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# Climate Change and the Willingness to Pay to Reduce Ecological and Health Risks from Wastewater Flooding in Urban Centers and the Environment

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## ABSTRACT

Climate change scenarios predict an increase of extreme rain events, which will increase the risk of wastewater flooding and of missing legal water quality targets. This study elicits the willingness to pay to reduce ecological and health risks from combined sewer overflows in rivers and lakes, and wastewater flooding of residential and commercial zones under the uncertainty of climate change. We implement a discrete choice experiment on a large representative sample of the Swiss population. We find that about 71% of the respondents are willing to pay a higher annual local tax to reduce the risk of wastewater overflowing in rivers and lakes. Swiss households strongly value the protection of water bodies, and mostly, the avoidance of high ecological risks and health risks for children related to combined sewer overflows in rivers and lakes. Our findings also show that climate change perception has a significant effect on the willingness to pay to reduce these risks. These results are important to support policy makers' decisions on how to deal with emerging risks of climate change in the water sector and where to set priorities.

**Keywords:** choice experiment; climate change; ecological risk; health risk; wastewater

**JEL Codes:** D61, D81, I10, Q25, Q51, Q54, Q57

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## 1. Introduction[1]

In the future, water management faces daunting challenges because of complex changes and large uncertainties, a prime driver being climate change (Milly et al., 2008). Climate change scenarios predict an increase of extreme rain events (May, 2008). Studies in Europe and the U.S. predict an increase of severe storms between 35-100 percent (Grum et al., 2006; Butler et al., 2007). Enhanced weather variability will substantially affect the water sector, and increase flood-related risks (e.g., Kysley et al., 2011). Intense precipitation increases the risk of wastewater flooding of urbanized areas, and combined sewer overflows (CSOs) in rivers and lakes causing an increase in ecological and health risks by missing legal water quality targets.[2] Under climate change, it is highly unlikely that the current level of services supplied by the wastewater system can be maintained without substantial additional investments into urban drainage infrastructures (Arnbjerg-Nielsen and Fleischer, 2009; MacDonald et al., 2010). This paper estimates the willingness to pay to reduce ecological and health risks related to combined sewer overflows in rivers and lakes, and sewer surcharges resulting in flooding of residential and commercial zones under the uncertainty of climate change in Switzerland.

Untreated sewage contains pathogens (e.g., bacteria, parasites, and viruses), chemicals, pharmaceuticals, and nutrients that can pose a risk to human health and the environment (Kim et al., 2007; Donovan et al., 2008; Kummerer, 2009; Ham et al., 2009; Weyerauch et al., 2010; Musolff et al., 2010). Children, the elderly, and those with a weakened immune system are particularly vulnerable to negative health effects (e.g., diarrhea, nausea, and infections). For instance, the U.S. EPA estimates that between 1.8 and 3.5 million people fall ill from recreational contact with waters contaminated by sewer overflows alone every year (U.S. EPA, 2001). In addition, wastewater overflowing into rivers and lakes implies an ecological risk for animals and water plants. For example, nutrients such as nitrogen and phosphorus can lead to eutrophication (Jankowski et al., 2006; Thevenon and Pote, 2012). Pharmaceuticals and

[1] We thank the Swiss Federal Office for the Environment, FOEN for funding this research (project number J054-2223/2010), Michael Schärer (FOEN) for his encouragement, the LINK institute (www.link.ch) for carrying out the representative survey, and in particular, Stefan Neubert and Matthias Winzer for their support, Sabine Sonderegger for the translations, Peter Rickenbacher (Gasthaus zum Weissen Kreuz, Seewen, CH) for providing pictures for the questionnaire, the interview partners for their valuable feedback to earlier versions of the questionnaire, and professors Roy Brouwer and Stefanie Engel for discussion on an earlier version of this study.

[2] For example, in Wisconsin it is expected that the frequency of combined sewer overflows into Lake Michigan will rise by 50–120 percent by the end of this century, threatening the usability of recreational beaches (Patz et al., 2008). Likewise, simulations of waste and stormwater flows under climate change in Sweden are predicted to worsen existing drainage problems (Semadeni-Davies et al., 2008). In Norway, the number of CSOs is expected to increase 1.5-3 times as much as the increase in precipitation (Nie et al., 2009).

personal care products contained in the wastewater pose a risk to the aquatic life even at low concentrations (Daughton and Ternes, 1999; Kolpin et al., 2002; Ankley et al., 2007).

A number of studies have simulated the effects of increased heavy precipitation under climate change scenarios on the urban drainage system. They all conclude that the current wastewater system is likely inadequate to deal with the excess water (and sewage in combined systems). Examples of such simulations come from the UK (Butler et al., 2007), Sweden (Semadeni-Davies et al., 2008), the U.S. (Patz et al., 2008), and Norway (Nie et al., 2009). Urban drainage systems have to cope with climate change that may seriously affect urban planning, and adaptation strategies must be defined and implemented to reduce ecological and health risks.

Engineers have different technical solutions to counter the effects of climate change on the wastewater sector. For instance, to reduce CSOs, it is possible to build wastewater retention tanks that buffer the wastewater during rain events; to reduce wastewater flooding of streets and cellars it is possible to build larger sewers (Butler et al., 2007). However, these countermeasures to climate change require substantial investments. For countries such as France, Germany, Italy, UK, and U.S.A., the replacement values for the public system are typically 2,600 US$ $cap^{-1}$ and for small countries such as Austria, Denmark, and Switzerland 4,800 US$ $cap^{-1}$ (Maurer et al., 2005).[3] Therefore, an estimate of the benefits from adapting the sewer system to maintain current service levels under climate change is needed.

