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VALUING DRINKING WATER QUALITY AFTER A PFAS CONTAMINATION EVENT: RESULTS FROM A META-ANALYSIS BENEFIT TRANSFER

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Valuing drinking water quality after a PFAS contamination event: results from a meta-analysis benefit transfer

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Abstract

Drawing upon an extensive body of valuation literature focused on water quality, I conduct a meta-analysis benefit transfer exercise with the aim of quantifying the Willingness to Pay (WTP) for an enhancement in drinking water quality among households directly exposed to Perfluoroalkyl Substances (PFAS) over recent decades in Italy. My analysis comprises a metadata compilation encompassing 72 WTP estimates extracted from 39 previous valuation studies conducted in advanced economies. The transfer of values is realized estimating a meta regression model (MRM) which includes both study design and socio-economic explanatory variables, according to the Weak Structural Utility Theoretic approach. To determine the most suitable MRM specification, I engage in a comparative evaluation of various model configurations, assessing their predictive performance in terms of transfer errors and explanatory capability. The mean transfer error and the adjusted R-squared of the preferred MRM are in line with previous published meta-analysis and equal respectively to 0.665 and 0.607. Furthermore, the parameters estimated within the model align with both intuitive expectations and economic theory. As a result of the benefit transfer process, I estimate an annual WTP of €250.80 per household for improved drinking water quality within the PFAS-affected area, and an aggregate value of social benefits from PFAS decontamination of around €12 million.

Keywords: WTP; Meta-Analysis; Benefit Transfer; PFAS; Drinking Water.
JEL classification: Q25, Q51, Q53, D61.

1 Introduction

The need of environmental valuation studies goes hand in hand with the development of new forms of persistent contamination which may dramatically affect ecosystem services' quality standards citizens should always rely on. One of the main motivations behind non-market valuations is, indeed, the ability of the estimated results to efficiently inform policy makers, thereby enhancing public welfare and mitigating uncertainty surrounding the social benefits linked to various policy alternatives (Freeman et al., 2014).

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Drinking water contamination resulting from Perfluoroalkyl Substances (PFAS) has emerged as a pressing environmental concern, particularly affecting advanced economies such as Italy, Scandinavian countries, and the United States, but increasingly prevalent worldwide in recent times (Hoppin et al., 2019; Stoiber et al., 2020). PFAS fall under the category of PMOC (Persistent Mobile Organic Compounds), emerging contaminants. These highly polar compounds exhibit remarkable thermal stability, allowing them to endure throughout the entire water cycle, with limited susceptibility to natural degradation processes. The easy with which PFAS infiltrate groundwater and subsequently enter household drinking water systems places individuals dangerously exposed to several health risks that are likely associated with certain threshold of PFAS blood concentrations (Mastrantonio et al., 2018; Pitter et al., 2020a,b). More recently, further studies also figured out that higher mortality risk for Covid-19 has been observed in individuals heavily exposed to PFAS over years (Catelan et al., 2021).

Starting from 2013, a significant concentration of PFAS has been detected in the groundwater of Veneto Region, in Italy, primarily stemming from irregular industrial waste discharges that were inadequately monitored. This contamination impacted over 100,000 households, as the groundwater had been utilized for drinking purposes, and its intensity and longevity were particularly alarming, spanning roughly four decades. After the rapid implementation of short-term mitigation strategies aimed at immediately stopping the direct human exposure to contaminants (i.e., activated carbon filters), a massive research focused on potential long-term environmental protection interventions began, and it is still ongoing, across all European countries. A remarkable example is the LIFE-PHOENIX project, funded by the European Commission in 2017, which developed in three years a new inter-institutional governance system aimed at improving the risk-management of health and environmental risks caused by PFAS contamination, with the final objective of reducing future public expenditures connected to other forms of persistent emerging contaminants (Regione Veneto et al., 2021).

The meta-analysis involves the estimation of a Meta Regression Model (MRM) and utilizes an original meta-dataset constructed by aggregating information from various prior valuation studies. The estimated parameters are then exploited to compute the WTP for better drinking water quality in the policy site of interest. The valuation function is structured according to the Weak Structural Utility Theoretic (WSUT) approach, encompassing therefore both socio-economic and study design variables of each environmental site examined (Bergstrom and Taylor, 2006). The study selection process and the collection of data follows a rigorous meta-analysis protocol designed to mitigate the most common inconsistencies which may reflect in huge transfer errors and compromise the reliability of the meta-analysis' estimates (Stapler and Johnston, 2009; Johnston and Rosenberger, 2010). It's worth noting that beyond the primary objective of benefit transfer, conducting this meta-analysis serves several other key purposes. In particular: (1) I create, by collecting and adjusting data from selected past environmental valuation studies, a new original meta-dataset on drinking water quality changes measured in advanced economies over last decades; 2) I conduct a comprehensive systematic literature review, providing an overview and analysis of the body of research on drinking water valuation in advanced economic; (3) I delve into the factors that contribute to the observed heterogeneity in the WTP estimates for better drinking water quality in advanced economies, considering both socio-economic features of the population and methodological characteristics of the studies, thus testing also economic theory.

The preferred model specification is found estimating different MRMs and comparing their performance in terms of transfer error and explanatory power. The final MRM displays an adjusted R-squared and a Mean Transfer Error (MTE) equal respectively to 0.623 and 0.663. Both results are in line with past published and unpublished meta-analysis and most of the statistically significant relationships coming from the preferred model are consistent with economic theory and intuition. By incorporating the values of the explanatory variables specific to the policy site of interest into the final MRM, the benefit transfer yields an estimated WTP of 205.80 €.Considering the population of households residing in the contaminated area, the potential social benefits stemming from decontamination efforts would reach approximately €12 million.

In the context of environmental protection interventions (e.g., mitigation strategies, restoring actions, surveillance plans), assessing and assigning value to quality improvements in non-market resources subject to decontamination is paramount. In a cost-benefit analysis (CBA) framework, this value represents the unique form of social benefits to consider and compare with the economic costs associated to the quality restoration of a specific natural resource (Allen and Loomis, 2008; Newbold et al., 2018). Indeed, without a clear comprehension of the magnitude of these benefits, policy makers would not be able to identify the optimal degree of economic support required for the environmental reconditioning of a specific sector. In environmental economics there is now large consensus that the willingness to pay (WTP) for better water quality represents the best proxy for individual social benefits from decontamination, and the extensive literature on this subject comprises numerous primary studies that endeavor to quantify households' preferences for positive water quality enhancements by conducting tailored surveys across various environmental sites worldwide (e.g., Edwards, 1988; Shultz and Lindsay, 1990; Sun et al., 1992; Tervonen et al., 1994; Hurley et al., 1999; Genius and Tsagarakis, 2006; Beaumais and Millock, 2010; Guerrini et al., 2018).

