Assessing the benefits of different groundwater protection levels: results and lessons learnt from a contingent valuation survey in the Upper Rhine valley aquifer, France

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Abstract

The paper presents the results of a contingent valuation survey aiming at assessing population willingness to pay for groundwater protection in the Upper Rhine Valley (URV) aquifer. The perception of groundwater pollution issues is first described based on a sample of 668 questionnaires. Values are elicited for two scenarios consisting of restoring drinking water quality (scenario 1) and eliminating all traces of polluting substances (restoration of natural quality, scenario 2). Stated WTP amounts are on average equal to respectively 42.6 € and 77 € per household per year (for a ten years period during which remediation measures are implemented). Factors determining WTP are investigated using various multivariate analyses. Finally, the total benefits associated with each scenario are estimated at the regional level: 31.3 and 49.3 millions € per year are found for scenarios 1 and 2 respectively.

KEYWORDS: Contingent valuation, Willingness to pay, groundwater, quality thresholds

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1 Introduction

Following the publication of the Water Framework Directive (2000/60/EC) in 2000, European Member States are currently initiating very ambitious water protection programs aiming at restoring good ecological and chemical status for all water bodies before 2015. Whilst the directive defines environmental objectives for surface water bodies, it has not been considered appropriate to define new groundwater quality standards which would be applied uniformly to all groundwater bodies across Europe. Instead, the legislator has preferred to leave up to each Member State to determine concentration threshold values for all major polluting substances. According to the recent groundwater Daughter Directive, such thresholds values can be set at regional or local levels in order to reflect local natural or economic specific characteristics. The Directive explicitly recognizes that the costs of groundwater protection actions should remain proportionate with the environmental and economic benefits they generate. As a result, policy makers express a growing demand for economic assessment of costs and benefits associated to different levels of groundwater protection. However, existing studies generally focuses on a unique groundwater protection or restoration scenario and rarely assess the benefits associated with different protection scenarios. This study presents an attempt to fill this gap through a case study where the benefits of two groundwater protection scenarios and corresponding environmental quality standards are assessed through a contingent valuation survey.

2 A presentation of the Upper Rhine aquifer and groundwater improvement scenarios

The Upper Rhine Valley (URV) alluvial aquifer was selected to conduct a case study as part of the European 7th PCRD BRIDGE project. This cross-border alluvial aquifer, located between Germany and France, extends over 4 200 km^2 (Figure 1). With a reserve of approximately 45 billions cubic meters of water, that is approximately half of the volume of Lake Geneva, this aquifer is one of the largest fresh water reserves in Europe. Groundwater from the URV fulfils 75% of the drinking water needs and about half of the industrial water needs. More than three millions inhabitants of the Alsace Region (France) and the Land of Baden-Wurttemberg (Germany) directly depend on this resource for their water supply. Although usable for drinking purposes without prior treatment in most locations, groundwater has progressively been affected by diffuse and point source pollution since the 1970's.
The URV aquifer is severely affected by four major pollutions: nitrates, pesticides, chloride and Volatile Organic Compounds (VOCs). The nitrate

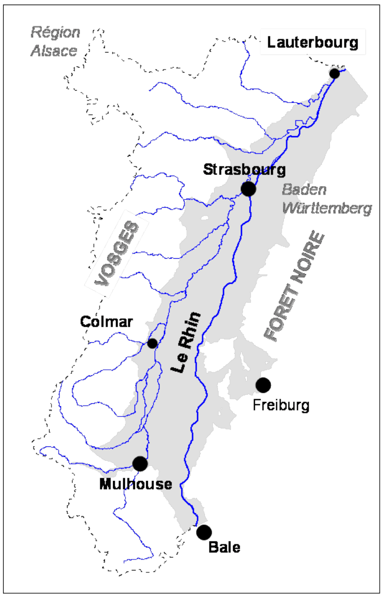

Figure 1: Location of the Upper Rhine Valley aquifer (shaded area)