This interdisciplinary study estimates the benefits of adapting the wastewater discharge system to climate change to reduce ecological and health risks from three events: (i) combined sewer overflows in rivers and lakes, which are likely to increase the ecological and human health risks, (ii) sewer surcharges in streets resulting in flooding of residential and commercial zones, which induce personal and communal disutility for instance by disrupting the traffic; and iii) sewer surcharges of cellars, which result in personal disutility to the people owning cellars.

This study implements a discrete choice experiment to elicit the willingness to pay to reduce these risks in Switzerland. A representative survey among the Swiss adult online population from a panel of about 110,000 members of the Italian, French and German parts of Switzerland was conducted. The final representative sample of the Swiss population amounts to 1,022 interviews. The final dataset contains a rich set of variables. Information has been

[3] In Switzerland, generations of engineers have developed a highly advanced water supply and wastewater infrastructure system – financed by the population – that provides highest quality services to all. This infrastructure is expensive; the replacement value has been estimated at $218 \cdot 10^9$ CHF, with $6.3 \cdot 10^9$ CHF annual costs. It is also worth to note that in Switzerland 70% of the sewer system is combined and that pure separate systems are rare (Maurer and Herlyn, 2006; Martin, 2009).

gathered on the perception of climate change, the level of concern associated with the previous events about human health (children and adults, separately), and the environment. Respondents were asked to pick the most preferred option among a choice set of two alternatives. Each option differs from the others (i) in the type of event (wastewater flooding of cellars, wastewater overflowing in rivers and lakes, wastewater flooding of streets); (ii) in the average number of occurrences of an event; (iii) the health risk related to the event defined in terms of total cases of illness per year; (iv) the population affected (children or adults); (v) the ecological risk; and (vi) the cost (higher local taxes).

An additional attribute describing the scientists' confidence in the prediction for the average number of occurrences of the event has also been included for half of the sample. This treatment allows us to test whether climate change uncertainty influences respondents' willingness to pay. Indeed, the outcomes of policy measures are not known to the researcher with certainty, in particular, in the context of climate change. However, typically in economic valuation it is assumed that the outcomes are certain as if they could be predicted accurately. Only recently, a couple of studies started to include the outcome uncertainty in stated preference surveys (Roberts et al., 2008; Gleck and Colombo, 2011). For example, Roberts et al. (2008) show that including uncertainty in the environmental outcomes affects the willingness to pay of people for water quality. Our study also contributes to this literature by presenting realistic scenarios that account for the uncertainty in outcomes because of climate change.

Our results show that Swiss households strongly value the protection of water bodies, and are concerned about the consequences of wastewater surcharges on the environment and on human health. We find that about 71% of the respondents are willing to pay a higher annual local tax to reduce the risk of wastewater overflowing in rivers and lakes. Our findings also suggest that climate change perception has a significant and positive effect on the willingness to pay to reduce these risks: people that perceived long term changes in climate are significantly more willing to pay to reduce these risks than people that did not perceive any change. These results are important to support policy makers' decisions on how to deal with emerging risks of climate change in the water sector and where to set priorities.

## 2. Literature Review

Flood risks have been the main focus of studies addressing climate change, namely in the Netherlands, where severe effects are to be expected (e.g., Botzen et al., 2009), (Botzen and van den Bergh, 2012), but also in Scotland, the U.K. (Glenk and Fischer, 2010), or the U.S.A. (see the meta-analysis by Daniel et al., 2009). With respect to infrastructures, a number of studies have focused on the provision of (potable) water. Various studies concern developing countries, which face quite different problems than industrialized countries (see e.g., the meta-analysis by Abramson et al., 2011), or a contingent valuation study about water supply in an Andean watershed (Moreno-Sanchez et al., 2012). In industrialized countries, the willingness to pay for the (uninterrupted) provision of potable water to households or the willingness to accept interruptions was elicited e.g., in the USA (Griffin and Mjelde, 2000), Australia (MacDonald et al., 2005); (MacDonald et al., 2010) and in Spain in the context of the European Water Framework Directive (Martin-Ortega et al., 2011). The latter study, for example, found a high willingness to pay, not only to secure the household's own water provision, but also to maintain a good ecological status of the river.

The willingness to pay for high ecological water quality has been elicited in a number of studies, but often without explicitly mentioning the wastewater infrastructure (see reviews of economic valuation for water resources Birol et al., 2006) and stormwater management (Braden and Johnston, 2004). An early contingent valuation study elicited the willingness to pay for minimum water quality levels for boating, fishing or swimming in the USA (Carson and Mitchell, 1993). This was followed by a later large study concerning the value of water quality (Viscusi et al., 2008). An Australian contingent valuation study focused on protest responses, using the example of stormwater pollution abatement (Jorgensen and Syme, 2000). While methodologically very interesting, the suggested policy measures, however, were not related to the wastewater infrastructures. In some European countries, wastewater is still not treated state-of-the-art; and several contingent valuation studies from Greece elicited the populations' willingness to pay to install or operate a wastewater treatment plant (e.g., Genius et al., 2012). A recent paper concerning the influence of the respondents' political orientation in choice experiments is based on three earlier studies about the services provided by water supply and wastewater infrastructures in the UK, one of them also concerns upgrades of the wastewater treatment plan to reduce eutrophication (Dupont and Bateman, 2012).

We found two studies that specifically addressed health risks associated with low bathing water quality. The first had a methodological focus, the temporal stability of contingent values in dichotomous choice experiments (Brouwer, 2006). The problem was addressed with two identical studies before and during the extreme conditions of the very hot summer 2003. As measures to implement more stringent bathing water quality standards, different upgrades of the wastewater system were proposed, such as increasing the storage capacity of sewers or disinfection of wastewater. The second study was a choice experiment in Canterbury, NZ that estimated the population's willingness to pay for improving the ecological water quality of rivers, reducing the risk of sickness and the number of months that a river is in low flow (Tait et al., 2012). However, this study is not directly linked to climate change and the wastewater infrastructures.