However, in case of significant resource and time constraints, primary valuations studies have been often replaced in recent years by secondary analysis conducted via benefit transfer methodologies. Benefit transfer enables the utilization of specific economic or environmental findings estimated in one or several "study sites" to retrieve the same value for a different and novel "policy site" (Bergstrom and Taylor (2006). The existing non-market valuation literature owns, indeed, great valuable information which should be exploited to build transfer functions able to enrich the body of environmental value estimates (whose application is key to inform policy evaluations) without the specific need of conducting a new contingent valuation survey on the population (Newbold and Johnston, 2020). Practically, researchers' efforts to apply rigorous methodologies for leveraging existing metadata on welfare and environmental estimates should be considered as a viable alternative to the substantial financial costs associated with conducting an entirely new survey, when this is possible conditional to low transfer errors and reliable estimates. Moreover, valuations aimed at assessing the social benefits of decontamination are often characterized by tight deadlines for the implementation of suitable protective measures, which might be incompatible with the standard timing required for a primary valuation study.

Among the possible approaches for benefit transfer, the meta-analysis (i.e., the statistical summary of previous valuation results drawn from several past papers) generally represents the most accurate and rigorous strategy. This is particularly true when there are limited or no closely related primary studies available (Boyle and Bergstrom, 1992; EPA, 2000; Spash and Vatn, 2006). Conducting a meta-analysis is aimed at estimating parameters which convey the influence of study's methodologies, survey's design and socio-economic characteristics of the environmental site on an outcome valuation variable (e.g., WTP). The inclusion of such a comprehensive set of control variables enables researchers to encompass environmental valuations from papers that may differ significantly in these aspects, all without loosing their valuable information.

Given the scarcity of prior water valuation studies in Italy[1], the benefit transfer performed in this study is actually an *international benefit transfer*, whose effectiveness and validity are currently topics of discussion within the literature, especially when compared to meta-analyses conducted at the national level (i.e., involving only primary valuation studies conducted within the same country) (Lindhjem and Navrud, 2007; Johnston and Thomassin, 2010). However, controlling for country fixed effects, the transfer errors obtained in this paper's analysis are in-line with most of the MRM performed at national level and published in peer-reviewed journals.

To the best of my knowledge, there are no published peer-reviewed meta-analysis whose main common economic outcome is WTP for an improvement in drinking water quality. The existing literature closest in scope tends to concentrate on the valuation of quality changes in surface water bodies exploited for recreational activities (Ge et al., 2013; Johnston et al., 2003; Alvarez and Asci, 2014). Van Houtven et al. (2017) conducts a meta-analysis related to drinking water but their main outcome measured the WTP for enhanced water access, rather than improved water quality. Furthermore, WTP for a positive water quality change, whether for drinking or recreational purposes, has never been measured in the context of PFAS contamination, neither through primary valuation studies nor within a meta-analysis framework.

The reminder of the paper is structured as follows: Section 2 outlines the meta-analysis protocol, the criteria established to select prior primary environmental studies and presents the metadata; Section 3 delves into the structure of the MRM, the included explanatory variables and the possible functional forms; Section 4 presents the main results from the model estimations and illustrates in detail the benefit transfer procedure employed to derive a WTP value for the PFAS-affected area; finally, Section 5 draws conclusions.

2 Meta analysis - benefit transfer: protocol, data and regression model

The meta-analysis, often known as "the study of the studies", has the objective of statistically synthesize data and results coming from previous valuation studies by assessing systematic relationships between a common economic outcome and both methodological and socio-economic characteristics (Bergstrom and Taylor, 2006). Leveraging meta-analysis as a statistical tool for conducting benefit transfer and enriching the information available to policymakers demands a meticulous implementation of a multi-step procedure, including:: (1) the definition of a meta-analysis protocol, which serves as guide for the selection of primary studies; (2) the systematic review of the primary valuation studies selected, defining the explanatory variables and gather data, potentially supplemented by information from publicly available external sources; (3) the creation of the definitive meta-dataset with standardize observations across studies, which may

[1] The only two primary valuation studies come from Guerrini et al. (2018) and Beaumais and Millock (2010).

involve adjustments for purchasing power and currency; (4) the estimation of a MRM and the assessment of its statistical performance; (5) the use of the estimated parameters to exploit the model as valuation function and produce an environmental estimate of the outcome for the specific policy site under analysis, which constitutes the core of benefit transfer.

In the following, the paper illustrates how these different steps have been implemented to fulfill my main objective: conducting a meta-analysis for a positive drinking water quality change and subsequently utilizing the estimated parameters for a benefit transfer exercise within the PFAS-contaminated area of Italy. It is essential to emphasize that every effort has been made to align with the meta-analysis guidelines outlined by Stanley et al. (2013) and their subsequent revision by Havránek et al. (2020) throughout each step of the process, with a particular focus on ensuring data consistency within the original meta-dataset.

2.1 Meta-analysis protocol and study selection

As argued, ensuring the high quality of the results obtained from the meta-analysis and minimizing potential biases in their interpretation hinges on establishing precise inclusion criteria before starting reviewing any environmental valuation paper and select the related WTP estimates. To this extent, I structure a rigorous meta-analysis protocol, describing specific selection criteria which have to guide the identification of the primary valuation analysis from which data and information are to be gathered.

First, papers must estimate the same economic outcome: annual total (use and non-use) WTP for improved drinking water quality. Specifically, suitable primary studies are those that provide values for water quality changes in water bodies supporting ecosystem services related to domestic uses.[2] To this regard, I instead exclude from the meta-dataset studies valuing water quality changes in water bodies primarily associated with recreational activities and aquatic life, such as boating, fishing, and swimming, which have been the primary focus of past meta-analyses (Ge et al., 2013; Johnston et al., 2003; Alvarez and Asci, 2014; Van Houtven et al., 2017). Such a condition is necessary to satisfy the *commodity consistency* requirement: the commodity being valued in the primary analysis selected must be as similar as possible both between and within studies. Moreover, papers must report aggregated results of WTP for a positive drinking quality change, presented as either the mean or median of the surveyed sample. Concerning the geographical scope, primary valuation studies monetizing quality changes in drinking water in developing countries are excluded from consideration. The reason is to avoid a significant bias due to commodity inconsistency. The true consistency in the commodity should not be valued for the environmental resource itself, but rather for the service it provides to citizens. Embodying this perspective, t tap water may represent a markedly different resource in developing countries, where its potability cannot always be taken for granted. Consequently, the same quality variation (in absolute terms) may be associated with a significantly higher WTP compared to advanced economies. This phenomenon has been documented in recent empirical studies comparing the valuations in meta-analysis within groups of developing and developed countries (Roldán et al., 2021). Finally, I also get rid of primary studies clearly claiming the bad quality of their results due to significant asymmetries between the socio-economic characteristics of the surveyed sample and the target population.

