Ring 2 than in Ring 1, but they are not significantly more satisfied living in Ring 3 than in Ring 1. For individuals with tertiary education life satisfaction in Rings 2 and 3 does not differ significantly from life satisfaction in Ring 1.

Regarding age, column D reveals a significantly positive relationship between life satisfaction and living in Rings 2 and 3 for individuals below mean age (42 years), but not for individuals above mean age.

Greater distance from nuclear power plants thus matters only for the life satisfaction of women, not men, and it matters mainly for the life satisfaction of individuals with lower and intermediate levels of education, and for people below mean age.

4.3 The Fukushima Nuclear Accident

As mentioned above, the Fukushima nuclear accident on March 11, 2011, changed environmental awareness among German citizens (Goebel et al. 2013), property prices close to NPPs in Germany (Bauer et al. 2013), and the relationship between European citizens’ life satisfaction and the share of nuclear power in their countries’ electricity supply (Welsch and

Biermann 2014b). In this section we investigate whether the accident has changed the relationship between Swiss citizens' life satisfaction and the distance of their place of residence from NPPs.

Similar as Fink and Stratmann (2013) in their property value study, we conceive of the Fukushima disaster as an information shock that may have changed people's assessment of nuclear risk. In the case of the Fukushima disaster information on the severity and spatial extent of the disaster became known gradually and accumulated over time. The delay in perception refers to the fact that the incident actually constituted a nuclear meltdown, the information on the number of affected reactor blocks at the Fukushima-Daiichi plant, and the spatial extent of evacuations. The information shock thus cannot be identified with one specific calendar date.

For these reasons we experimented with several dates, beginning with March 11, to differentiate the post-Fukushima period from the pre-Fukushima period. As seen in Figure 1, we have an appropriate distribution of observations around the time of the event. Referring to equation (5), Figures 3a and 3b show how the coefficients of the interactions of *postevent* with the distance categories change when the *postevent* date is shifted on a day by day basis starting with March 11. Columns A – C of Table 5 report detailed results from three selected definitions of the *postevent* data: March 11, March 19, and March 27. As seen in Figure 3a and in column A - C, the interactions of Ring 2 (40-85 km) with *postevent* are all negative, and they increase in magnitude as time proceeds. They become significant at March 27 as the start of the *postevent* period: The difference in satisfaction between Ring 2 residents and Ring 1 residents (base category) is significantly smaller if interviewed after March 27 than if interviewed before March 27. In contrast to Ring 2, the interactions of Ring 3 (>85 km) with *postevent* are all insignificant regardless of the definition of the latter variable: The satisfaction difference between Ring 3 residents and Ring 1 residents is the same regardless of the time of the interview .

Quantitatively, for *postevent* starting at March 27 (column C), the coefficient on the 40-85km distance dummy (Ring 2) is significantly positive and its magnitude (0.185) is almost twice the magnitude as in column B of Table 2. The coefficient on *postevent*40-85* is significantly negative and of a considerable magnitude (-0.156). Hence, life satisfaction was substantially greater in Ring 2 (40-85 km) than in Ring 1 before the disaster, but that difference dropped in a statistically and economically significant way after the disaster. As to Ring 3, the coefficient on the *postevent*>85* interaction is positive, but insignificantly so.

These results suggest that Ring 2 residents' perception of their nuclear safety relative to Ring 1 dropped after the Fukushima disaster. While before the disaster they felt substantially less exposed to nuclear risk than Ring 1 residents, perceived relative safety dropped by about 84 percent (0.156/0.185) after the disaster. For Ring 3 residents there were no significant changes in perceived relative safety.

Columns D and E report the results of robustness checks on column C with respect to the omission of Ring 3 residents (column D) and the inclusion of the French and Italian speaking regions (column E). As seen, all of the qualitative results reported in column C remain intact. In particular, Ring 2 residents' life satisfaction (relative to Ring 1) dropped after March 27, 2011, presumably as a result of accumulating information on the severity and spatial extent of the Fukushima disaster.

4.4 Monetary Valuation

The monetary value of greater distance from NPPs is obtained by dividing the marginal utility (marginal life satisfaction) from distance by the marginal utility of income, yielding the marginal rate of utility-constant substitution (MRS) of income for distance. Referring to specification (4), we have

$$MRS = \frac{\gamma}{\alpha} income \qquad (6)$$

For German speaking Switzerland, the linear specification of distance (column A in Table 2) yields MRS = 0.025**income* for a 5-km increase in distance and, hence 0.005**income* for a 1-km increase in distance: living 1 km farther away from the nearest NPP is worth 0.5 percent of equivalized disposable income. This corresponds to CHF 291 per km at mean income (CHF 58,300). Turning to the distance categories (column B in Table 2), living at 40-85 km instead of distance <40 km is worth 39.3 percent of income, and the corresponding value for living at distance >85 instead of distance <40 km is 39.2 percent of income. When we restrict the sample to persons living at distance <85 km (column B of Table 3) the value of living at 40-85 km instead of <40 km is 35.9 percent of income. For Switzerland overall (all language regions) we get 27.8 percent of income for 40-85 km, whereas living at distance >85 km instead of distance <40 km does not constitute a (statistically) significant benefit (column C of Table 3).

The figures just mentioned refer to the average of 2011. Considering the pre- and post-Fukushima sub-periods, we find that before March 27 living at 40-85 km instead of <40 km was worth 72.8 percent of income. This value dropped by 61.4 points after the event, leaving a post-event value of greater perceived nuclear safety amounting to 11.4 percent.

5. Summary and Discussion

This paper has used data on Swiss citizens' reported subjective well-being to investigate the proposition that externalities from nuclear risk depend on distance from nuclear power plants (NPPs). Using reported life satisfaction as a proxy for utility, we estimated several specifications of an indirect utility function which includes distance from the nearest NPP along with equivalized disposable income, the costs of housing per household member, and a rich set of socio-demographic controls. We also estimated versions of those specifications that omit income and housing costs. In these latter specifications, utility is expected not to vary with distance if, as predicted by hedonic locational equilibrium theory, distance-related nuclear risk is capitalized in income and housing costs. In addition, we investigated whether the marginal utility from distance changed after the Fukushima nuclear disaster in March 2011. We differentiated our analysis by citizens' socio-demographic characteristics and by regions of Switzerland for which the relationship between utility and distance from NPPs can be expected to differ because of meteorological and topographical conditions.