In Australia, a choice experiment elicited the willingness to pay of households to avoid interruptions in water service as well as overflows of wastewater into the houses, near houses or in sewer manholes in the street (Hensher et al., 2005). Here, the customer's main concern about wastewater overflows was hygiene, but specific attributes addressing the effects of overflows on receiving waters were not included. In contrast, a choice experiment in the UK included water supply as well as sewage flooding into properties and the effects of wastewater on water quality (Willis et al., 2005).

In conclusion, we are not aware of any study that directly combines climate change with an upgrade of the wastewater infrastructures to protect human health and the ecological quality of receiving waters under uncertainty.

## 2. Data and Methods

### *2.1. Sample Selection and Data Description*

We implemented a representative stated preference online survey of the Swiss population. Respondents were randomly selected from a panel of the institute for opinion research LINK consisting of about 110,000 members of the Italian, French and German parts of Switzerland. Panel members are representative of the Swiss population between 15 and 74 years of age that uses the internet at least once a week for private purposes. The questionnaire was tested and modified in several steps to account for the respondents' understanding of the choice tasks, the adequacy of the number of policy options, attributes and levels, and the duration of the survey. In a first step, 15 one-to-one interviews in German and English were carried out in July–August 2010. In September 2010 an internet pre-test was carried out by LINK with 55 respondents in the German part of Switzerland; the questionnaire was again adapted, translated to French and Italian, and pretested with another 22 respondents. The final survey was administered online by LINK in November–December 2010 in the three linguistic regions of Switzerland. A random selection of 4,270 panel members (from a total of about 110,000 panel members) received an invitation by email. The response rate was 33%, which is in the range usually found for stated preference surveys (Brouwer, 2006). We had to drop an additional 381 individuals because they did not complete the survey. The final sample consists of 1,022 individuals: 513 women and 509 men. The average age of the respondents is 41 years. A summary of the socio-demographic characteristics of our sample is presented in Table 1.

Our sample shows that 78% of the respondents perceived long term changes in precipitation and/or temperature in Switzerland. Climate change is of high or very high concern for 35% of the respondents while 45% have medium concern. Respondents are in general satisfied with the Swiss wastewater system (84% revealed high or very high satisfaction), and most of them (94%) have already experienced some adverse events related to wastewater (in Switzerland or in another country). The most commonly cited event is smelling wastewater (82%). More than half of the respondents (58%) have also experienced a prohibition to bathe in a lake or a river because of wastewater in the water, and around the same percentage (56%) has already seen algae in rivers or lakes. Nearly 30% of the respondents have experienced a street and/ or a cellar flooding with wastewater. Respondents are quite often in contact with water bodies, as only 20% answered that they rarely or never go to rivers or lakes; and 25% of the respondents have already taken measures to avoid wastewater entering the cellar.

< insert Table 1 about here >

*2.2 Survey Instrument*

The survey was organized in six sections: the first section elicited climate change perceptions by asking whether respondents noticed any long term changes in temperature and/or rainfall in Switzerland, and whether they were concerned about an increase in heavy rainfall in Switzerland in the next 20 years because of climate change. The second section focused on the respondents' knowledge of the wastewater system and composition, their level of satisfaction with the current wastewater system, and their past experience with events related to wastewater such as streets, cellars or garages flooded with wastewater, prohibition to bathe in rivers or lakes, algae blooming in river and lakes, or illnesses contracted because of contact with wastewater. In addition, at the end of this section we provided information about the wastewater composition, the wastewater system, and the effects of climate change on the Swiss wastewater system to ensure that respondents had sufficient knowledge to make an informed decision in the choice experiment. The third section elicited the level of concern about wastewater flooding of cellars, streets, and overflowing in rivers and lakes (CSOs) including the level of concern about possible effects of these events on the health of adults, children, and the environment. The fourth section was designed to communicate the concepts of the average number of occurrences of an event, and the probability of forecasts. The probability of the forecast describes the scientists' confidence in the prediction of the average number of occurrences of the event. Box 1 presents the definition and an example of these concepts. In particular, we adapted probability communication techniques by Adamowicz et al. (2011) to the case of two cities with equal number of occurrences but different probability of the forecast, and tested whether respondents' understood these concepts. About 93% of the respondents correctly answered the control question.

The fifth section introduced the policy object of study and presented the choice experiment. The last section of the survey focused on socio-demographic characteristics of the respondents including their risk attitudes, and political orientation.

The goal of the policy was described as follows:

*"The goal is to lower the risk of the following three events in the next 20 years:*

*(i) wastewater flooding of streets;*

*(ii) wastewater overflowing in rivers and lakes;*

*(iii) wastewater flooding of cellars.*

*To lower the risk of wastewater flooding of streets or cellars, it is possible to build bigger sewer pipes. To lower the risk of wastewater overflowing in rivers and lakes, it is possible to build retention tanks to store the wastewater during the rainfall. Without these measures, all three events may occur within the next decades.*

*Below you will have the opportunity to choose between two options. Each option*

- *lowers the number of occurrences of one event but not of the other;*
- *can imply different health and ecological risks;*
- *can cost a different amount of money. A cost of 0 CHF means that no measure will be taken."*

To minimize protest responses, we described the policy as an "extraordinary upgrade" of the wastewater system to address climate change effects and not as a regular upgrade. Then, we emphasized that additional funding were needed to achieve this goal, and that the money collected would have been devoted exclusively to upgrading the wastewater system. To account for substitution and income effects, we added that the respondent should keep in mind his/her income level, and that paying for the policy option would have meant having less money for other things that the respondent and his/her family could have needed.