[2] It is essential to clarify that the term "drinking water" here refers to water supplied to households, serving not only for drinking but also for various domestic purposes such as cleaning and washing.

Two important remarks need to be incorporated alongside the listed criteria. First, a contamination event occurred prior to the valuation survey is not a necessary condition to consider a valuation study suitable for selection. Indeed, in the MRM I control for the severity level of the experienced water contamination in the study sites by including a set of dummy variables whose classifications also include the case of no contamination. Second, studies can report annual WTP both at household or individual level. This flexibility exists because, by knowing the number of households residing in the contaminated area and the average number of individuals per household, it is always feasible to convert data between the two dimensions. In the current meta-analysis, the dependent variable under examination is the annual WTP at the household level.

In addition to the aforementioned *ex-ante* selection criteria, a straightforward *ex-post* condition of exclusion of studies from the meta-dataset is the data availability of the main socio-economic and study design variables considered. In meta-analysis, a common trade-off exists between the number of observations and the number of explanatory variables to be incorporated into the regression model. Increasing the number of explanatory variables (both study design and socio-economic controls) most of the time implies a reduction in the number of observations employed, which may clearly affect the statistical performance of the MRM if the final sample size becomes too small. To this regard, it is key to specify that socio-economic data have been primarily gathered from the summary statistics of the specific papers. Afterwards, as a second best strategy, data have been obtained from high-quality public available databases approximating to the smallest possible geographical area, as already done by previous published meta-analysis.

The data collection process begins with an extensive literature review encompassing all primary environmental studies that have administered surveys with the common economic objective of measuring the WTP for positive improvements in water quality. These papers are primarily sourced through the Environmental Valuation Reference Inventory (EVRI)[3], which is a huge storehouse of environmental valuation studies conducted around the world (both published on scientific journal or in the grey literature). A preliminary selection phase is aimed at identifying all papers focused on valuing positive drinking water quality changes, regardless to the geographical area or specific commodity use. This initial sweep results in a collection of over 90 studies. Filtering by the criteria reported in the protocol (e.g., adjusting for commodity consistency, data availability and excluding surveys conducted in developing countries), the final meta-dataset is made up by a total of 39 studies and 72 observations. In cases where a single study reports more than one estimates for WTP according to a different methodology implemented or surveyed sample, the estimates are taken as separate observations while controlling for the study design or socio-economic variables in the regression function. Some of the primary valuation studies only provide one measure for WTP, while the paper with the highest number of observations is Kim and Cho (2002) which includes 9 WTP estimates. A comprehensive list of the primary valuation studies selected is reported in Table 1, together with the study sites, the year of the survey[4] and the type of water contamination, whether occurred (N.C. indicates no previous contamination event occurred).

[3]https://www.evri.ca

[4]Where missing in the paper and in other external public available sources, the year of the survey has been replaced in the table simply by the year of publication

Study	Year of the survey	Study site	Contaminant
Edwards (1988)	1988	Cape Cod, Massachussets (Barnstable and Plymouth Counties), US	Nitrate
Harrington et al. (1989)	1984	Luzerne County, Pennsylvania, US	Giardia
Shultz and Lindsay (1990)	1988	Dover, New Hampshire, US	Generic contaminants
Abdalla et al. (1992)	1989	Perkasie, southestern Pennsylvania, US	TCE
Musser et al. (1992)	1989	Milesburg, Pennsylvania, US	Giardia
Sun et al. (1992)	1989	Dougherty County, Georgia, US	Agricultural chemicals
Collins and Steinback (1993)	1990	West Virginia, US	Bacteria contaminatin
Du Vair et al. (1993)	1989	California, US	Heavy metals
Jordan and Elnagheeb (1993)	1991	Georgia, US	Nitrate
Wattage (1993)	1983	Iowa, US	Acgricultural chemicals
Bergstrom and Dorfman (1994)	1989	Dougherty County, Georgia, US	Agricultural chemicals
Powell et al. (1994)	1994	Massachussetts, Pannysilvania, New York, US	TCE, Dissel fuel
Tervonen et al. (1994)	1994	Oulu, Finland	N.C.
Laughland et al. (1996)	1989	Milesburg, Pennsylvenia, US	Giardia
Cho (1996)	1996	Southwestern Minnesota, US	Copper and sulfates
Crutchfield and Hellerstein (1997)	1994	Mid-columbia basin, US	Nitrate
Luzar and Cosse (1998)	1998	Lousiana, US	N.C.
Piper (1998)	1995	Montana, US	N.C.
Hurley et al. (1999)	1995	Iowa, US	Nitrate
Poe and Bishop (1999)	1996	Portage County, Wisconsin, US	Nitrate
Abrahams et al. (2000)	1995	Georgia, US	Generic contaminants
Bergstrom et al. (2001)	1997	Aroostock County, Maine, US	Nitrate
Delavan and Epp (2001)	1996	Lebanon and Lancaster counties, Pennsylvania, US	Nitrate
Eisen-Hecht and Kramer (2002)	1998	Catawba basin, North Carolina, US	N.C.
Kim and Cho (2002)	1995	Southwester Minnesota, US	Copper
Brox et al. (2003)	1994	Grand River, Souther Ontario, Canada	Chemical spills
Nielsen et al. (2003)	2000	Denmark	Toxic substances
Dupont (2005)	2003	Canada	E. coli
Genius and Tsagarakis (2006)	2004	Haraklion, Greece	Water shortage
Aulong and Rinaudo (2008)	2006	Alsace Region, France	Clorinant solvents
Genius et al. (2008)	2004	Rethymno, Crete Grecce	Soil infiltration
Beaumais and Millock (2010)	2008	10 OECD countries (Italy, Korea and Brazil)	N.C.
Konishi and Adachi (2010)	2007	Minnesota, US	Arsenic
Adamowicz et al. (2011)	2004	Canada	Trihalomethanes
Polyzou et al. (2011)	2009	Mitylene, Greece	Water shortage
Tanellari et al. (2015)	2007	Northern Virginia and Maryland, US	Generic contaminants
Nielsen-Pincus et al. (2017)	2012	The McKenzie River watershed, Oregon, US	N.C.
Chatterjee et al. (2017)	2016	Jacksonville, Florida, US	Chemical components
Guerrini et al. (2018)	2016	Province of Verona, Italy	N.C.

