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Economic valuation meta-analysis of freshwater improvement in developed and developing countries. Are they different?

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ABSTRACT

The quality of drinking water differs across countries, so households show different levels of willingness to pay (WTP) to improve it, which is also influenced by their income levels. This study presents a meta-analysis using studies from 30 developed and developing countries, representing 4.7 billion inhabitants. At the international level, by standardizing these values (PPP) to international US dollars of 2011, developing countries show, on average, a greater WTP than developed countries relative to their income and an inverse correlation between their water footprint and their WTP.

Key words: contingent valuation, meta-analysis, water footprint, water improvement, willingness to pay

HIGHLIGHTS

- A comparative meta-analysis between developed and developing countries.
- Developing countries are willing to pay more to improve their drinking water.
- Policy-makers can use these results to guide their decisions.
- Developing countries are willing to pay more to improve their freshwater, but do not trust their governments.
- Developing countries are willing to pay more for the freshwater in relation to their income.

1. INTRODUCTION

The United Nations (UN 2019) believes that water is the central factor for sustainable development; however, more than 2 billion people do not have access to safe drinking water services (WHO/UNICEF 2017), one in nine people lack access to safe water (Water.org 2019), water scarcity already affects up to 40% of people (WHO), and every year, 340 thousand children under five die from diarrheal diseases (WHO/UNICEF 2015). These are all problems that can get worse with droughts caused by climate change (Boisvert-Marsh *et al.* 2020) or with phenomena like El Niño in some South American countries (Pécastaing & Chávez 2020).

There are many international and local initiatives that address water issues, seeking to help people exercise their rights as internationally recognized by the United Nations General Assembly's Sustainable Development Goal 6, which aims to 'Ensure access to water and sanitation for all.' This organization insists on the need to reach a minimum level of sufficiency, safety, acceptability, affordability, and physical accessibility for quantities of water between 50 and 100 litres per person per day. The costs should not exceed 3% of household income, the source should not be farther than 1 km, and collection time should not exceed 30 min (UN 2019).

However, despite the progress that has been made in this field, problems persist, especially in the least-developed countries. The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) reports that by 2015, 70% of people used *safely managed* drinking water services, but in a very heterogeneous manner. Thus, while in North America and Europe this figure reaches 94%, in sub-Saharan Africa it is only 24%, and in Oceania, 0%, although with 52% *basic* coverage. Latin America and the Caribbean were the regions closest to the world average. Moreover, of '159 million people [who] still collected drinking water directly from surface water sources, 58% lived in sub-Saharan Africa' (WHO/UNICEF 2017).

On the other hand, worldwide, around one billion people have intermittent piped water supply, in both urban and rural areas (Kaminsky & Kumpel 2018).

In terms of sustainability, this is very uneven. According to the Sustainable Cities Index (ARCADIS 2016), which uses a sample of 100 cities around the planet, while Rotterdam has an index of 85.5%, Sao Paulo reaches 60% and New Delhi reaches only 27.3%. Based on the same source, concerning the quality of drinking water, Toronto ranks first with an index of 0.166, Sao Paulo 38th with an index of 0.118, and New Delhi 42nd with an index of 0.063.

On the other hand, access to drinking water has a cost that is not always affordable for families or local governments in many regions. This situation is aggravated by problems of inappropriate management. Water tariffs in developing economies are frequently insufficient to cover costs, risking the sustainability of these utilities and forcing subsidies to balance their budget. 'As an illustration, in 2002 for a typical utility in South Africa it was estimated that technical and commercial losses represented 60% of total water produced' (Le Blanc 2007).

This defective circle involves problems of mismanagement, low-quality drinking water, low tariffs, subsidies, increasing block tariffs, and problematic political decisions, all of which tend to result in permanently poor water quality in many populations, especially in developing countries. For this reason, some research has 'hypothesized that utilities can fall into a 'low-level equilibrium trap', with a negative feedback loop created between poor utility performance and low willingness to pay (WTP) for water' (Bhanwar *et al.* 1993; Tamayo *et al.* 1999; Galiani *et al.* 2005; Kaminsky & Kumpel 2018). However, studies around the world show that families are willing to pay more than they already do to improve drinking water quality and break this defective circle.