*2.3. Discrete Choice Experiment*

Discrete choice experiments have been applied in many different fields such as community health improvement (e.g., Bosworth et al., 2009), contaminated site cleanup (e.g., Alberini et al., 2007), environmental quality (e.g., Viscusi et al., 2008), or river rehabilitation (e.g., Loomis et al., 2000). In choice experiments respondents are shown alternative options of a good or policy. The options differ from one another in the levels taken by two or more of their attributes. The attributes are not "purchased" separately (or separately integrated into the options), but come in a bundle, which also includes the cost of the respective option. Respondents are then asked to pick their most preferred option.

We implemented a fractional factorial experimental design to identify the combination of attributes and options in a choice set (Louviere et al., 2000; Adamowicz et al., 2011).[4] In particular, respondents were presented with three randomly assigned choice questions, one question for each event: wastewater flooding of streets, wastewater flooding of cellars, and wastewater overflowing in rivers and lakes. In each question, the respondents were asked to choose the most preferred of two possible options (Figure 1): (A) a costly option corresponding to the implementation of the policy that would upgrade the wastewater system to adapt to climate change; (B) a non-costly option corresponding to the future scenario of no policy implementation. This implies no extra costs for the taxpayer but higher health and/or ecological risks in the future. We define this non-costly option as the "future quo." The decision to compare only two options of which one is non-costly was dictated by the pre-tests. Respondents showed cognitive difficulties in choosing between three options that were characterized by different attribute levels. In addition, in our context the standard approach to use a "status quo" option that is fixed for all respondents would not have been realistic. In our case, the "status quo" corresponds to a "future quo" that is uncertain given climate change. This implies that we do not have one fixed status quo scenario that is equal for everybody; rather we have different "future quo" scenarios that we randomly assigned to the respondents.[5]

< insert Figure 1 about here >

[4] We used Ngene 1.0.2 for the experimental design.

[5] One could argue that this study is not a discrete choice experiment because of the binary choice between a costly and a non-costly option. However, we want to emphasize that our study satisfies the two essential elements of discrete choice experiments identified by Carson and Louviere (2011): "(1) a respondent is asked to make a discrete choice between two or more alternatives in a *choice set*, and (2) the alternatives presented for choice are constructed by means of an *experimental design* that varies one or more attributes *within*-and/or *between* respondents to be able to estimate economic quantities ties to preference parameters" (p. 542-543).

Each option is described by seven attributes: (i) the type of event (wastewater flooding of cellars, wastewater overflowing in rivers and lakes, wastewater flooding of streets); (ii) the average number of occurrences of an event (e.g., 1 flooding in 20 years); (iii) the health risk related to the event defined in terms of total cases of illness per year; (iv) the population affected (children or adults), (v) the ecological risk (very low, low, medium, high, very high), (vi) the cost represented by a higher annual local tax, and (vii) the probability of the forecast as described above (Box 1). The latter attribute has been included randomly for half of the sample. The purpose of this split sample treatment was to test how uncertainty in the scenario influences the respondents' willingness to pay. Table 2 summarizes the attributes and their levels.

< insert Table 2 about here >

The levels of the attributes were defined with the help of experts, mainly engineers at the Swiss Federal Institute of Aquatic Science and Technology (Eawag),[6] with data from cantonal and municipal services in wastewater treatment, and from scientific publications. The "probability of the forecast" describes the scientists' confidence in the prediction of the average number of occurrences of the event. The medium level of the "average number of occurrences of an event" corresponds about to todays' situation; lower levels correspond to an improvement of the situation, and higher levels to a degradation (because of climate change). The frequency of wastewater flooding of streets and cellars was estimated according to the common practice for dimensioning wastewater pipes in Switzerland (return periods of 5–10 years). The frequencies of combined sewer overflows (CSOs) were determined after Waeber (2009) and with the help of the municipality of Lausanne. The numbers of "cases per event" were derived from concentrations of bacteria in water (Dufour, 1984; Patz et al., 2008), and a rough estimation of how many people could get into contact with the wastewater.[7]

We minimized overloading of the respondents by reducing the variation of the attributes. For example, the two alternatives (A) and (B) always displayed an identical event and identical probability of the forecast. However, the type of event and the percentage of the

[6] www.eawag.ch

[7] These numbers for the attributes are only rough estimations. They were necessary to give realistic orders of the magnitude of effects to the respondents, but they should not be considered as reference values.

probability were randomly selected. After the choice questions, we also elicited which attributes were most important in taking the decision.

*2.4 Econometric Model*

In this study, we apply the mixed logit model (McFadden and Train, 2000; Train, 2003) to address some limitations of the standard conditional logit model (McFadden, 1974) such as homogenous preferences and the assumption of the independence of irrelevant alternatives (IIA) (Hausman and McFadden, 1984). In the standard conditional logit model, it is assumed that the choice between the alternatives is driven by the respondent's underlying utility, which we denote as *U*. Respondents are assumed to choose the alternative *j* in the choice set that results in the highest utility. Formally, a respondent chooses alternative *k* from the choice set *S* of alternatives if and only if $U_k > U_j, \forall j \neq k \in S$. The respondent's utility *U* is broken down into two components. The first component, which we denote as $V(\mathbf{X_{ij}}, \boldsymbol{\beta})$ is deterministic, and it is assumed to be a function of a vector **X** of the attributes of the alternatives including their cost, and the socio-demographic characteristics of the individual *i* such as gender, age, education, marital status, income, region of residence (Italian, French or German part of Switzerland), risk preferences, political orientation, and whether the respondent perceived climate change (see Table 1 for the full list of variables).[8] The socio-demographic variables were included as interactions with the alternative-specific constant (ASC). The second component is a random component ($\varepsilon$), which captures individual- and alternative-specific factors that influence utility but are not observable to the researcher (Alberini et al., 2006). Formally, $U_{ij} = V_{ij}(\mathbf{X_{ij}}, \boldsymbol{\beta}) + \varepsilon_{ij}$.