Our empirical results reveal a statistically and economically significant positive relationship between life satisfaction and distance to the nearest NPP. A simple linear specification for German speaking Switzerland suggests that a 1-km increase in distance is worth 0.5 percent of equivalized disposable income. Evaluated at mean income, this amounts to CHF 291 annual income per km of distance. This is a magnitude roughly comparable to the range of USD 200-300 per mile of distance (in 1993 dollars) reported in a literature survey by Farber (1998). The similarity of estimates is remarkable because of fundamental methodological differences, as previous valuation studies used property value methods or stated choice methods instead of subjective well-being data.

In addition to a linear specification of distance, we estimated models with discrete distance categories. The results for these specifications suggest that, due to non-linearity and specific meteorological and topographical conditions, "distance" may not be a homogeneous factor of Swiss citizens' perceived nuclear risk. In addition, perceptions of distance-related nuclear risk were found to be heterogeneous across socio-demographic subgroups of the population and to be different before and after the nuclear disaster at Fukushima, Japan.

As regards non-linearity, our results suggest that from a certain point on, greater distance is not associated with a further increase in life satisfaction. Specifically, the benefit from living at a distance >85 km instead of <40 km is practically the same as living at 40-85 km instead of <40 km. This finding roughly corresponds to the finding of Schneider and Zweifel (2013) that Swiss citizens' stated willingness to pay for insurance against nuclear risk is decreasing in distance only up to about 50 – 100 km of distance (depending on sex and attitudinal characteristics of respondents).

With respect to meteorological and topographical conditions, we found that the benefit from distance becomes smaller when the sample is extended to include more individuals that may feel protected from radioactivity by the prevailing wind direction or because they are separated from NPPs by the Alps.

With respect to socio-demographic characteristics, we found a great deal of heterogeneity. Specifically, the benefit from greater distance to NPPs is (statistically) significant only in women, not in men, in individuals below mean age, and in individuals that have no tertiary education.

A final type of heterogeneity refers to the periods before and after the nuclear accident at Fukushima, Japan. We found that the relationship between life satisfaction and the distance to NPPs changed with the gradual accumulation of information on the severity and geographical extent of the disaster. While individuals living at distance 40-85 km were substantially more satisfied than those living at distance <40 km before the accident, that difference dropped gradually as the information about the event accumulated. The drop in life satisfaction became statistically significant about two weeks after the initial news and amounted to 84 percent of the initial benefit from living at greater distance.

An additional finding from our analysis is that the relationship between life satisfaction and the distance from NPPs is unaffected by the inclusion or omission of income and housing costs in the life satisfaction regressions: Life satisfaction significantly varies with distance from NPPs even if income and housing costs are omitted. Together with the result on the relationship of housing costs to distance from NPPs, this suggests that perceived nuclear risk is not capitalized in these variables and that locational equilibrium with respect to nuclear risk is absent in Switzerland.

An important question that remains to be discussed is whether the statistical association between life satisfaction and distance to the nearest NPP is in fact related to distance-dependent differences in perceived nuclear risk or may not in fact represent other, unobserved factors correlated with “distance”. With respect to this issue, we note that several of our more detailed results are consistent with a “nuclear risk” interpretation of our findings:

First, the satisfaction-distance gradient becomes smaller when the sample is extended to include more individuals that may feel protected from radioactivity by the prevailing wind direction (French speaking Switzerland) or because they are separated from NPPs by the Alps (Italian speaking Switzerland). We concede that those changes may reflect not only geographical features but also different culture-specific attitudes towards nuclear risk, in particular, French speaking people being less concerned about nuclear power than German speaking people. Either way, however, the satisfaction-distance gradient changes in a way consistent with a nuclear-risk interpretation.

Second, the satisfaction-distance relationship changes after the Fukushima disaster in an intuitive fashion: While people at distance 40-85 km were substantially more satisfied than people at distance <40 km before the disaster, the difference dropped by 84 percent after the disaster. This is consistent with people realizing that, as demonstrated by the Fukushima event, the spatial extent of a nuclear disaster may be considerably larger than they had assumed previously. By contrast, the life satisfaction of people at distance >85 km did not change, which is consistent with that range being beyond the evacuation zone at Fukushima.

Third, the satisfaction-distance gradient is greater for those subgroups of the population that are known to be more concerned about nuclear risk, in particular women.

For these reasons we are confident that the satisfaction-distance relationships reported above in fact reflect distance-dependent externalities from subjective nuclear risk. In addition, we are confident that issues of endogeneity do not substantially affect our results: First, we control for the factors that were commonly found to be correlated with life satisfaction, such that omitted variable bias should not be an issue off concern. Second, though life satisfaction may be measured with error, there is no reason to expect measurement error to be correlated with our explanatory variables of interest.

A final issue relates to distance from NPPs being a choice variable, selected on the basis of distance-related factors, rather than being exogenous. As stated above, housing costs in Switzerland do not seem to adjust to such factors. This indicates considerable costs of locational choice (Schneider and Zweifel 2014) and may justify the assumption of distance being unaffected by endogeneity.

6. Conclusion

To our knowledge, this is the first study to find a significantly positive relationship between life satisfaction and greater distance from nuclear power plants. The case of Switzerland is interesting because some of its geographical features offer the possibility of including into the analysis factors that may affect the satisfaction-distance relationship, thus permitting to check the plausibility of results. Nevertheless, more detailed information on people's place of residence other than distance from the nearest NPP would have been desirable, but has been unavailable for reasons of confidentiality. Future research may strive to overcome such limitations with the help of alternative data sets and investigate the generalizability of our results to other countries.

References

Bauer, T.K., Braun, S., Kvasnicka, M. (2013), Distant Event, Local Effects? Fukushima and the German Housing Market, Working Paper No. 1857, Kiel institute for the World Economy.

Berger, E. (2010), The Chernobyl Disaster, Concern about the Environment, and Life Satisfaction, *Kyklos* 63: 1-8.

Clark, D.E., Michelbrink, L., Allison, T., Metz, W.C. (1997), Nuclear Power Plants and Residential Housing Prices. *Growth and Change* 28, 496–519.

Clark, D.E., Allison, T. (1999), Spent Nuclear Fuel and Residential Property Values: The Influence of Proximity, Visual Clues and Public Information, *Papers in Regional Science* 78, 403-421.

Davis, L.W. (2011), The Effect of Power Plants on Local Housing Prices and Rents. *Review of Economics and Statistics* 93, 1391–1402.