Table 1: Final list of environmental valuation studies included in the meta-dataset.
Source: Author's own elaboration

2.2 Metadata and explanatory variables

2.2.1 Theoretical background: WSUT approach

After having selected the final set of primary valuation studies, the identification of the explanatory variables to include in the MRM strictly depends on the assumptions made about the theoretical model underlying the households' WTP valuation function. To this regard, I follow a Weak Structural Utility Theoretic (WSUT) approach (Bergstrom and Taylor, 2006).

According to standard economic theory, valuing a water quality change means to estimate a "price" for the quality variation of the ecosystem service provided by drinking water. Specifically, this monetary value can be measured by estimating the level of utility individuals get (or lose) from the occurred change in drinking water quality (Bergstrom et al., 2001). Formally, the general representation of the indirect utility function $V(.)$ that the representative household i retrieves from drinking water quality is:

$$V_i = V(M_i, N_i, QL_i, I_i) \tag{1}$$

where: M_i is the income of household i, Z_i are household i's other socio-economic characteristics, QL_i is the drinking water quality available for the household i and I_i is the value of the information available to household i. If we assume no uncertainty on both the demand and the supply side, the value of the utility that household i gets (loses) due to an occurred variation in drinking water quality from a scenario A to a scenario B, which represents household's WTP for $\Delta QL_i =$

$QL_i^B - QL_i^A$, is given by:

$$WTP = V_i^B - V_i^A = V(M_i^B, Z_i^B, QL_i^B, I_i^B) - V(M_i^A, Z_i^A, QL_i^A, I_i^A) \quad (2)$$

According to the WSUT approach, the households' underlying conditional indirect utility describing the WTP function for water quality changes is assumed to be of a certain unknown form f. In addition, inside the MRM, beside to standard *socio-economic characteristics*, also *study design variables* are allowed to be included. MRMs following a WSUT approach are, therefore, empirical models where the connection between the explanatory variables included in the regression and both the theoretical underlying utility (Equation 1) and the differentiated utility (Equation 2) are explicated in the valuation function. Nonetheless, it's important to note that a certain degree of flexibility and discretion is maintained, permitting researchers to incorporate explanatory variables into the MRM that may not have a direct theoretical link to the WTP model, but rather conditional to the methodological characteristics of the different valuation studies. Consequently, in a MRM focused on assessing changes in drinking water quality and following a WSUT approach, the WTP valuation function can be defined as follows:

$$WTP_{js} = f(Z_j, X_s, \Delta QL_{js}) \quad (3)$$

where: WTP_{js} is the aggregate willingness to pay (e.g., mean or median) among households of the environmental site j estimated by the study s, Z_j are the socio-economic characteristics of the environmental site j (including income), X_s are the methodological and study-design characteristics of the study s and ΔQL_{js} is the drinking water quality change for the environmental site j valued by the study s.

2.2.2 Variables selection

The socio-economic variables of my MRM (i.e., Z_j) are standard characteristics of the study sites selected. Specifically, I include personal income, classical demographic controls (i.e., age, sex, education) and population density of the environmental site. As argued, data were primarily collected from the aggregated descriptive statistics of the valuation studies selected and, if missing, from external public available data sources. Furthermore, I introduce a country fixed effect specifically for the United States within the vector of socio-economic predictors. Given that approximately 75% of the observations within the meta-dataset originate from primary valuation studies carried out in the US, this is the sole country-fixed effect that I incorporate into the MRM. This strategic inclusion serves the purpose of mitigating any potential overestimation or underestimation of the WTP during the benefit transfer process, uniquely attributable to geographical disparities. In other terms, this procedure allows me to dampen the increase in the mean transfer error potentially caused by the international nature of my metadata. Moreover, the inclusion of a country fixed effect works as an instrument to face the international dimension of the benefit transfer exercise, leading the statistical performances of my MRM to be in line with past previous meta-analysis developed at national level. I am well aware that the effectiveness and validity of international benefit transfers remain an ongoing subject of discussion within the environmental economics literature, particularly in comparison to meta-analyses conducted at the national level, which exclusively involve primary valuation studies conducted within a single country (Lindhjem and Navrud, 2007;

Johnston and Thomassin, 2010).

The study design variables of my MRM (i.e., X_s) capture the heterogeneity across valuation studies' results that is conditional to: the type of aggregate WTP measure provided (i.e., mean or median WTP), the characteristics of the primary survey (i.e., if Contingent Valuation methodology is used or others, which mean of administration is exploited), the technicalities of the specific WTP questions (i.e., elicitation format, payment's dimension, payment's vehicle) and the estimation method implemented, if an econometric analysis is conducted in the primary study (i.e., if Maximum Likelihood or others). Moreover, potential sources of publication bias are controlled introducing a dummy variable for valuation studies found in the grey literature.

The most significant challenge in my meta-analysis is the introduction of one or more explanatory variables that account for the magnitude of the valued water quality variation at each study site (i.e., ΔQL_{js}). According to economic theory, the welfare change associated to a positive (or negative) variation in the quality of a natural resource strictly depends on the scope of the variation. To account for the relationship between WTP_{js} and ΔQL_{js}, the *first best* strategy would be the introduction in the MRM of two different explanatory variables measuring the starting and final level of drinking water quality for each of the observation in the meta-dataset. Of course, opting for this strategy would require to homogenize data coming from different papers with respect to a unique quality scale (or index), as previously done in other meta-analyses focused on surface water quality using the RFF water quality ladder (Johnston et al., 2003; Ge et al., 2013). Nonetheless, there are at least two compelling reasons why incorporating the magnitude of water quality variation in this manner is not feasible here. First, from the best of my knowledge, there is not a unique international water quality index for drinking water that, starting from data about contaminants' concentration and water's appearance, provides me with homogeneous values for different quality levels across valuations studies in different countries around the world. Moreover, the majority of the selected studies do not provide information regarding the initial and final concentrations of specific contaminants in the water body under consideration. Instead, they only describe the environmental context that necessitated the execution of a primary survey to estimate the WTP for potential decontamination efforts. I try to overcome this problem by inserting among the explanatory variables, as a *second best* strategy, a set of dummy variables conveying the gravity level of the drinking water contamination discovered before the administration of the primary valuation survey. In order to create my dummy variables, I use the classification of drinking water contaminants provided by the United States Environmental Protection Agency (US-EPA) as a reference, which categorizes contaminants based on the severity of the contamination. According to the US-EPA, drinking water can be affected by various types of contaminants, including physical contaminants (e.g., sediments, organic materials, soil erosion), chemical contaminants (e.g., nitrates, pesticides, salts), biological contaminants (e.g., bacteria, viruses, protozoa), and radiological contaminants (e.g., cesium, plutonium, uranium, heavy metals). Since I have five possible severity levels of contamination (taking into account also the possibility of no previous contamination), I need to include in the vector of predictors four dummy variables. Considering the case of no contamination allows me to incorporate in the meta-dataset even studies conducted without a prior detection of any type of contaminant in the water body being valued. From a methodological point of view, retaining only valuation studies which administrated a survey after an experienced contamination would have led to the exclusion of some high-quality primary valuation papers, wasting their valuable information. Moreover, estimating the regression models with the intercept, I can interpret the values of the parameters attached to the dummy variables as the potential mark-up on the WTP reasonably associated with an higher level of awareness of people who experienced contamination events of different degrees.