In the mixed logit model, unlike the standard conditional logit model, heterogeneity in preferences is accounted for by allowing the vector of parameters $\boldsymbol{\beta}$ to vary among individuals with values that depend on a underlying distribution *f*, which captures the respondents' random taste. However, the probability that individual *i* chooses a sequence of alternatives cannot be solved analytically, and so it is simulated by maximum simulated likelihood method (Train, 2003).[9]

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[8] The risk attitude was elicited using an estimation of the certainty equivalent (CE) of the respondents. Respondents were given the choice between two outcomes that occur with a certain probability (i.e., a lottery) and a sure outcome (i.e., occurring with 100% probability). If CE equals 0.5 the respondent is assumed to be risk neutral; the closer to zero CE is the more risk loving the respondent is; and the closer to one CE is the more risk averse the respondent is.

[9] We used 500 Halton draws for the maximum simulated likelihood estimation.

**3. Results**

Table 3 shows the average concern for wastewater-related events on the health of children and adults, and on the environment. Respondents are very concerned about the effect of combined sewer overflows (CSOs) and pharmaceuticals in wastewater on the health of adults (respectively, about 60% and 63% have a high or very high level of concern), on the health of children (73% and 77%, respectively), and on the environment (75% and 77%, respectively). In contrast, they are the least concerned about the effects of street and cellar flooding on the health of adults and children, and on the environment. However, the respondents showed an increased concern for the effect of street flooding on the environment compared to cellar flooding (54% versus 42%). This shows that the respondents were aware that wastewater that floods streets can reach the environment while that wastewater that floods cellars is usually pumped back to the sewers.

< insert Table 3 about here >

These results are confirmed by the analysis of the willingness to pay to reduce these events. We find that about 71% of the respondents are willing to pay a higher annual local tax to reduce the risk of wastewater overflowing in rivers and lakes while about 54% are willing to pay to reduce the risk of flooding in streets and about 43% of cellars. Table 4 presents the estimated coefficients by the mixed logit model, and Table 5 reports the marginal willingness to pay as an annual increase of local taxes. The marginal willingness to pay of each attribute is computed as the negative of the coefficient on that attribute, divided by the coefficient on the cost variable reported in Model 1 of Table 4 (Alberini et al., 2006).

< insert Table 4 about here >

As predicted by the theory, the percentage of respondents willing to pay an annual local tax significantly decreases as the cost increases (at the 1% significance level); as the scientists' confidence in the prediction of the average number of occurrences of the event increases, then the willingness to pay seems to increase as well, as expected. However, the mean willingness to pay of the average respondent in the subsample that included the attribute related to the forecast confidence is not statistically different from the willingness to pay of the average respondent in the subsample without this attribute. This implies that the inclusion of the uncertainty in the scenario did not have a significant effect, and so we pool the two subsamples.

< insert Table 5 about here >

As expected, we find that as the number of occurrences of an event increases, then the willingness to pay increases, and respondents are willing to pay more to avoid high and very high ecological risks (CHF 188 and CHF 259, respectively) than to guarantee very low or low ecological risks (CHF 102 and CHF 70, respectively). In addition, we find that the average respondent is significantly willing to pay more for a scenario where the risk reduction concerns the health of children than a scenario where the population affected consists of adults.

Our results also suggest that the highest mean willingness to pay is associated with reducing the risk of wastewater overflowing in rivers and lakes, and the lowest willingness to pay with reducing the risk of wastewater flooding of cellars. In particular, the average respondent is willing to pay CHF 1,218 higher annual local taxes (that is, about CHF 100 per month, and about 1% of household average annual income) to reduce the risk of wastewater overflowing in rivers and lakes, CHF 430 more per year (about CHF 36 per month) in local taxes to reduce the risk of wastewater flooding of streets, and CHF 145 (CHF 12 per month) to reduce the risk of wastewater flooding of cellars.[10] Focus groups showed that this lower willingness to pay to prevent cellar flooding might be related to the fact that cellars are usually insured for these damages, and people stated that it is the responsibility of the owner to take self-protection measures against flooding of cellars, and not of the public.

Internal validity of the willingness to pay responses can be checked by showing that the willingness to pay correlates in predictable ways with socio-economic variables. We estimate a second model where we include the socio-demographic characteristics of the respondents, and in particular, whether they perceived long term changes in temperature and/or precipitation. This model shows that climate change perception has a significant positive effect on the willingness to pay to reduce the risks. In addition, wealthier respondents and those with a higher education are willing to pay more, while respondents that are rarely in contact with water bodies and risk loving respondents are willing to pay less. We also find that the political orientation of the respondents has a significant effect on the willingness to pay. Left-wing respondents have a significantly higher willingness to pay than right-wing respondents. In contrast, age, gender, and location do not seem to affect the willingness to pay: older and younger persons, male and

[10] These values might appear as very high estimates. However, they should be interpreted at the household level and considering that the average household annual income is about CHF 120,000.

female, German, French, and Italian speaking respondents, and persons living in urban or rural areas do not have significantly different willingness to pay.

Finally, we asked the respondents to rank the attributes they used in choosing an alternative. The most important attribute to help choosing between the two alternatives were the consequences on the environment and health, with 84% and 79% of the respondents, respectively, answering “important” or “very important”. The cost (64% of people saying that it was important or very important) came in third position, followed by the number of events (60%). The probability of occurrence was the least important characteristic for choosing between alternatives (54%).