Davis, L. W. (2012), Prospects for Nuclear Power. *Journal of Economic Perspectives* 26, 49–66.

Diener, E., Suh, E.M., Lucas, R.E., Smith, H.L. (1999), Subjective Well-Being: Three Decades of Progress, *Psychological Bulletin* 125: 276-302.

Dolan, P., Peasgood, T., White, M. (2008), Do we really know what makes us happy? A review of the economic literature on the factors associated with subjective well-being, *Journal of Economic Psychology* 29, 94-122.

Farber, S. (1998), Undesirable Facilities and Property Values: A Summary of Empirical Studies, *Ecological Economics* 24, 1-14.

Ferrer-i-Carbonell A., Frijters, P. (2004), How Important is Methodology for the Estimates of the Determinants of Happiness?, *Economic Journal* 114, 641-659.

Ferreira, S., Moro, M. (2010), On the Use of Subjective Well-Being Data for Environmental Valuation, *Environmental and Resource Economics* 46, 249-273.

Fink, A., Stratmann, T. (2013), U.S. housing prices and the Fukushima nuclear accident: To update, or not to update, that is the question, Working Paper No. 4/2013, International Center for Economic Research.

Folland, S., Hough, R. (2000), Externalities of Nuclear Power Plants: Further Evidence, *Journal of Regional Studies* 40, 735-753.

Frey, B.S., Stutzer, A. (2002), What Can Economists Learn from Happiness Research?, *Journal of Economic Literature* XL: 402-435.

Frey, B.S., Luechinger, S., Stutzer, A. (2010), The Life Satisfaction Approach to Environmental Valuation, *Annual Review of Resource Economics* 2: 139-160.

Gamble, H.B., Downing, R.H. (1982), Effects of Nuclear Power Plants on Residential Property Values, *Journal of Regional Science* 22, 457-478.

Goebel, J., Krekel, C., Tiefenbach, T., Ziebarth, N.R. (2013), Natural Disaster, Policy Action, and Mental Well-Being: The Case of Fukushima, Working Paper 13/4, German Institute for Japanese Studies.

Kahneman, D., Wakker, P.P., Sarin, R. (1997), Back to Bentham? Explorations of Experienced Utility, *Quarterly Journal of Economics* 112, 375–405.

MacKerron, G. (2012), Happiness Economics from 35 000 Feet, *Journal of Economic Surveys* 26, 705-735.

MacKerron, G., Mourato, S. (2013), Happiness is Greater in Natural Environments, *Global Environmental Change* 23: 992-1000.

Nelson, J. (1981), Three Mile Island and Residential Property Values: Empirical Analysis and Policy Implications, *Land Economics* 57, 363-372.

Ohtake, F., Yamada, K. 2013. Appraising the Unhappiness due to the Great East Japan Earthquake: Evidence from weekly Panel Data on Subjective Well-Being, GCOE Discussion Paper No. 310, Graduate School of Business, Osaka University.

Rehdanz, K., Welsch, H., Narita, D., Okuba, T. (2013), Well-Being Effects of a Major Negative Externality: the Case of Fukushima, Working Paper 1855, Kiel Institute for the World Economy.

Schneider, Y., Zweifel, P. (2013), Spatial Effects in Willingness to Pay for Avoiding Nuclear Risks, *Swiss Journal of Economics and Statistics* 149, 357-379.

Welsch, H. (2002), Preferences over Prosperity and Pollution: Environmental Valuation Based on Happiness Surveys, *Kyklos* 55: 473-494.

Welsch, H., Biermann, P. (2014a), Electricity Supply Preferences in Europe: Evidence from Subjective Well-Being Data, *Resource and Energy Economics* 38, 38-60.

Welsch, H. Biermann, P. (2014b), Fukushima and the Preference for Nuclear Power in Europe: Evidence from Subjective Well-Being Data, *Ecological Economics* 108, 171-179.

Welsch, H. Ferreira, S. (2014), Environment, Well-Being, and Experienced Preference, *International Review of Environmental and Resource Economics* 7, 205-239.

Welsch, H., Kühling, J. (2009), Using Happiness Data for Environmental Valuation: Issues and Applications, *Journal of Economic Surveys* 23: 473-494.

Yamane, F., Ohgaki, H., Asano, K., 2013. The Immediate Impact of the Fukushima Daiichi Accident on Local Property Values, *Risk Analysis* 33, 2023-2040.

Table 1: Distance, income and housing costs

	A	B	C	D	E	F
Dep. Variable	Income	Income	Housing	Housing	Housing	Housing
Distance (5km steps)	-115.1**		-3.912***		-4.264***	
	(58.02)		(0.824)		(0.844)	
Distance 40-85km		1125.4		-9.977		-6.556
		(872.8)		(11.07)		(11.48)
Distance >85km		-4075.0***		-88.08***		-100.5***
		(922.0)		(14.54)		(14.80)
Equival. Disp. Income			0.00306***	0.00304***		
			(0.000281)	(0.000281)		
Constant	27706.4***	26826.1***	-88.97*	-109.5**	-4.250	-27.96
	(3972.3)	(3956.7)	(47.83)	(47.28)	(47.57)	(47.09)
Micro Variables	included	included	included	included	included	included
Observations	9092	9092	9092	9092	9092	9092
R-squared	0.127	0.128	0.270	0.271	0.220	0.222

Note: The dependent variables are equivalized disposable annual income (CHF) and monthly housing costs per household member, respectively, in German speaking Switzerland. The omitted distance category is <40 km. Method: least squares. *p<0.1, **p<0.05, ***p<0.01.

Table 2: Main specifications of life satisfaction regression

	A	B	C	D
ln(Income)	0.256***	0.254***		
	(0.0397)	(0.0396)		
Housing cost	-0.0000918**	-0.0000912**		
	(0.0000399)	(0.0000400)		
Distance (5km steps)	0.00649**		0.00662**	
	(0.00329)		(0.00330)	
Distance 40-85km		0.0998***		0.108***
		(0.0375)		(0.0378)
Distance >85km		0.0996*		0.0987*
		(0.0585)		(0.0583)
Constant	7.219***	7.254***	9.820***	9.835***
	(0.455)	(0.450)	(0.172)	(0.168)
Micro Variables	included	included	included	included
Observations	9054	9054	9054	9054
R-squared	0.171	0.172	0.164	0.165

Note: The dependent variable is 11-point life satisfaction in German speaking Switzerland. The omitted distance category is <40 km. Method: least squares. *p<0.1, **p<0.05, ***p<0.01.