Before proceeding with the estimation of the MRM, a final key step is the transformation of monetary values (i.e., WTP and income) into homogeneous units across time and countries. Looking at the surveys' year, my metadata covers a time interval of over thirty years (1986-2018) and includes eight different countries. I deal with these issues, as commonly done in previous meta-analyses, by adjusting past and foreign values: for inflation, using the Harmonized Consumer Price Index (HCPI) in the different countries; for the currency, using the Purchasing Power Parity (PPP) adjusted exchange rate in the year of the survey[5]. Through this procedure, all monetary values have been converted to \$ 2018. Once converted, the average WTP in the metadata is 343.65 \$. Moreover, the distribution of households' annual WTP values across studies is highly disperse, ranging between 8.60 \$ and 2104.52 \$, with a standard deviation of 445.92 \$.

A list of all the explanatory variables included in the MRM is reported in Table 2, together with a detailed description, the main descriptive statistics and the unit of measurement.

Variable	Description	Unit of Measurement	Mean	Standard Deviation
WTP	Annual households' WTP	\$/2018	343.65	445.92
Income	Average Annual Personal Income in the study site	\$/2018	33093.56	10035.31
Population Density	Population density in the study site	Inhab/km^2	234.56	572.83
Age	1 if average age is higher than 45 y.o., 0 otherwise	Binary (0; 1)	0.31	0.46
Sex	1 if percentage of female is higher 50 %, 0 otherwise	Binary (0; 1)	0.59	0.49
Education	Percentage of individual holding at least a bachelor's degree	Numerical	0.20	0.06
US	1 if the study site is located in US, 0 otherwise	Binary (0; 1)	0.75	0.43
Mean	1 if the study reported the mean WTP, 0 otherwise	Binary (0; 1)	0.80	0.39
CVM	1 if the study employs the Contingent Valuation Method, 0 otherwise	Binary (0; 1)	0.91	0.27
Phone Interview	1 if the survey is conducted by phone interviews; 0 otherwise	Binary (0; 1)	0.15	0.362
Face Interview	1 if the survey is conducted by face-to-face interviews, 0 otherwise	Binary (0; 1)	0.08	0.27
Elicitation Format	1 if dichotomous choice is employed in the WTP question, 0 otherwise	Binary (0; 1)	0.43	0.49
Dimension Payment	1 if WTP is asked in the form of periodic payment; 0 if single payment	Binary (0; 1)	0.87	0.33
Payment Vehicle	1 if the payment vehicle used is extra taxes on water bills, 0 otherwise	Binary (0; 1)	0.58	0.49
Estimation Method	1 if ML estimation; 0 otherwise (OLS, GLS, no estimation, ...)	Binary (0; 1)	0.76	0.42
Grey Literature	1 if the WTP estimation comes from grey literature; 0 otherwise	Binary (0; 1)	0.30	0.46
Physical Cont	1 if physical contaminants detected; 0 otherwise	Binary (0; 1)	0.02	0.16
Chemical Cont	1 if chemical contaminants detected; 0 otherwise	Binary (0; 1)	0.63	0.48
Biological Cont	1 if biological contaminants detected; 0 otherwise	Binary (0; 1)	0.09	0.29
Radiological Cont	1 if radiological contaminants detected; 0 otherwise	Binary (0; 1)	0.01	0.11

Table 2: Descriptive statistics of the explanatory variables in the meta-dataset.

2.3 Meta-regression model (MRM)

Formally, the MRM I estimate is represented, given the study site s, by the equation:

$$wtp_s = \beta_0 + \sum_{i=1}^{k} \beta_i x_{is} + \sum_{i=1}^{h} \gamma_i z_{is} + \sum_{i=1}^{4} \sigma_i Ql_{is} + \varepsilon_s \tag{4}$$

which in matrix notation may be expressed as:

$$\boldsymbol{Y} = \boldsymbol{X\beta} + \boldsymbol{Z\gamma} + \boldsymbol{QL\sigma} + \boldsymbol{\varepsilon}, \tag{5}$$

where: $\boldsymbol{Y}$ is the vector of WTP estimates (wtp_s) reported by the study sites, $\boldsymbol{X}$ is the matrix of the k study-design explanatory variables (x_s), $\boldsymbol{Z}$ is the matrix of the h socio-economic explanatory variables (z_s) and $\boldsymbol{QL}$ is the matrix of the 4 dummy variables conveying the severity level of the

[5] Both data on countries' HCPI (2016 based) and PPP adjusted exchange rate are taken from the OECD database.

drinking water contamination in the study sites, while $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$, $\boldsymbol{\sigma}$ and $\boldsymbol{\varepsilon}$ are the vectors of parameters and error terms of the MRM.

My empirical strategy pays attention on two critical aspects: the functional form of the MRM and the specific vector of explanatory variables to include in the final specification. The former is a standard problem when it comes to setting up MRM, primarily revolving around the decision of whether to linearly introduce numerical variables into the regression function or opt for a logarithmic transformation. The logarithmic specification is generally preferred. It allows the regression models to better capture curvature in the WTP valuation function, since the MRM reflects the contributions of the independent variables in a multiplicative manner, rather than additive (Johnston et al., 2005; Johnston and Thomassin, 2010). Concerning the vector of explanatory variables to include in the final specification of the MRM, there might be two different approaches. First, since the selection of the predictors (i.e., socio-economic and study design variables) for which metadata have been collected is theory-based[6], the *all-explanatory* model's specification should always be preferred. Namely, from an economic perspective, all variables selected may have a role in shaping the valuation function and the estimated parameters from the regression should convey the degree to which each of them contributes in explaining the WTP measures' heterogeneity across primary studies. On the other hand, since my final objective is to exploit the MRM's results to perform a benefit transfer exercise and estimate a WTP value for a different policy site, the statistical out-of-sample performance of the estimated MRM may have a room in choosing a specific subset of independent variables, excluding some of them from the model.