## 4. Discussion and Conclusions

This study investigated the willingness to pay to reduce the ecological and health risks associated with three events: (i) wastewater overflowing in rivers and lakes; (ii) wastewater flooding of streets; and (iii) of cellars. We carried out a survey among 1,022 respondents in the three linguistic regions of Switzerland. Our results show that Swiss households are concerned about climate change and its effects on the wastewater system. The effects of combined sewer overflows (CSOs) in lakes and rivers on the health of children and on the environment are of high priority. We find that about 71% of the respondents are willing to pay a higher annual local tax to reduce the risk of wastewater overflowing in rivers and lakes while about 54% are willing to pay to reduce the risk of wastewater flooding of streets and about 43% of cellars.

Our results show a very high willingness to pay to reduce the frequency of CSOs in rivers and lakes with respect to the willingness to pay to reduce the risks of wastewater surcharges in streets and cellars, which are associated with low ecological risks. One must keep in mind that the absolute numbers may seem very high from an international perspective. However, in Switzerland income and general costs are higher than in most other countries. Even the highest elicited willingness to pay of about CHF 1,200 higher annual local taxes (that is, about CHF 100 per month) amounts to 1% of the annual household income. Moreover, Switzerland in general places strong importance on clean water. This can be seen with the recent decision of the Federal Office for the Environment (FOEN, 2012) to upgrade the 100 largest wastewater treatment plants (of totally 700 wastewater treatment plants) with a fourth treatment step to approximately halve micropollutants in water bodies. It is estimated that the investments will amount to CHF 1.2 billion. We are not aware that any other country has taken such far-reaching decisions to date to keep micropollutants away from water bodies. Also in other areas than water protection, Switzerland has been found as one of the countries in the world with very high environmentally-friendly behavior (Kaiser et al., 2000; Binder and Mosler, 2007). Given the results of our representative nationwide survey, the intended measures of the Swiss Federal Office for the Environment to reduce micropollutants in water bodies for environmental (and precautionary) reasons will likely be met with high acceptance by the Swiss population.

It is difficult to make a direct comparison about the willingness to pay found in other studies not only because the attributes of the scenarios are different, but also because the context is different. To the best of our knowledge, none of the existing studies elicited the willingness to pay for an extraordinary upgrade of the wastewater system to protect the environment and human health because of wastewater overflowing under climate change. Nevertheless, our results are supportive of previous findings of high willingness to pay to reduce ecological and health risks (e.g., Willis et al., 2005; Martin-Ortega et al., 2011).

In addition, our willingness to pay estimates show what services offered by the Swiss wastewater system are most important to the citizens, and they are a measure of the value that citizens assign to the benefits of these investments. Then, these benefits can be compared with the cost of improving the services. This allows the policy maker to identify the net welfare gains from different investments and to set priorities. Our results show that Swiss households value in particular the quality of water bodies, and priority should be given to an upgrade of the wastewater system that implements additional measures to avoid CSOs in rivers and lakes and protect the environment and human health. However, we also wish point out that we did not fully capture all services of the urban drainage and wastewater system. We tried to avoid overloading the survey with attributes that can be considered as less relevant in the context of climate change (e.g., smell).

Interestingly, we also find that the political orientation of the respondents has an influence on their willingness to pay. Left-wing respondents have a higher willingness to pay than right-wing respondents. Our result supports previous findings that liberal or left-oriented respondents are more supportive of policies towards environmental protection (Dunlap et al., 2001; Neumayer, 2004; Dupont and Bateman, 2012; Tobler et al., 2012). Finally, our study contributes to the recent literature on introducing the uncertainty of the outcomes in stated preference survey instead of presenting scenarios as if the outcomes were certain (Roberts et al., 2008; Gleck and Colombo, 2011). We find that the uncertainty in the scenarios does not seem to affect the willingness to pay of respondents. This is in contrast to the findings of Roberts et al. (2008), who show that including uncertainty in the environmental outcomes affects the willingness to pay of people for water quality.

In our opinion there is still insufficient evidence that concerns willingness to pay choices under uncertainty. A recent review of the psychological literature concludes that not only the probability information provided to respondents is important, but also the context, in which the message is presented (Vischers et al., 2009). Our results indicate that our respondents might have used simple heuristics to process the probability information. This is in line with psychological findings. However, how such cognitive limitations can best be avoided when designing choice experiments that include risk information remains to be tested. Further research should be directed at refining the communication of uncertainty about the outcomes, in particular under the context of climate change. With respect to choice experiments, we suggest that future research should test how different levels of uncertainty can be included in the choice sets, and how this information affects the welfare estimates.

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**Box 1** Example of “probability of forecast” communication

**Average number of occurrences of an event**
In the following sections, we will often speak in terms of “average number of occurrences of an event.” For example, we will speak in terms of 2 street floodings in 20 years or one event per 10 years. Specialists say that it has a return period of 10 years.
Rain are random events. There is no certainty that a rain event will happen. The return period defines the probability that a specific event is exceeded within a time period.

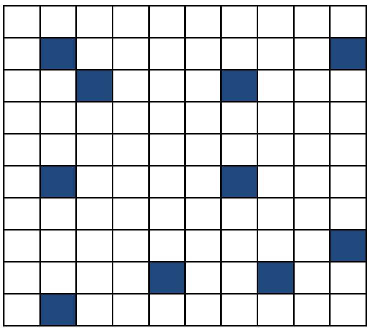
**Probability of the forecasts**
We don’t know exactly what the future will be. Therefore, the forecasts of the future always involve uncertainty. A typical example is the probability of rain in the weather forecasts. We don’t know exactly how much more heavy rainfalls will occur because of climate change. For this reason, we use a “probability of the forecast” for the average number of occurrences of an event. This is the probability estimated by specialists and that characterizes the confidence in the prediction. For example, a probability of a forecast of 80% means that the number of occurrences of a given event will be reached or exceeded in 80 of 100 calculations by the climatic models. The bigger the probability of the forecast is, the more confidence in the prevision the specialists have.