Table 3: Robustness checks

	A Alternative rings	B Only obs<85km	C Overall CH	D Alternative rings	E Only obs<85km	F Overall CH
ln(income)	0.256***	0.274***	0.298***			
	(0.0397)	(0.0420)	(0.0346)			
Housing cost	-0.0000922**	-0.0000926**	-0.000113***			
	(0.0000402)	(0.0000418)	(0.0000361)			
Distance 35-65km	0.0723*			0.0759**		
	(0.0373)			(0.0375)		
Distance >65km	0.0982**			0.100**		
	(0.0499)			(0.0500)		
Distance 40-85km		0.0984***	0.0723**		0.108***	0.0813**
		(0.0375)	(0.0343)		(0.0378)	(0.0345)
Distance >85km			-0.0116			-0.00954
			(0.0498)			(0.0499)
French			-0.260***			-0.277***
			(0.0411)			(0.0411)
Italian			-0.0666			-0.0912
			(0.114)			(0.114)
Micro Variables	included	included	included	included	included	included
Observations	9054	8127	12264	9054	8145	12287
R-squared	0.171	0.178	0.170	0.165	0.171	0.162

Note: The dependent variable is 11-point life satisfaction. The omitted distance category is <40 km. Method: least squares. *p<0.1, **p<0.05, ***p<0.01.

Table 4: Effect heterogeneity (dep. variable: 11-point life satisfaction)

	A Basic	B Gender	C Education	D Age
ln(income)	0.254***	0.255***	0.254***	0.254***
	(0.0396)	(0.0396)	(0.0396)	(0.0397)
Housing cost	-0.0000912**	-0.0000917**	-0.0000919**	-0.0000913**
	(0.0000400)	(0.0000400)	(0.0000400)	(0.0000400)
Distance_40-85km	0.0998***			
	(0.0375)			
Distance>85km	0.0996*			
	(0.0585)			
Female *Distance 40-85km		0.114**		
		(0.0522)		
Female *Distance >85km		0.202**		
		(0.0804)		
Male *Distance 40-85km		0.0846		
		(0.0537)		
Male *Distance >85km		-0.00917		
		(0.0839)		
Primary Education *Distance 40-85km			0.224* (0.129)	
Primary Education *Distance >85km			0.346* (0.184)	
Secondary Education *Distance 40-85km			0.0764* (0.0456)	
Secondary Education *Distance >85km			0.0212 (0.0694)	
Tertiary Education *Distance 40-85km			0.0766 (0.0629)	
Tertiary Education *Distance >85km			0.142 (0.0976)	
Age <42 *Distance 40-85km				0.124** (0.0553)
Age <42 *Distance >85km				0.195** (0.0819)
Age >42 *Distance 40-85km				-0.0324 (0.0689)
Age >42 *Distance >85km				-0.143 (0.107)
Constant	7.254***	7.269***	7.207***	7.199***
	(0.450)	(0.450)	(0.456)	(0.457)
Micro Variables	included	included	included	included
Observations	9054	9054	9054	9054
R-squared	0.172	0.172	0.172	0.172

Table 5: Fukushima and distance to NPPs (dep. variable: 11-point life satisfaction)

	A	B	C	D	E
	11mar	19mar	27mar	obs <85	Overall CH
ln(income)	0.255***	0.256***	0.254***	0.274***	0.299***
	(0.0396)	(0.0396)	(0.0396)	(0.0419)	(0.0345)
Housing	-0.0000916**	-0.0000906**	-0.0000871**	-0.0000880**	-0.000110***
	(0.0000401)	(0.0000401)	(0.0000400)	(0.0000418)	(0.0000360)
Distance 40-85km	0.140**	0.166***	0.185***	0.184***	0.180***
	(0.0687)	(0.0587)	(0.0509)	(0.0509)	(0.0477)
Distance >85km	0.136	0.0490	0.0846		-0.0244
	(0.0981)	(0.0824)	(0.0723)		(0.0644)
Post 11mar2011	0.0439				
	(0.0501)				
POST 11mar2011 *Distance 40-85km	-0.0547 (0.0818)				
POST 11mar2011 *Distance >85km	-0.0501 (0.121)				
Post 19mar2011		0.0303			
		(0.0458)			
POST 19mar2011 *Distance 40-85km		-0.105 (0.0756)			
POST 19mar2011 *Distance >85km		0.0821 (0.114)			
Post 27mar2011			-0.00757	-0.00572	0.0279
			(0.0447)	(0.0447)	(0.0427)
POST 27mar2011 *Distance 40-85km			-0.156** (0.0738)	-0.159** (0.0738)	-0.203*** (0.0672)
POST 27mar2011 *Distance >85km			0.0282 (0.115)		0.0274 (0.0939)
French					-0.262***
					(0.0410)
Italian					-0.0681
					(0.115)
Micro Variables	included	included	included	included	included
Observations	9054	9054	9054	8127	12264
R-squared	0.172	0.172	0.172	0.179	0.171

Table A1: Variables and summary statistics

Variable	Label	Obs	Mean	Std. Dev.
Satisfaction with life in general	Life Satisfaction	9054	8.300751	1.451527
age at the time of the interview	Age	9054	50.24442	17.10805
	Age-sqr	9054	2817.155	1744.845
Gender Dummy	Male	9054	0.4697371	0.4991109
	Female	9054	0.5302629	0.4991109
Education dummy for highest level of respondents education	Primary	9054	0.1426994	0.3497853
	Secondary	9054	0.6138723	0.4868873
	Tertiary	9054	0.2434283	0.4291752
Employment status	Full-time	9054	0.3945218	0.4887747
	Part-time	9054	0.1597084	0.3663556
	Self Employed (full-time)	9054	0.0547824	0.2275676
	Self Employed (part-time)	9054	0.0241882	0.1536416
	In education	9054	0.0351226	0.1840998
	Retired	9054	0.2173625	0.412474
	Sick	9054	0.0085045	0.0918321
	Civil Service or Military	9054	0.0020985	0.045764
	Household	9054	0.0843826	0.2779761
	Other	9054	0.0050806	0.0711011
	Unemployed	9054	0.0142478	0.1185175
Marital status	Single	9054	0.2506075	0.4333868
	Married	9054	0.5797438	0.4936272
	Separated	9054	0.0174509	0.1309512
	Widowed	9054	0.0619616	0.241099
	Divorced	9054	0.0902364	0.2865359
inverse health status (1-5 where 5 is bad health)	Poor Health	9054	1.877071	0.7565889
Equivalised disposable income (yearly the ln is labled as log Income)	Equ. Disp. Inc.	9054	58271.7	39988.2
Total housing cost (including electricity, water, gas and heating)	Housing	9054	739.0691	477.9721
distance in 5 km steps	Distance	9054	8.562182	5.164097
dummy for distance 0-40km	distance 0-40km	9054	0.6251381	0.484114