Based on the above, two questions arise: first of all, what is the maximum economic value that people are willing to pay to improve the quality of drinking water across the planet? And in a complementary way, we also ask, who is willing to pay more, those with the highest income or those who most need to improve water?

A tentative answer to this last question is that the WTP for improving drinking water is higher in developed countries because of the higher income level compared to developing countries. This hypothesis is in line with Verlicchi *et al.* (2018) and Chui & Ngai (2016), who argue that the expected results of a case study on water improvement indicate that – as already found in the literature – 'the higher the annual family income of the respondent, the higher the corresponding average WTP'. According to Van Houtven *et al.* (2017), if we consider that drinking water service is a normal good, then 'the average household income is expected to have a positive effect on WTP'. This effect is reflected in the positive estimated regression coefficients for WTP. Thus, for example, although for Amondo *et al.* (2013) the *income* variable was not significant, Moffat *et al.* (2011) and Roldán (2016) obtained positive coefficients with statistical significance at the 5% level, and Jalilov (2018), Cooper *et al.* (2018), Wang *et al.* (2015), Meibodi *et al.* (2011), Diamini (2015), Kwak *et al.* (2013)'s results were significant even at the 1% level.

However, although many primary studies find this positive correlation between income level and WTP, results may differ when integrated into a meta-analysis because the *ceteris paribus* of each base study is not homogeneous, which implies that new variables emerge.

In most of the cited studies, the positive correlation between WTP and household income occurs in a scenario in which the deficiency in the quality of the water consumed by the respondents is very similar (samples from the same population). However, the current meta-analysis compares several studies that integrate populations with very heterogeneous water quality levels across developed and developing countries. From this perspective, it is reasonable to expect that the lower the need for improvement, the lower the WTP.

In summary, if when compared to a developing country, a developed country has a higher *per capita* income but less need for the improvement of the water consumed, then which of the two factors will most influence the determination of the WTP for the improvement of water for consumption at home? This divergent *income–quality–WTP* water relationship justifies the inclusion of some explanatory variables described below.

Studies assessing public support for improving drinking water quality usually estimate the public's WTP for these directly (Kreye Adams & Escobedo 2014) or through the improvement and conservation of the sources of this water. This study presents the results of a meta-analysis of WTP studies that focus on improving water quality. The results of the econometric model indicate that the main factor significantly influencing the WTP to improve water quality is GDP *per capita*. These results also confirm that considering values in international US dollars at 2011 (PPP), developing countries have a greater WTP than developed countries. That is, they are willing to give up a larger part of their income.

These results are expected to clarify public preferences regarding the level of support for policies and programmes related to water quality improvement and protection.

2. METHODS

An international WTP study is extraordinarily complex to conduct within a single primary study. A quite common alternative for this type of objective is to resort to meta-analysis. According to Nelson & Kennedy (2009), a meta-analysis consists of combining results from different primary studies with a common outcome measure and exploring the reasons behind variation in this measure. The variation is reported in the literature with different metrics, currencies, and periods that must be standardized in order to be compared (Reynaud & Lanzanova 2017). In the case of our study, we sought to combine the WTP averages of different investigations throughout the globe, which allowed us to contrast the hypothesis stated in the previous section.

Meta-analysis studies are not free of criticism, so the risks cautioned by some researchers must be taken into account (Van Houtven 2008; Nelson & Kennedy 2009). One possible problem in a meta-analysis is the inclusion of several estimates of the same population due to multiple studies starting from the same data (primary data), overlapping subsamples, or even several estimates in the same study obtained using different methods, which implies assigning these too much weight in the meta-analysis, assuming undue independence of those results.

Van Houtven *et al.* (2017) carried out a meta-analysis on the WTP for the improvement of drinking water, closely related to our objective of domestic water, but delimited their analysis to the *developing world*. They used 60 studies but worked with several estimates from the same study and several studies from the same country, which, in our opinion, leaves the results open to the risks described above.