pollution problem is particularly acute on both sides of the Rhine. About 15% of the 1 100 monitored points showed in 1997 a nitrate concentration exceeding 50 mg/l and the European guide value of 25 mg/l was exceeded in 36% of the monitored points. On the French side of the aquifer, atrazine and its metabolite (desethyl-atrazine) are detected in respectively 59% and 63% of monitored points in 1997 due to intensive use for maize and vine crops. Concentrations exceed the drinking quality thresholds (0.1 μg/l) in around 15% of the samples [3]. A large area is affected by chloride pollution, originating from the potash mining industry, on the French and German side of the aquifer. The latest maps produced in 2000 show that the plumes extend over approximately 40 km. Because of the relatively higher density of saline water, deep layers are more affected than surface layers. High concentrations in VOCs have been detected downstream of several industrial areas. In a groundwater quality measurement campaign carried out in 1996-97, VOC were found in 38% of the french and german groundwater samples. Around 6% of the samples show concentrations higher than 10 μg/l, which is the maximum value for drinking water use according to the EU standard [3]. Other contaminants have been locally reported, including heavy metals, polycyclic aromatic hydrocarbons (PAH) and oils. Nitrates, pesticides and chloride pollutions benefit from years of investment aiming at shifting increasing concentrations tendancies. Measures will still operate in the next 10 years and positive results can be already observed. Thus, VOCs remain the fourth and important groundwater problem to consider. VOCs regulations exist in air pollution sector and contribute to limit groundwater impacts.

Though, as high VOCs concentrations are found in groundwater, specific measures are to be taken, in order to improve groundwater quality.

3 Methodology

The objective of the study is to assess population willingness to pay for restoring two alternative levels of groundwater quality [2]. The standard contingent valuation method is used in order to catch both use and non-use values. The questionnaire employed is designed for postal mailing. Two set of questions are asked to respondents: (i) whether or not they are willing to pay for the proposed scenarios; and (ii) how much they are willing to pay for each scenario. The elicitation format used is a payment card, range of which was tested during the questionnaire pretest. The questionnaire includes additional questions on groundwater perceptions and uses and socioeconomic characteristics of the respondents.

The business as usual scenario described in the questionnaire (reference situation) assumes that in 2015: (i) nitrates, pesticides and chlorides concentrations in groundwater should satisfy the standards thanks to the maintained efforts to reverse the tendencies; (ii) in the absence of specific VOCs groundwater protection and remediation actions, VOCs pollution plumes would extend leading to the contamination of urban drinking water wells and to negative environmental impacts.

An action scenario, consisting in restoring groundwater quality up to current drinking water standards, is first considered and assessed by respondents. A second scenario consisting of restoring natural quality (removal of all traces of solvents) is then assessed by respondents. Scenarios are presented in Figure 2 below.

The contingent valuation survey was carried out between March and July 2006. Following a pretest of the questionnaire through 140 face-to-face interviews, the questionnaire was sent out by mail to 5 000 Alsatian households. Over this sample, 4 000 households fed through the aquifer were selected, half in rural localities and half urban areas. The remained questionnaires (1 000) were sent in municipalities located outside the aquifer and using other water resources. The data collected are then used to model households' decision to pay for the two scenarios (Logit model, where the explained variable is a binary one taking the value one if the households accept to pay, zero otherwise). The stated willingness to pay amount is modelled using a linear regression (excluding protest answers) and a Tobit model (including and excluding protest answers). Based on the results of the multivariate analysis, an assessment of the total benefits of each groundwater protection scenario is carried out, based on assumptions related to the population concerned by groundwater protection in the region.

	Scenario 1	Scenario 2
Objective	**Restoring drinking groundwater quality**	**Restoring natural groundwater quality (no traces of solvents in the long term)**
PoM timing	**10 years**	**10 years**
Actions implemented as part of the scenario	- **Remediation measures implemented in historical contaminated sites located in areas where CS exceeds drinking water threshold value** - **Preventive measures applied (through regulation) in all enterprises using chlorinated solvents and located in areas** where concentrations in solvents exceed drinking water threshold.	- **Remediation measures implemented in historical contaminated sites located in areas where traces of solvents are detected** - **Preventive measures applied (through regulation) in all enterprises using chlorinated solvents and located in areas** where traces of solvents have been detected
Expected benefits	- **Drinking water quality level restored within 10 years but traces of CS remain in the aquifer, with risk of impacts on ecosystems.** - **Reduction in drinking water treatment cost.**	- **Natural quality restored, traces of CS disappear within 50 years: natural attenuation contribution.** - **Environmental benefits for ecosystems and water related species, absence of risk for humans using groundwater.** - **Heritage benefits (for future generations).**