dummy for distance 40-85km	distance 40-85km	9054	0.2724763	0.4452582
dummy for distance >85km	distance >85km	9054	0.1023857	0.3031716
dummy for distance 0-35km	distance 0-35km	9054	0.521427	0.4995683
dummy for distance 35-65km	distance 35-65km	9054	0.3152198	0.464629
dummy for distance >65km	distance >65km	9054	0.1633532	0.369708
dummy for interview taking place after 11th march	Post 11th march	9054	0.7200133	0.4490172
dummy for interview taking place after 19th march	Post 19th march	9054	0.6256903	0.4839709
dummy for interview taking place after 27th march	Post 27th march	9054	0.5299315	0.4991309

Table A2: Detailed estimation results

	A	B
Age	-0.0515***	-0.0514***
	(0.00730)	(0.00730)
Age^2	0.000653***	0.000652***
	(0.0000696)	(0.0000696)
Male	omitted	omitted
Female	0.161***	0.161***
	(0.0359)	(0.0359)
Primary Education	omitted	omitted
Seoundary Education	0.0637	0.0621
	(0.0668)	(0.0666)
Tertiary Education	0.0172	0.0185
	(0.0731)	(0.0729)
Self Employed	0.209***	0.210***
	(0.0686)	(0.0684)
Unemployed	-0.916***	-0.920***
	(0.227)	(0.226)
Single	omitted	omitted
Married	0.265***	0.262***
	(0.0556)	(0.0558)
Separated	-0.893***	-0.898***
	(0.216)	(0.216)
Widowed	0.212**	0.210**
	(0.0912)	(0.0912)
Divorced	-0.0325	-0.0362
	(0.0822)	(0.0825)
Poor Health	-0.652***	-0.651***
	(0.0319)	(0.0320)
Ln(income)	0.256***	0.254***
	(0.0397)	(0.0396)
Housing	-0.0000918**	-0.0000912**
	(0.0000399)	(0.0000400)
Distance	0.00649**	
	(0.00329)	
Distance 40-85km		0.0998***
		(0.0375)
Distance >85km		0.0996*
		(0.0585)
Constant	7.219***	7.254***
	(0.455)	(0.450)
Observations	9054	9054
R-squared	0.171	0.172