Having in minds the caveats presented above, I proceed as follows. Looking at the functional forms, according to what theory and previous literature suggest, I only estimate log-log regression models, discarding any possible log-level configuration of my MRM. In the choice of explanatory variables, instead, I change the configuration of the meta-regression estimating different models by varying the pool of included explanatory variables. The benchmark model's specification is the *all-explanatory* model, which involves the estimation of 20 coefficients (including the intercept). Afterwards, I repeat the estimation retaining only some subsets of the full vector of independent variables. The criterion guiding the selection of variables is the LASSO (Least Absolute Shrinkage and Selection Operator), which suggests me the optimal eleven coefficients to estimate, given my full set of predictors[7]. I utilize LASSO's guidance to establish the minimum number of explanatory variables (referred to as the lower-bound model), and I explore all possible configurations of the MRM by considering predictor vectors whose length spans from the LASSO-selected model to the *all-explanatory* models. In practice, starting with the LASSO's model (Model 10), I progressively incorporate additional explanatory variables, one at a time. For each predictor vector length ranging from 11 to 20, I identify the optimal specification.

In total, I have ten distinct model specifications, and all regressions are estimated using Ordinary Least Squares (OLS) with robust standard errors. When it comes to selecting my preferred specification, which will subsequently be employed for the benefit transfer, there is no single definitive rule of thumb. Instead, I deal with a trade-off among various considerations. Specifically, I

[6]The identification of the explanatory variables to include in the MRM have been carried out by looking at the factors influencing the WTP's indirect utility function in standard theoretical economic model (for socio-economic variables) and following the suggestions of the international meta-analysis guidelines (for study-design variables).

[7]According to the LASSO selection criterion, I should include in the MRM: Population Density, Age, Sex, US, Mean, Elicitation Format, Dimension Payment, Physical Contamination, Biological Contamination, Radiological Contamination and the intercept.

assess the results based on several dimensions, including:

- values of the parameters of interest (sign and magnitude), which should match the extant literature's evidences and the theoretical suggestions of standard economic models;
- explanatory power, evaluated computing the adjusted R^2, which provides me a measure of the percentage of variability in the WTP estimates of my metadata which is explained by the set of predictors included in the MRM. Intuitively, an higher adjusted R^2 stands for a better estimated model;
- mean transfer error (MTE), computed through the Leave-One-Out Cross Validation procedure (LOOCV). The LOOCV is a cross validation technique often used to assess the out-of-sample validity of predictive models. In details, the procedure involves multiple estimations of the model on subsets of data corresponding to the entire sample minus one of the observation. Assuming that the observations collected are $n = 1, 2, ..., N$, the MRM is fitted on $N - 1$ observations and the parameters estimated are employed in the out-of-sampling estimation of the n^{th} excluded observation. A transfer error is then computed comparing the real data of the n^{th} excluded observation and the out of sample prediction from the restricted model. The procedure is repeated N times excluding one-by-one all observation in the sample, and a mean transfer error (MTE) is retrieved. Clearly, since my objective is to exploit the estimated results for benefit transfer, a lower MTE stands for a better estimated model;
- number of explanatory variables introduced. As argued, since all the selected variables are theoretically significant for the prediction of the WTP for better water quality, an higher number of variables inserted in the model would be preferred.

The trade-off arises from the fact that some of these conditions may have an inverse relationship; for example, a larger model might exhibit a lower R-squared or a higher MTE, while a model with a small transfer error may not yield reliable parameter estimates. Consequently, there isn't a singular, definitive best model specification. Instead, I must choose my preferred MRM by taking all of these factors into account, all while keeping my ultimate objective in mind: utilizing the MRM for benefit transfer, which involves making out-of-sample predictions.

3 Results

The estimated results from the ten MRMs are illustrated in Table 3. In the last rows of the table are reported the main indicators I analyse to identify the best specification of my MRM: the adjusted R-squared, the mean MTE computed through the LOOCV procedure and the number of predictors included in the model. In terms of statistical performances, both in-sample and out-of sample, the evidences suggest that as the number of included predictors decreases, the explanatory power (adjusted R-squared) of the MRM tends to increase, while I observe lower values of the transfer error (MTE). Regarding the values of the estimated parameters, the direction and, to some extent, the magnitude of the effects are generally consistent across different specifications. Taking all these dimensions into consideration, the two best MRM configurations are those of Model 9 and Model 10, as they exhibit higher adjusted R-squared values and lower MTE. However, when comparing the two models, I prefer Model 9. Despite having roughly similar adjusted R-squared and MTE values, Model 9 retains all the dummy variables accounting for the contamination level, which I find important for the overall model's comprehensiveness.

log(WTP)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
log(Income)	-0.0274	-0.0341	-0.0898	-0.123	-0.151	-0.143				
	(0.947)	(0.932)	(0.837)	(0.769)	(0.704)	(0.717)				
log(Population Density)	-0.0917	-0.0859	-0.131	-0.161**	-0.165**	-0.171**	-0.174**	-0.173**	-0.171**	-0.183***
	(0.326)	(0.333)	(0.101)	(0.041)	(0.036)	(0.020)	(0.018)	(0.017)	(0.014)	(0.010)
Age	0.377	0.375	0.393	0.446*	0.458*	0.485**	0.487**	0.508**	0.485**	0.515**
	(0.151)	(0.143)	(0.142)	(0.095)	(0.082)	(0.048)	(0.045)	(0.027)	(0.025)	(0.028)
Sex	1.033***	1.036***	1.056***	1.025***	1.014***	1.005***	1.008***	1.032***	1.028***	1.092***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Education	-2.385	-2.538								
	(0.171)	(0.148)								
US	0.536	0.597	0.656*	0.766*	0.755*	0.755*	0.724*	0.726*	0.729*	0.927**
	(0.192)	(0.110)	(0.096)	(0.062)	(0.064)	(0.063)	(0.065)	(0.059)	(0.051)	(0.012)
Mean	0.618***	0.622***	0.674***	0.662***	0.662***	0.674***	0.659***	0.652***	0.653***	0.713***
	(0.009)	(0.009)	(0.006)	(0.006)	(0.005)	(0.003)	(0.002)	(0.003)	(0.003)	(0.001)
CVM	0.170	0.0771	-0.0174	-0.112	-0.127	-0.173	-0.155	-0.146		
	(0.641)	(0.800)	(0.957)	(0.715)	(0.704)	(0.573)	(0.614)	(0.631)		
Phone Interview	-0.0000363	-0.0430	-0.160	-0.0723						
	(1.000)	(0.900)	(0.622)	(0.814)						
Face Interview	-0.730	-0.737	-0.657							
	(0.330)	(0.322)	(0.370)							
Elicitation Format	0.793***	0.860***	0.802***	0.790***	0.794***	0.797***	0.773***	0.734***	0.725***	0.789***
	(0.008)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)
Dimension Payment	-0.685**	-0.761**	-0.854***	-0.777*	-0.757*	-0.735**	-0.716**	-0.720**	-0.726**	-0.594*
	(0.042)	(0.023)	(0.010)	(0.054)	(0.051)	(0.044)	(0.040)	(0.039)	(0.036)	(0.093)
Payment Vehicle	-0.155									
	(0.582)									
Estimation Method	-0.101	-0.121	-0.147	-0.166	-0.174	-0.157	-0.125			
	(0.704)	(0.663)	(0.578)	(0.501)	(0.491)	(0.528)	(0.579)			
Grey Litarature	-0.279	-0.233	-0.180	-0.0722	-0.0765					
	(0.221)	(0.306)	(0.423)	(0.750)	(0.728)					
Physical Cont	1.223**	1.185**	1.356**	0.988**	1.009***	1.043***	0.966***	0.965***	0.968***	0.744***
	(0.040)	(0.047)	(0.027)	(0.010)	(0.006)	(0.004)	(0.002)	(0.002)	(0.002)	(0.004)
Chemical Cont	0.390	0.378	0.457	0.492	0.497*	0.483*	0.440	0.448	0.458	
	(0.237)	(0.244)	(0.158)	(0.107)	(0.097)	(0.093)	(0.126)	(0.118)	(0.106)	
Biological Cont	1.594***	1.619***	1.566***	1.551***	1.514***	1.497***	1.501***	1.582***	1.669***	1.289***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Radiological Cont	1.170**	1.075**	1.125**	1.269***	1.297***	1.317***	1.263***	1.265***	1.267***	0.797***
	(0.037)	(0.030)	(0.029)	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.006)
_cons	4.593	4.670	4.952	5.273	5.578	5.498	4.045***	3.925***	3.784***	3.787***
	(0.291)	(0.267)	(0.269)	(0.227)	(0.186)	(0.189)	(0.000)	(0.000)	(0.000)	(0.000)
N	72	72	72	72	72	72	72	72	72	72
adj. R^2	0.645	0.650	0.644	0.639	0.645	0.650	0.656	0.660	0.665	0.651
Number of predictors	20	19	18	17	16	15	14	13	12	11
Transfer error (LOOCV)	0.693	0.686	0.670	0.646	0.639	0.631	0.621	0.616	0.607	0.603