Figure 2: Description of groundwater restoration scenarios

4 Empirical results

4.1 Description of respondents' population

A total of 668 usable questionnaires were returned out of the 5 000 sent by mail. The response rate (13.4%) is conforming to similar methods. The survey first allows understanding the perception of groundwater pollution problem by the population. Concerning the perception of groundwater pollution, 22% of the respondents never heard about Upper Rhine pollution aquifer cases whereas 54% did. According to the respondents, the main causes of groundwater pollution are agriculture and industry. When asked to identify within a list the polluting substances which are present in the aquifer, respondents mainly quote nitrates (86%) and pesticides and herbicides (84%). They are fewer to quote heavy metals (44%), chlorides (45%) and hydrocarbons (33%). Chlorinated solvents are quoted by 53%, putting them in third position after nitrates and pesticides. After having read the description of the current situation in terms of water quality in Alsace, 82% declare that they were not well (or not at all) informed about it before reading the text. Most respondents (80%) consider the two proposed hypothetical scenarios as credible.

Sixty two percent of the respondents accept to contribute to the first scenario: the mean WTP declared is 42.6 €2007 per households. In the case of the second scenario, 54% of the respondents are willing to contribute. The corresponding mean WTP is 77 €2007 per household. Unexpectedly and in both scenario cases, the average willingness to pay of respondents living above with aquifer is not higher than WTP declared by respondents living outside the aquifer - which was one of the assumptions to be tested. These values can be compared with the 117 €2007 and 65 €2007 for users and non-users respectively found in a 1993 contingent valuation assessing WTP for groundwater protection in the same region [5, 4]. A major finding is the relatively high protest rate close to 53% for the first scenario (17% for the second). This attitude is mainly due to the fact that the scenario is perceived as inconsistent with the polluter pays principle. Other respondents reject the scenario due to the proposed payment vehicle and assert that they would be willing to pay but not through an increase of their water bill.

4.2 Models results and aggregation

The results of the linear Logic model shows that the main significant variables are the realism of the described scenarios, the number of children in the household, the income and the number of known polluting substances (Figure 3). The frequency of tap water consumption does not appear as a significant variable as found by Stenger and Willinger.

Logistic regression
Scenario 1

Number of obs = 488
LR chi2(14) = 42.75
Prob > chi2 = 0.0001
Log likelihood = -292.80856
Pseudo R2 = 0.0680

q17potac	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
q1loisir	-.0388534	.0450092	-0.86	0.388	-.1270699	.049363
q2puit	.3665211	.2813201	1.30	0.193	-.1848561	.9178983
freq_tap_w~r	.4000523	.2056253	1.95	0.052	-.0029659	.8030706
q5distrpol	.005608	.2790467	0.02	0.984	-.5413135	.5525295
q6facteau	-.2318023	.2209524	-1.05	0.294	-.664861	.2012564
pb_nappe	.0156403	.0843727	0.19	0.853	-.1497272	.1810077
poll_indus~s	-.2693017	.2062646	-1.31	0.192	-.673573	.1349696
subst_poll	.061832	.0717338	0.86	0.389	-.0787637	.2024276
situation_~e	.8607737	.431483	1.99	0.046	.0150825	1.706465
one_progra~c	.5469368	.2489254	2.20	0.028	.059052	1.034822
log_age	-1.26276	.3552239	-3.55	0.000	-1.958986	-.5665339
log_q27prf~f	-.5798394	.2620281	-2.21	0.027	-1.093405	-.0662738
log_income	.325762	.1343498	2.42	0.015	.0624413	.5890828
q30asso	.6268109	.3187228	1.97	0.049	.0021258	1.251496
_cons	1.729821	1.738225	1.00	0.320	-1.677038	5.136679

Rows in red show variables significant with a 1% confidence; in green at 5%; in blue at 10%.