Figure 1: Distribution of interviews across dates

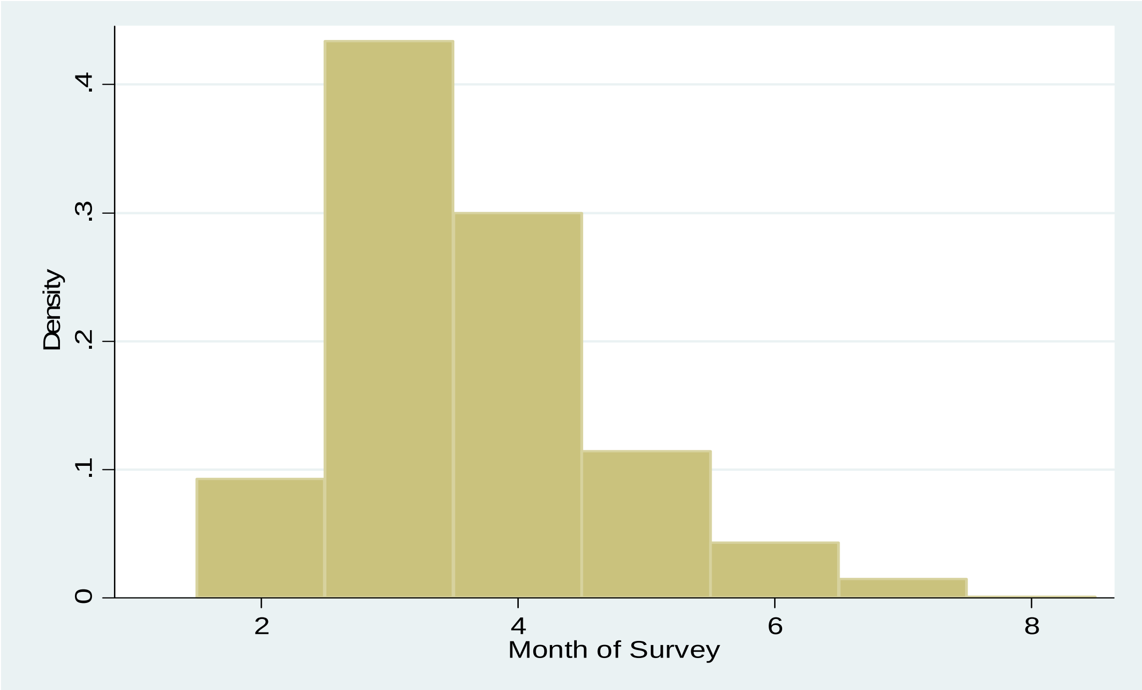


Figure 2a: Map of NPPs in Switzerland with 40km radius rings

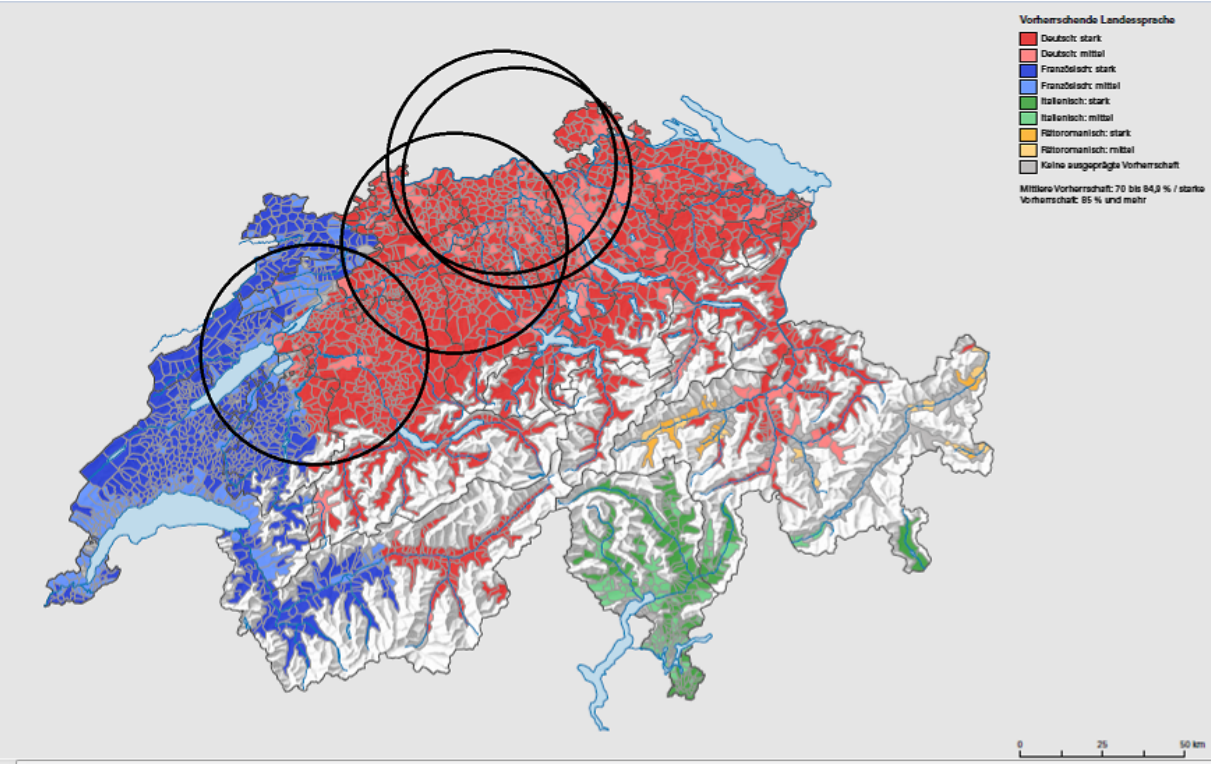


Figure 2b: Map of NPPs in Switzerland with 40km and 85km radius rings

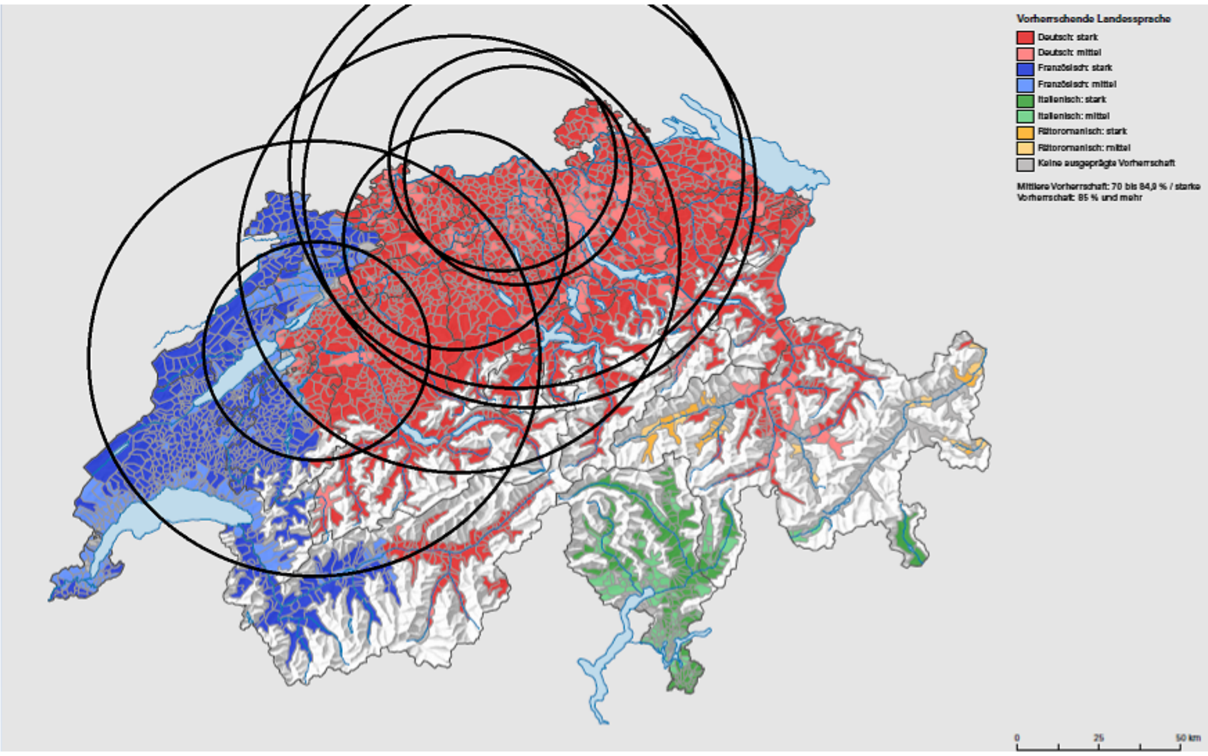


Figure 3a: Coefficient and confidence interval of the Postevent*distance 40-85km variable