p-values in parentheses. All models have been estimated with OLS using robust standard errors for heteroskedasticity.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Results from the different MRMs estimation. Model (10) is the LASSO MRM and Model (1) is the *all-explanatory* variables model. Model (9) is the preferred model.

The preferred model specification for my MRM (i.e., Model 9) displays a MTE of 0.607 and an adjusted R-squared of 0.665. The latter result is strongly consistent with the bulk of meta-analysis in the environmental valuation literature. Nelson and Kennedy (2009), indeed, reports an average adjusted R-squared of 0.479 in a quantitative summary of 130 meta-analysis from 115 published and unpublished studies covering various topics of environmental and resource economics. Looking at the estimated values, eleven out of twelve parameters are significantly different from zero at least at 10 % confidence level (among which 7 are significant at 1 % level and 3 at 5 % level).

Notably, a first result is represented by the fact that some of the socio-economic explanatory variables show relevant statistical relationships with the dependent variable. In particular, the WTP for better drinking water quality reported across studies is significantly higher in sample with a large fraction of women (Sex = 1.028) and in older sample (Age = 0.485). Conversely, the estimated WTP is lower the more densely populated is the study sites (Population density = -0.171).

Concerning prior experienced contamination, three out of four parameters associated with the severity level of the water contamination are significant and positive (Physical Cont = 0.968; Biological Cont = 1.669; Radiological Cont = 1.267), confirming the idea that contamination events generally lead to higher social awareness about drinking water quality and therefore bigger WTP measures. However, a prior water chemical contamination does not show a significant impact on the estimated WTP across studies while exhibiting a positive estimated parameter. It is worth to note that the value of these parameters are, however, asymmetric with respect to the severity level of the contamination. For instance, a prior biological contamination results in a higher WTP estimate with respect to the radiological one, ceteris paribus. In my view, there are two possible explanations for this misalignment. First, this difference may be attributed to the limited sample size, since only one valuation studies have been conducted after radiological contamination, while nearly 10% of the papers in the meta-dataset are primary valuations conducted after detecting biological contaminants in the water body being valued. Moreover, biological contaminants are clearly the most comprehensible form of contamination (virus and bacteria above all) and is therefore likely that they are the most impactful on individual awareness and WTP.

Another noteworthy finding is shown by the United States fixed effect included in the regression, which is both positive and statistically significant (US = 0.729). This suggests that primary valuation studies conducted in the United States consistently report higher average or median WTP measures compared to study sites in other countries worldwide. The importance of this result is twofold. First, the direction of this effect aligns with real-world scenarios: the United States has a history of water contamination events of varying magnitude and seriousness which has certainly increased the level of demand for higher drinking water quality. Second, from a benefit transfer perspective, obtaining a significant country-fixed effect allows me to control for potential sources of bias in the transfer error due to the international dimension of my metadata. Omitting this regressor from the MRM would have likely led to an overestimation of the WTP measure, and therefore of the social benefits, in the relevant policy site (the PFAS-contaminated area in Italy).

Concerning the study design variables, two results are mostly in line with the past primary valuation literature. WTP measures across study sites are systematically higher when the WTP reported is the mean of the distribution with respect to the median (Mean = 0.653) and when the dichotomous choice format is employed in the WTP question (Elicitation Format = 0.752). The former result indicated that the distribution of WTP across individuals tends to be positive skewed, following the shape of standard income distribution in the population.

3.1 Benefit transfer: social benefits from PFAS decontamination

Once the MRM has been estimated in his best specification, the final objective of the current analysis is to conduct a benefit transfer exercise aimed at estimating the WTP for better drinking water quality among Italian households who experienced PFAS contamination in the recent decades. The benefit transfer exploits the parameters estimated in a systematic and quantitative review of primary valuation studies' results to provide a monetary value for the same result but in a different, and new, policy site. In practice, the transfer of values is realized plugging in inside the valuation function (i.e., the MRM equation) values of the explanatory variables relative to the policy site and computing the fitted value of the WTP for improved water quality.

For the socio-economic variables, it is key to carefully identify the geographical area corresponding to the policy site of interest before collecting information. The PFAS-contaminated portion of Veneto Region has been formally dived with a resolution of the regional council (DGR n.691 2018) in four different areas according to the degrees of health risks exposure (Red, Orange, Yellow and Green areas in Figure 1). In particular, the Red Area includes all the municipalities which experienced direct PFAS exposure. The Orange Area, instead, accounts for districts in which the PFAS exposure has been experienced only due to autonomous water catchment (e.g., private wells). Finally, the Yellow and Green areas are only attention areas, given the mobile nature of the contaminant. For the sake of homogeneity with the primary studies included in the meta-dataset, I consider as policy site only the Red area, since all the WTP estimates collected in the meta-analysis come from valuation surveys administrated to households who have directly experienced the water contamination, if occurred. Therefore, starting from the data collected in the surveillance plan conducted by the Health Department of Veneto Region on the population living in the PFAS red area, I retrieve the measure for Population density (287.07 h/km^2), average age (43.9 years; therefore Age = 0) and percentage of female (0.516; therefore Sex = 1). Moreover, given that PFAS are chemical contaminants, I set all the binary variables controlling for the type of contamination to zero except for Chemical Contamination.