Nelson & Kennedy (2009), citing Lipsey & Wilson (2001), argue that 'the simplest method involves using only one estimate from each primary study, which is often recommended', but that this alternative may result in a very small sample. However, increasing the sample with more estimates from the same primary study is not an adequate option because of the problem of *dependency*. In our study, as a precautionary measure to avoid this problem, we have chosen to select only one estimate from each country included in our sample.

A second problem to anticipate is the fact that primary studies may present their WTP estimates in different currency units and over different periods. Most of the studies we found correspond to different research years between 2001 and 2018, express their results in different local currencies, and are therefore not directly comparable. To overcome this drawback, it is necessary to convert to a common currency such as the US dollar, which implies taking into account the inflationary processes of each country and, on the other hand, the difference in purchasing power of each of the original currencies. Based on Groot *et al.* (2012) and other studies (Van Houtven 2008; Van Houtven *et al.* 2017), in the current work, the values of WTP were then adjusted to the year 2011 using each country's GDP deflators[1] and converted to international dollars using purchasing power parity (PPP) conversion factors, which 'account for differences in market prices across countries', relative to the same year. GDP deflators and PPP conversion factors were obtained from World Bank (WB) (2020).

The form of payment and its frequency is another issue that we need to standardize to make primary WTPs comparable. Some were presented in annual payments, others in monthly payments, and one in bimonthly payments. To handle this issue, we opted to convert all payment forms into their monthly equivalents.

Although there are many studies on WTP, they often differ in regard to the service for which WTP is being analysed. Water provides various services to the population, be it in agriculture, electricity generation, recreation, or transportation. In our study, we focus on the services it provides within households. To be more specific, we have restricted our sample to studies mainly concerned with WTP for the improvement of the quality of water consumed domestically.

Not all studies report the information needed to perform an adequate meta-analysis. We have excluded from our research any studies that do not allow us to directly or indirectly obtain the WTP in monthly payments and that do not show the size of the sample. Initially, we tried to include only those studies that allow obtaining the variance of their estimates directly or indirectly; however, this problem reduced the number of suitable primary studies to an unacceptable number, so we decided to dispense with that variable.

[1] The consumer price index can also be used, although we have opted for GDP deflators, 'which capture changes in the overall domestic purchasing power of the currency', and according to van Houtven (2008), are 'generally most appropriate'.

Concerning the variable household income, Van Houtven *et al.*'s (2017) meta-analysis of developing countries found that 24 observations did not have household income data, and they opted to substitute these with the average of the 36 studies that did have these data. We consider that this is a very high percentage of missing data (40%) and, finding a similar problem in our work, we opted to discard this variable and substitute it with the GDP *per capita* of each country. Another factor in this decision was the fact that we include both developed and developing countries, which implies a greater dispersion of household income, meaning that the WTP–income ratio of each country would be significantly altered if we substitute it with the average income.

2.1. Specification of independent variables

The dependent variable in our regression equation is the natural logarithm of WTP in USD 2011. The objectives of the study are to quantify WTP to improve water for domestic use around the world and determine some factors affecting this WTP.

gdp: Just as it is necessary to homogenize the values in which WTP is expressed, it is also necessary to carry out the same standardization and conversion for the monetary explanatory variables, which in our case corresponds to the *GDP per capita* of each of the countries to which the primary studies in our sample belong. Likewise, we selected 2011 as the reference year and considered the PPP. We used the GDP of the year before publication because very few authors report the year of their research. The source was the World Bank website (February 2019). The GDP deflators and the PPP conversion factor were also obtained from the same World Bank website.

hdi: The Human Development Index (HDI) was obtained from the United Nations Development Program (Human Development Reports) website (February 2019).

co2pc: CO_2 emissions (metric tons *per capita* of each country). This variable represents one of the main components of the greenhouse gases that are affecting water cycles. As a source of information, we turn to the World Bank (February 2019).