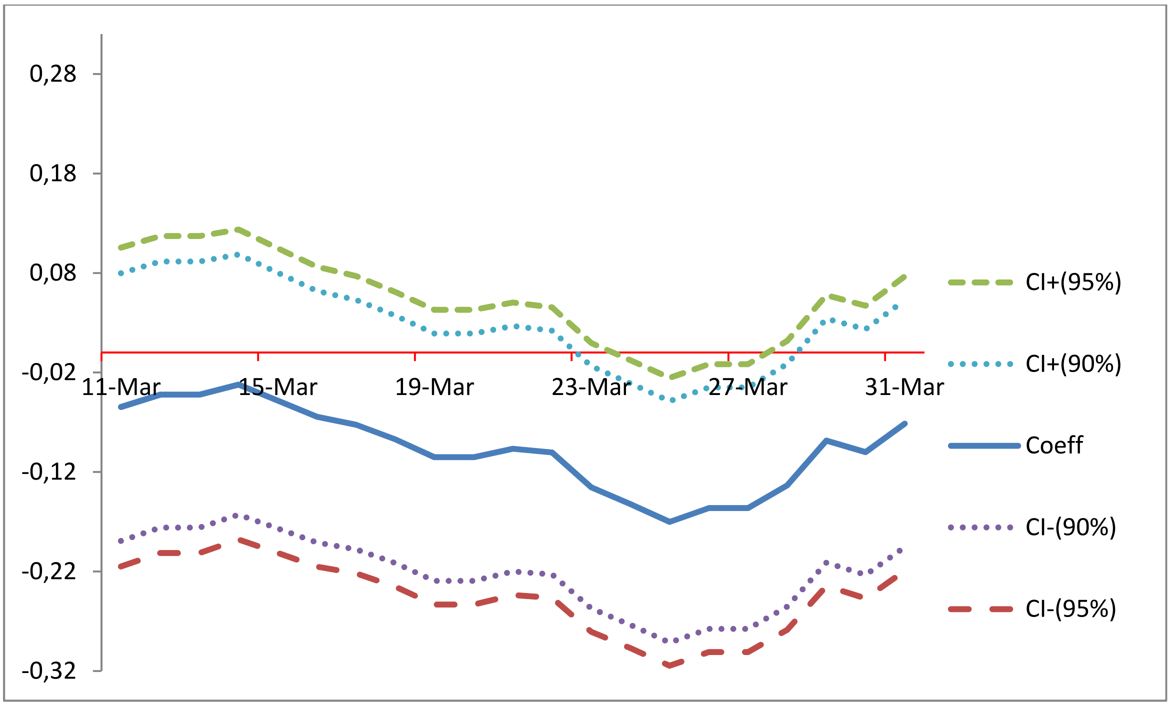
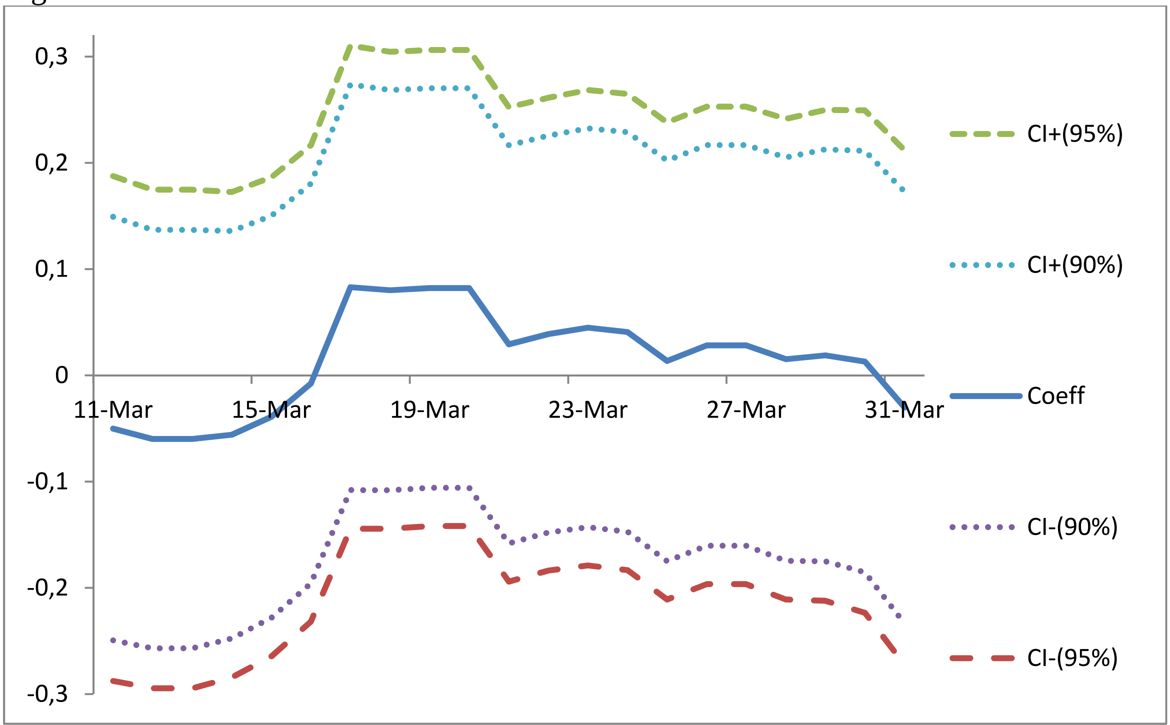


Figure 3b: Coefficient and confidence interval of the Postevent*distance >85km variable



Note: The coefficients are those of the interaction variables *postevent*distance40-85km* and *postevent*distance>85km*, respectively for alternative choices of the *postevent* date. The interaction variables are equal to 1 for persons in the respective distance category interviewed after the respective date and equal to 0 for persons interviewed before the respective date. The coefficients measure the change in the relationship between life satisfaction and the distance categories after the respective dates.

Zuletzt erschienen /previous publications:

V-375-15 **Heinz Welsch, Philipp Biermann**, Measuring Nuclear Power Plant Externalities Using Life Satisfaction Data: A Spatial Analysis for Switzerland
V-374-15 **Erkan Gören**, The Relationship Between Novelty-Seeking Traits And Comparative Economic Development
V-373-14 **Heinz Welsch, Charlotte von Möllendorff**,
V-372-14 **Heinz Welsch, Jan Kühling**, Affective States and the Notion of Happiness: A Preliminary Analysis
V-371-14 **Carsten Helm, Robert C. Schmidt,** Climate cooperation with technology investments and border carbon adjustment
V-370-14 **Christoph Böhringer, Nicholas Rivers, Hidemichi Yonezawa**, Vertical fiscal externalities and the environment
V-369-14 **Heinz Welsch, Philipp Biermann,** Energy Prices, Energy Poverty, and Well-Being: Evidence for European Countries
V-368-14 **Marius Paschen**, Dynamic Analysis of the German Day-Ahead Electricity Spot Market
V-367-14 **Heinz Welsch, Susana Ferreira,** Environment, Well-Being, and Experienced Preference
V-366-14 **Erkan Gören**, The Biogeographic Origins of Novelty-Seeking Traits
V-365-14 **Anna Pechan,** Which Incentives Does Regulation Give to Adapt Network Infrastructure to Climate Change? - A German Case Study
V-364-14 **Christoph Böhringer, André Müller, Jan Schneider**, Carbon Tariffs Revisited
V-363-14 **Christoph Böhringer, Alexander Cuntz, Diemtar Harhoff, Emmanuel A. Otoo,** The Impacts of Feed-in Tariffs on Innovation: Empirical Evidence from Germany
V-362-14 **Christoph Böhringer, Nicholas Rivers, Thomas Ruhterford, Randall Wigle**, Sharing the burden for climate change mitigation in the Canadian federation
V-361-14 **Christoph Böhringer, André Müller**, Environmental Tax Reforms in Switzerland A Computable General Equilibrium Impact Analysis
V-360-14 **Christoph Böhringer, Jared C. Carbone, Thomas F. Rutherford,** The Strategic Value of Carbon Tariffs
V-359-13 **Heinz Welsch, Philipp Biermann**, Electricity Supply Preferences in Europe: Evidence from Subjective Well-Being Data
V-358-13 **Heinz Welsch, Katrin Rehdanz, Daiju Narita, Toshihiro Okubo,** Well-being effects of a major negative externality: The case of Fukushima
V-357-13 **Anna Pechan, Klaus Eisenack**, The impact of heat waves on electricity spot markets
V-356-13 **Heinz Welsch, Jan Kühling,** Income Comparison, Income Formation, and Subjective Well-Being: New Evidence on Envy versus Signaling
V-355-13 **Christoph Böhringer, Knut Einar Rosendahl, Jan Schneider,** Unilateral Climate Policy: Can Opec Resolve the Leakage Problem?
V-354-13 **Christoph Böhringer, Thomas F. Rutherford, Marco Springmann;** Clean-Development Investments:An Incentive-Compatible CGE Modelling Framework
V-353-13 **Erkan Gören,** How Ethnic Diversity affects Economic Development?
V-352-13 **Erkan Gören,** Economic Effects of Domestic and Neighbouring Countries'Cultural Diversity
V-351-13 **Jürgen Bitzer, Erkan Gören**, Measuring Capital Services by Energy Use: An Empirical Comparative Study
V-350-12 **Heinz Welsch, Jan Kühling**, Competitive Altruism and Endogenous Reference Group Selection in Private Provision of Environmental Public Goods
V-349-12 **Heinz Welsch,** Organic Food and Human Health: Instrumental Variables Evidence
V-348-12 **Carsten Helm, Dominique Demougin,** Incentive Contracts and Efficient Unemployment Benefits in a Globalized World
V-347-12 **Christoph Böhringer, Andreas Lange, Thomas F. Rutherford,** Optimal Emission Pricing in the Presence of International Spillovers: Decomposing Leakage and Terms-of-Trade Motives
V-346-12 **Christoph Böhringer, Jared C. Carbone, Thomas F. Rutherford**, Efficiency and Equity Implications of Alternative Instruments to Reduce Carbon Leakage

V-345-12 **Christoph Böhringer, Brita Bye, Taran Fæhn, Knut Einar Rosendahl,** Alternative Designs for Tariffs on Embodied Carbon: A Global Cost-Effectiveness Analysis

V-344-12 **Klaus Eisenack und Leonhard Kähler**, Unilateral emission reductions can lead to Pareto improvements when adaptation to damages is possible

V-343-11 **Heinz Welsch and Jan Kühling**, Anti-Inflation Policy Benefits the Poor: Evidence from Subjective Well-Being Data

V-342-11 **Heinz Welsch and Jan Kühling**, Comparative Economic Performance and Institutional Change in OECD Countries: Evidence from Subjective Well-Being Data

V-341-11 **Carsten Helm and Stefan Pichler**, Climate Policy with Technology Transfers and Permit Trading

V-340-11 **Christoph Böhringer, Jared C. Carbone, Thomas F. Rutherford**, Embodied Carbon Tariffs

V-339-11 **Christoph Böhringer, Carolyn Fischer, and Knut Einar Rosendahl**, Cost-Effective Unilateral Climate Policy Design: Size Matters

V-338-11 **Christoph Böhringer and Victoria Alexeeva-Talebi**, Unilateral climate policy and competitiveness: The implications of differential emission pricing

V-337-11 **Christoph Böhringer, Bouwe Dijkstra, and Knut Einar Rosendahl**, Sectoral and Regional Expansion of Emissions Trading

V-336-11 **Carsten Helm and Franz Wirl**, International Environmental Agreements: Incentive Contracts with Multilateral Externalities

V-335-11 **Christoph Böhringer and Andreas Keller**, Energy Security: An Impact Assessment of the EU Climate and Energy Package

V-334-11 **Klaus Eisenack**, Adaptation financing as part of a global climate agreement: is the adaptation levy appropriate?

V-333-11 **Udo Ebert and Patrick Moyes**, Inequality of Well-Being and Isoelastic Equivalence Scales

V-332-11 **Udo Ebert and Heinz Welsch**, Adaptation and Mitigation in Global Pollution Problems: Economic Impacts of Productivity, Sensitivity, and Adaptive Capacity

V-331-11 **Udo Ebert**, The redistribution of income when needs differ

V-330-11 **Heinz Welsch and Jan Kühling**, How Has the Crisis of 2008-2009 Affected Subjective Well-Being?

V-329-10 **Heinz Welsch**, Stabilität, Wachstum und Well-Being: Wer sind die Champions der Makroökonomie?

V-328-10 **Klaus Eisenack**, The inefficiency of private adaptation to pollution in the presence of endogeneous market structure

V-327-10 **Udo Ebert and Patrick Moyes**, Talents, Preferences and Inequality of Well-Being

V-326-10 **Christoph Böhringer and Knut Einar Rosendahl**, Greening Electricity More Than Necessary: On the Excess Cost of Overlapping Regulation in EU Climate Policy

V-325-10 **Udo Ebert**, The decomposition of inequality reconsidered: Weakly decomposable measures

V-324-10 **Udo Ebert**, Inequality reducing taxation reconsidered

V-323-10 **Heinz Welsch und Jan Kühling**, Nutzenmaxima, Routinen und Referenzpersonen beim nachhaltigen Konsum

V-322-10 **Heinz Welsch, Jan Kühling**, Is Pro-Environmental Consumption Utility-Maximizing? Evidence from Subjective Well-Being Data

V-321-10 **Jürgen Bitzer, Ingo Geishecker, and Philipp J.H. Schröder,** Returns to Open Source Software Engagement: An Empirical Test of the Signaling Hypothesis

V-320-10 **Edwin van der Werf,** Unilateral climate policy, asymmetric backstop adoption, and carbon leakage in a two-region Hotelling model