Logistic regression
Scenario 2

Number of obs = 513
LR chi2(17) = 72.11
Prob > chi2 = 0.0000
Log likelihood = -310.68087
Pseudo R2 = 0.1040

q23natac	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
q1loisir	.0333486	.0456727	0.73	0.465	-.0561683	.1228654
q2puit	.5208721	.2837307	1.84	0.066	-.0352298	1.076974
freq_tap_w~r	-.018596	.2023557	-0.09	0.927	-.4152059	.3780139
q5distrpol	-.1314781	.278212	-0.47	0.637	-.6767635	.4138074
q6facteau	-.2066828	.2097572	-0.99	0.324	-.6177993	.2044338
pb_env	-.402797	.1977438	-2.04	0.042	-.7903677	-.0152264
poll_menages	-.1925328	.5362893	-0.36	0.720	-1.24364	.8585748
situation_~e	.7052593	.4411472	1.60	0.110	-.1593734	1.569892
q21naturel~p	1.279202	.704164	1.82	0.069	-.1009345	2.659338
two_progra~c	.9254696	.2560194	3.61	0.000	.4236808	1.427258
sexe	-.4147685	.220355	-1.88	0.060	-.8466563	.0171193
log_q27prf~f	-.4267504	.2529312	-1.69	0.092	-.9224864	.0689856
duree	-.4946927	.2457321	-2.01	0.044	-.9763187	-.0130667
sec_ind	.0809067	.2736577	0.30	0.767	-.4554525	.617266
sans_travail	.8842334	.2321958	3.81	0.000	.429138	1.339329
q30asso	.6682801	.2968442	2.25	0.024	.0864763	1.250084
nappe	-.3992631	.2498045	-1.60	0.110	-.888871	.0903448
_cons	-1.554818	1.007611	-1.54	0.123	-3.5297	.4200636

Rows in red show variables significant with a 1% confidence; in green at 5%; in blue at 10%.

Figure 3: Results of the Logit model for scenarios 1 and 2

Two models were tested to explain stated WTP amounts: linear regression (Figure 4) and Tobit model. Unexpectedly, the knowledge of the water bill has a negative impact on the WTP amount. Significant variables are quite different from the Logit model. They are income, knowledge of water bill, concern about groundwater pollution, practice of water activities (leisure), and use and non-use values of groundwater advocated as motivations to pay. Explanatory powers of the models are satisfying in each case.

Linear regression
Scenario 1

Number of obs	= 314
F(18, 295)	= 2.31
Prob > F	= 0.0021
R-squared	= 0.1348
Root MSE	= .87177

log_one_wtp	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
q1loisir2	-.1338252	.0614521	-2.18	0.030	-.2547653	-.012885
q2puit	.0606671	.1248786	0.49	0.627	-.1850987	.306433
freq_tap_w~r	-.0692308	.1031826	-0.67	0.503	-.272298	.1338364
q5distrpol	-.0481493	.1362729	-0.35	0.724	-.3163396	.220041
q6facteau	-.2511293	.1104671	-2.27	0.024	-.4685327	-.0337259
pb_nappe	.0762135	.0409211	1.86	0.064	-.0043208	.1567478
poll_indus~s	-.0910288	.1053235	-0.86	0.388	-.2983094	.1162519
subst_poll	.0581349	.036764	1.58	0.115	-.014218	.1304879
situation_~e	.0864804	.3720691	0.23	0.816	-.6457658	.8187267
one_progra~c	.2807262	.1488416	1.89	0.060	-.0121998	.5736522
q19potvalu~e	-.0470717	.2212831	-0.21	0.832	-.4825652	.3884218
q19potvaln~e	.1980412	.1050523	1.89	0.060	-.0087056	.4047881
log_age	.1065005	.1765107	0.60	0.547	-.2408793	.4538804
log_q27prf~f	-.1718076	.1409732	-1.22	0.224	-.4492483	.1056331
log_income	.2641097	.1595885	1.65	0.099	-.0499664	.5781859
diffwtp	-.1371221	.1230652	-1.11	0.266	-.379319	.1050749
suff_info	-.0127608	.1238657	-0.10	0.918	-.2565333	.2310117
q30asso	.3745541	.1415722	2.65	0.009	.0959346	.6531736
_cons	.8128516	1.572673	0.52	0.606	-2.282229	3.907933

Rows in red show variables significant with a 1% confidence; in green at 5%; in blue at 10%.