**For example:**

**City A**

Average number of occurrences =
4 street floodings in 20 years

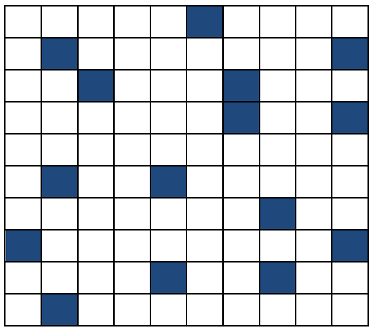
Probability of the forecast = 10%



**City B**

Average number of occurrences =
4 street floodings in 20 years

Probability of the forecast = 15%



**C4. Which city is more likely to experience a street flooding in the next 20 years?**

**Table 1**

Descriptive statistics.

| Variable | Description | Mean | Std. Dev. |
|---|---|---|---|
| Male | = 1 if male; 0 otherwise | 0.498 | 0.500 |
| Vocational School | = 1 if school degree from vocational school; 0 otherwise | 0.388 | 0.487 |
| High School | = 1 if school degree from high school; 0 otherwise | 0.133 | 0.340 |
| Technical University | = 1 if school degree from technical university; 0 otherwise | 0.166 | 0.372 |
| University | = 1 if school degree from university; 0 otherwise | 0.228 | 0.420 |
| Age | age in years; 0 otherwise | 41.046 | 14.638 |
| Risk Loving | = 1 if risk loving; 0 otherwise | 0.273 | 0.446 |
| Risk Adverse | = 1 if risk adverse; 0 otherwise | 0.233 | 0.423 |
| Annual Household Income | annual household income in CHF / 100; 0 otherwise | 1,210.685 | 677.992 |
| French Part | = 1 if living in the French part of Switzerland; 0 otherwise | 0.265 | 0.441 |
| Italian Part | = 1 if living in the Italian part of Switzerland; 0 otherwise | 0.113 | 0.316 |
| Urban | = 1 if living in an urban area; 0 otherwise | 0.720 | 0.449 |
| Contact with Water Rare | = 1 if respondent rarely goes to rivers/lakes and gets in contact with the water for example by swimming, fishing, sailing; 0 otherwise | 0.215 | 0.411 |
| Contact with Water Sometime | = 1 if respondent sometime goes to rivers/lakes and gets in contact with the water for example by swimming, fishing, sailing; 0 otherwise | 0.409 | 0.492 |
| Political Orientation Center | = 1 if political orientation is center; 0 otherwise | 0.585 | 0.493 |
| Political Orientation Left | = 1 if left-wing; 0 otherwise | 0.102 | 0.302 |
| No Political Orientation | = 1 if without political orientation; 0 otherwise | 0.254 | 0.436 |
| Climate Change Perception | = 1 if perceived long term changes in temperature and/or precipitation in Switzerland | 0.781 | 0.414 |

Note: Total number of observations is 1,022.

| | Option A | Option B |
|---|---|---|
| Event | Wastewater overflow in rivers and lakes | Wastewater overflow in rivers and lakes |
| Probability of the forecast | 30% | 30% |
| Average number of occurrences of an event | 100 wastewater overflows in 20 years (5 per year) | 600 wastewater overflows in 20 years (30 per year) |
| Health risk (total number of cases of illness) | 250 cases among children per 100 events (total number of cases of illness in 20 years: 250) | 250 cases among children per 100 events (total number of cases of illness in 20 years: 1500) |
| Ecological risk | Medium | High |
| Cost to you (increase in your local tax) | CHF 120 per year (CHF 10 per month) | CHF 0 per year (CHF 0 per month) |

**Fig. 1:** Example of choice question.

**Table 2**
Attributes and levels of the choice experiment.

| Attributes | Levels |
|---|---|
| Event [(a)] | Wastewater flooding of cellars<br>Wastewater flooding of streets<br>Wastewater overflowing in rivers/lakes (CSOs) |
| Probability of the forecast [(a)] | 10%, 30%, 50%, 70%, 90% |
| Average number of occurrences of an event [(b)] | 1 flooding in 20 years[1,2]<br>2 floodings in 20 years[1,2]<br>4 floodings in 20 years[1,2]<br>100 wastewater overflows in 20 years (5 per year)[3]<br>600 wastewater overflows in 20 years (30 per year) [3]<br>1’000 wastewater overflows in 20 years (50 per year) [3] |
| Population at risk [(a)] | Children, Adults |
| Health risk [(b)] | 20 cases per event[1,2]<br>40 cases per event[1,2]<br>60 cases per event[1,2]<br>250 cases per 100 events[3]<br>500 cases per 100 events[3]<br>750 cases per 100 events[3] |
| Ecological risk [(b)] | Very low[1,2,3]<br>Low[1,3]<br>Medium[1,3]<br>High[1,3]<br>Very high[1,3] |
| Cost (increase in your local tax) [(c)] | 0, 60, 300, 600, 1200 CHF per year<br>(0, 5, 25, 50, 100 CHF per month) |

Notes:
[(a)] Same event or attribute level used in the two options.
[(b)] The level is lower for option A (with costs) than for option B (“future quo” without costs).
[(c)] Option A > 0 CHF; option B = 0 CHF
[1] For the event “Wastewater flooding of streets.”
[2] For the event “Wastewater flooding of cellars.”
[3] For the event “Wastewater overflow in rivers and lakes.”