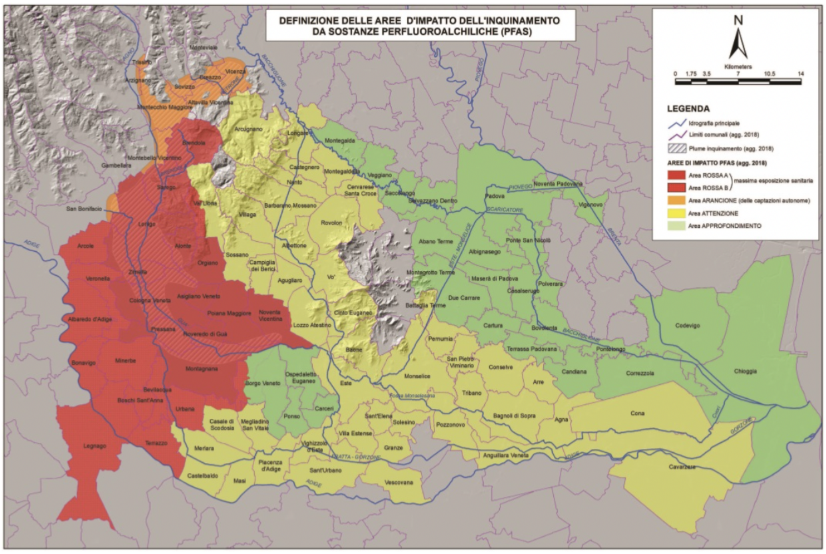

Figure 1: Different PFAS-contaminated area in Veneto (Italy) according to the level of human exposure
Source: DGR n.691 2018 Veneto Region.

Concerning the value of the study design variables, the benefit transfer procedure is implemented simulating the administration of a primary survey which replicates the methodological characteristics resulted to be statistically significant in the MRM. Therefore, I assume that the aggregate collected measure is the average WTP rather than the median one (Mean = 1) and that in the simulated survey the WTP question is formulated in a dichotomous choice manner and it involves a periodic payment commitment (Elicitation Format = 1; Dimension Payment = 1). Finally, in the transfer procedure the variable controlling for the US country fixed-effect is set to zero being my policy site of interest in Italy (US = 0).

Plugging in the policy site's variables for the treatment area, transforming the log function in level form, and correcting for the PPP exchange rate, I obtain an average annual households WTP for better drinking water quality in the PFAS area of around 205 €. In a cost-benefit analysis (CBA) framework, this results is the key input to provide a measure of the aggregate social benefits deriving from a potential decontamination of the environmental site of interest. Given the number of households living in the Red area (59634), indeed, the aggregate social benefits amount to around 12 millions euro, which is hence the monetary value to compare with the economic costs associated to any possible environmental intervention aimed at restoring the drinking water quality in the Red area. The exploitation of the WTP estimates for an environmental resource's quality change to assess the economic convenience of an investment in protection or restoration actions is the main policy motivation behind valuation analysis, both in primary or secondary studies. The computation of the households WTP and the aggregate social benefits through the use of the valuation function estimated in the MRM is summarized in Table 4.

Variable	MRM Coefficient (A)	Policy Site Data and Assumption	Variable Value (B)	Source	Product (A*B)
log_Pop_Density	-0.171	282.07 h/km^2	5.642	Health Department Survey	1
Age	0.485	43.9 years	0	Health Department Survey	1
Sex	1.028	0.516	1	Health Department Survey	1.225
US	0.729	Italy (Outside US)	0	Scenario	0.000
Mean	0.653	Mean WTP	1	Scenario	0.660
Elicitation_Format	0.725	Dichotomous Choice	1	Scenario	0.886
Dimension_Payment	-0.726	Periodic Payment	1	Scenario	0.000
Physical_cont	0.968	No	0	US-EPA	0.580
Chemical_cont	0.458	Yes	1	US-EPA	0.580
Biological_cont	1.669	No	0	US-EPA	0.580
Radiological_cont	1.267	No	0	US-EPA	0.580
_cons	3.784				3.784
Final computation of aggregate social benefits				**ln(WTP)**	4.957
Number of Households in the contaminated area		59634		**WTP ($-2018)**	142.197
Aggregate Social Benefits (€-2018)		12273222.276		**WTP (€-2018)**	205.809

Table 4: Summarize of the benefit transfer procedure to estimate WTP for better drinking water quality in the PFAS area of Italy.

4 Conclusions

In this paper, I conduct a meta analysis-benefit transfer exercise with the primary goal of calculating the WTP for improved drinking water quality among households residing in the PFAS-contaminated area of the Veneto Region, Italy. To execute this meta-analysis, I gather data from 39 previous primary valuation studies and construct an original meta-dataset comprising 72 observations. This dataset includes both socio-economic and methodological attributes of the selected study sites. The selection of primary studies adheres to a rigorous protocol designed in accordance with the most up-to-date international guidelines for meta-analysis in environmental economics. From a theoretical point of view, the valuation function shaping the WTP guiding the selection of variables follows a WSUT approach.

Subsequently, I employ a MRM to estimate the WTP, optimizing its specification based on out-of-sample performance metrics, specifically the adjusted R^2 and the mean transfer error (MTE).

The final MRM yields an adjusted R^2 of 0.665 and a MTE, computed through the LOOCV procedure, of 0.607. Both results are very much in line with previous meta-analysis published in environmental economics. Utilizing the estimated parameters from the MRM in the benefit transfer process, I compute an annual WTP for improved water quality among households directly exposed to PFAS contamination in Italy over the last few decades of approximately €205. This outcome leads to a social benefit of approximately €12 million from potential PFAS decontamination efforts, a crucial benchmark for policymakers when considering resource allocation for restoration interventions within a Cost-Benefit Analysis (CBA) framework.

Finally, beyond facilitating benefit transfer, the conducted meta-analysis allows for an overview of the valuation literature regarding drinking water quality in advanced economies. I find that aggregated WTP measures from primary studies exhibit significant variations based on socio-economic characteristics of the surveyed sample (such as age, gender, and population density), methodological survey features (including elicitation format and payment dimensions), and the type of contamination, if any, detected in the water quality assessment.

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