Linear regression
Scenario 2

Number of obs	= 284
F(19, 264)	= 2.74
Prob > F	= 0.0002
R-squared	= 0.1584
Root MSE	= .86878

log_tot_reg	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
q1loisir2	-.1540173	.0698701	-2.20	0.028	-.2915909	-.0164437
q2puit	.1069688	.1299674	0.82	0.411	-.1489358	.3628735
freq_tap_w~r	-.1070642	.1060549	-1.01	0.314	-.3158853	.1017569
q5distrpol	-.0093988	.1463656	-0.06	0.949	-.2975912	.2787936
q6facteau	-.252722	.1158362	-2.18	0.030	-.4808024	-.0246416
pb_nappe	.0863358	.0455433	1.90	0.059	-.0033386	.1760102
poll_indus~s	-.0181284	.1068515	-0.17	0.865	-.228518	.1922612
subst_poll	.0319438	.0392759	0.81	0.417	-.0453901	.1092777
situation_~e	.1561757	.406855	0.38	0.701	-.644918	.9572694
q21naturel~p	-.9550887	.5102668	-1.87	0.062	-1.959799	.0496217
two_progra~c	.2634047	.1645315	1.60	0.111	-.0605561	.5873656
q25natvalu~e	.1388614	.1673375	0.83	0.407	-.1906245	.4683473
q25natvaln~e	.1590197	.1143822	1.39	0.166	-.0661978	.3842371
log_age	.2432438	.1871698	1.30	0.195	-.1252918	.6117794
log_q27prf~f	-.2186178	.1583585	-1.38	0.169	-.5304243	.0931887
log_income	.1965147	.134555	1.46	0.145	-.0684228	.4614522
diffwtp	-.133453	.130267	-1.02	0.307	-.3899475	.1230414
suff_info	-.0614415	.1328555	-0.46	0.644	-.3230326	.2001497
q30asso	.408734	.1436584	2.85	0.005	.1258721	.691596
_cons	2.240611	1.40545	1.59	0.112	-.5267078	5.007929

Rows in red show variables significant with a 1% confidence; in green at 5%; in blue at 10%.

Figure 4: Results of the OLS regression for scenarios 1 and 2

The predicted WTP range between 19.6 and 29.7 €2007 per household for the first scenario and between 35 and 50.8 €2007 per household for the second scenario according to the regression model used and the inclusion of protest answers or not (Figure 5).

Estimated mean WTP (€2007)	OLS regression	Tobit with protests	Tobit without protest
Scenario 1	29,7 €	19,6 €	20,7 €
Scenario 2	50,8 €	35,7 €	35,0 €

Figure 5: Predicted WTP according to the models

4.3 Aggregation

Finally, the total benefits of the Upper Rhine Valley aquifer are estimated after a sample bias correction. The average WTP per socio-professional categories are reported and extrapolate to the Alsatian population according to its regional socio-professional distribution [1]. Thus, the total benefits of groundwater protection is estimated at 31.3 million €2007 per year for 10 years for the scenario 1 (drinking quality level) and 49.3 million €2007 per year for 10 years for scenario 2 (natural water quality level).

5 Conclusion

The results of the survey highlight that the population is concerned by groundwater protection. The average stated WTP amounts was estimated at 42.6 €2007 per households and per year for 10 years for restoring drinking water quality and 77 €2007 per year for 10 years for restoring natural. There is no statistical difference between WTP amounts declared by households living above the aquifer (and using it for water supply) and others living outside the aquifer. This suggests that groundwater option value and non-use value are significant. The methodology implemented however did not allow assessing separately direct use value, option value and non-use values. The study also reveals that the population is very sensitive to the implementation of the polluter pays principle. Many respondents have refused to contribute to the scenarios, arguing that polluters (industries) should pay. Similar attitudes would probably be encountered for all pollution issues where pollution damage cost can be attributed to legal entities - theoretically liable to pay for remediation costs.

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