**Table 3.**
Average concern for wastewater-related events on the environment, and the health of children and adults

| Event\Level of concern | Very Low/Low (%) | Medium (%) | High/Very High (%) |
|---|---|---|---|
| | | Adult health | |
| Cellar Flooding | 20.94 | 36.01 | 43.06 |
| Street Flooding | 21.92 | 36.59 | 41.49 |
| CSOs in Rivers/Lakes | 11.74 | 28.08 | 60.17 |
| | | Children health | |
| Cellar Flooding | 16.24 | 29.75 | 54.01 |
| Street Flooding | 14.38 | 27.98 | 57.63 |
| CSOs in Rivers/Lakes | 8.41 | 18.98 | 72.6 |
| | | Environment | |
| Cellar Flooding | 24.27 | 33.95 | 41.78 |
| Street Flooding | 16.34 | 30.14 | 53.52 |
| CSOs in Rivers/Lakes | 5.97 | 18.88 | 75.14 |

Note: Total number of observations is 1,022.

**Table 4.**

Estimated Coefficients – Mixed Logit Model

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| Variable | Coeff. | Std. Err. | | Coeff. | Std. Err. | |
| *Mean* | | | | | | |
| Cost (CHF) | -0.003 | 0.001 | *** | -0.003 | 0.001 | *** |
| Frequency of Events | 0.002 | 0.001 | * | 0.002 | 0.001 | * |
| Probability of Forecast | 0.235 | 0.245 | | 0.186 | 0.226 | |
| Street Flooding | 0.804 | 0.329 | ** | 0.778 | 0.313 | ** |
| CSOs in Rivers and Lakes | 3.022 | 0.900 | *** | 2.913 | 0.815 | *** |
| Children Health at Risk | 0.645 | 0.248 | *** | 0.627 | 0.230 | *** |
| Health Risk | 0.016 | 0.010 | | 0.014 | 0.009 | |
| Ecological Risk Very Low | 0.290 | 0.362 | | 0.313 | 0.335 | |
| Ecological Risk Low | 0.197 | 0.249 | | 0.201 | 0.227 | |
| Ecological Risk High | -0.530 | 0.244 | ** | -0.477 | 0.224 | ** |
| Ecological Risk Very High | -0.729 | 0.382 | * | -0.674 | 0.357 | * |
| ASC | 0.407 | 0.433 | | -2.075 | 0.865 | ** |
| *Standard Deviation of Parameter Distributions* | | | | | | |
| Probability of Forecast | 2.525 | 0.564 | *** | 2.313 | 0.465 | *** |
| Street Flooding | -0.135 | 1.298 | | 0.009 | 0.732 | |
| CSOs in Rivers and Lakes | 1.043 | 1.620 | | 0.743 | 1.702 | |
| Children Health at Risk | 2.369 | 0.594 | *** | 2.056 | 0.510 | *** |
| Health Risk | 0.104 | 0.030 | *** | 0.100 | 0.028 | *** |
| Ecological Risk Very Low | 2.470 | 0.571 | *** | 2.367 | 0.535 | *** |
| Ecological Risk Low | -0.128 | 0.442 | | -0.164 | 0.450 | |
| Ecological Risk High | 0.996 | 0.657 | | 0.742 | 0.710 | |
| Ecological Risk Very High | 2.254 | 0.648 | *** | 2.004 | 0.528 | *** |
| *Socio-Demographic Characteristics* | | | | | | |
| Male | | | | -0.292 | 0.226 | |
| Vocational School | | | | 0.386 | 0.416 | |
| High School | | | | 0.788 | 0.489 | |
| Technical University | | | | 0.302 | 0.466 | |
| University | | | | 0.878 | 0.459 | * |
| Age | | | | 0.012 | 0.008 | |
| Risk Loving | | | | -0.540 | 0.277 | * |
| Risk Adverse | | | | -0.019 | 0.273 | |
| Annual Household Income | | | | 0.0004 | 0.0002 | *** |
| French Part | | | | 0.175 | 0.271 | |
| Italian Part | | | | 0.267 | 0.367 | |
| Urban | | | | -0.060 | 0.237 | |
| Contact with Water Rare | | | | -0.982 | 0.332 | *** |
| Contact with Water Sometime | | | | -0.272 | 0.240 | |
| Political Orientation Center | | | | 1.215 | 0.512 | ** |
| Political Orientation Left | | | | 1.599 | 0.621 | ** |
| No Political Orientation | | | | 1.077 | 0.517 | ** |
| Climate Change Perception | | | | 0.485 | 0.263 | * |
| Log-likelihood | -1753.143 | | | -1725.569 | | |
| $\chi^2$ (df = 9) | 318.94 | | *** | 298.11 | | *** |

Notes: Estimation by maximum simulated likelihood method with 500 Halton draws. The total number of observations is 6,132; the total number of respondents is 1,022. Standard errors are in parentheses. Socio-demographic characteristics have been interacted with ASC. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

**Table 5.**
Estimated Marginal Willingness To Pay (CHF / year as annual local taxes)

| | Mean (CHF) | Std. Error | [95% Conf. Interval] | |
|---|---|---|---|---|
| Street Flooding | 430.138 | 121.422 | 192.155 | 668.121 |
| CSOs in Rivers/Lakes | 1,218.194 | 260.070 | 708.465 | 1,727.922 |
| Cellar Flooding | 144.604 | 143.882 | -137.399 | 426.608 |
| Ecological Risk Very Low | 102.953 | 126.728 | -145.430 | 351.335 |
| Ecological Risk Low | 70.051 | 86.265 | -99.025 | 239.126 |
| Ecological Risk Medium | 274.290 | 247.319 | -210.445 | 759.026 |
| Ecological Risk High | -188.291 | 83.962 | -352.853 | -23.730 |
| Ecological Risk Very High | -259.002 | 132.687 | -519.064 | 1.059 |
| Children Health at Risk | 229.316 | 87.492 | 57.834 | 400.797 |

Note: Standard errors estimated by the delta method. CSOs = combined sewer overflows.