frwater: The renewable internal freshwater resources *per capita* (cubic metres of each country). It is expected that the more renewable freshwater available, the lower the WTP will be, that is, there exists an inverse correlation. As a data source, we used the World Bank (March 2019), which presents data only up to the year 2014, making this the closest data for subsequent publication studies.

waterfp: The *water footprint per capita* variable (litres per day). It reflects the water demand of each country in the sample. It is expected that the higher the demand, the higher the WTP. The Water Footprint Network (March 2019) was used as the data source.

wtariff: Tariff of 1 m^3 based on a consumption of 15 m^3 per month (current USD), average tariffs per country. The data source was The International Benchmarking Network for Water and Sanitation Utilities (IBNET) (March 2019).

waterq: Water quality. Indicator: Proportion of population using improved drinking water sources. *Source*: UNICEF (Agosto 2019).

corrupt: Corruption Perception Index. A higher index corresponds to lower corruption; that is, it should be interpreted as a non-corruption index. *Source*: WB (August 2020).

dev_ec: Factor that indicates whether the country has an economy classified as developed (dev_ec = 1) or developing (dev_ec = 0), according to the classification of the International Statistical Institute[2] (ISI).

population: Population of each country in millions of inhabitants. The data source was the Population Pyramid Net (February 2019).

2.2. Primary studies in the sample

To evaluate WTP research for the improvement of domestic water quality around the world, we initially identified as many primary empirical studies as possible, searching extensively in various databases. We selected empirical studies that used primary data and non-market valuation methods. We preferred to select studies that used dichotomous choice contingent valuation surveys, and which describe the sample size.

Studies that did not use WTP using the contingent valuation method or that valued water resources services other than domestic water, such as water for agriculture and recreation, were excluded. We included peer-reviewed publications as well as PhD dissertations.

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[2] https://www.isi-web.org/index.php/resources/developing-countries (19 February 2019).

Based on these criteria, we selected 30 studies, each from a different country (see Figure 1). In total, 10 correspond to studies in developed countries and 20 to studies in developing countries (see Table 1).

2.3. Weighting WTP observations

Nelson & Kennedy (2009) conducted a meta-analysis study of 140 publications, 111 of which did not include data on variance or sample sizes, data that can serve as weights. In meta-analysis studies, it is common to assign weights to the primary estimates included (Van Houtven 2008), with the inverse of the variance being the most appropriate weight (Van Houtven *et al.* 2007; Marín-Martínez & Sanchez-Meca 2010). However, few WTP studies include this statistic, so other alternatives, less efficient, should be considered.

When variance is not available, the most frequent option is weighting by sample size (Van Houtven *et al.* 2007, 2017; Kreye *et al.* 2014), which, as we have seen, is much more widely reported. In any case, we should emphasize that many authors agree that 'this approach only provides an approximation of inverse variance weighting, because the sample size is not the only factor that determines variance', but it is a very important one (Van Houtven 2008). However, Brannick *et al.* (2010) and Field (2005), cited in Marín-Martínez & Sanchez-Meca (2010), have found that by using sample sizes as weights, better estimates can be obtained than with variances, although particularly for meta-analyses with the Pearson correlation coefficient as the effect size index.

On the other hand, Brannick *et al.* (2010) argue that 'If we have many large-sample studies, weights become essentially irrelevant.' In our study, we included 30 primary studies that, on average, use samples from 527 surveys.

Nelson & Kennedy (2009) analysed different meta-analyses, finding that of the 52 explicit weights used, 29 resorted to weights based on primary study sample size or the number of observations from the primary studies. In our case, only one out of five studies reported this measure of internal dispersion. However, we also estimated the average WTP using unit weights and population for comparative purposes.

Considering the previous arguments, in the absence of reported variances, we used sample size weighting, remembering that according to the literature, 'sample size may provide the most practical second-best approximation when we have data limitations' (Van Houtven 2008; Van Houtven *et al.* 2017).

2.4. Econometric model and analysis

To estimate the maximum value that people are willing to pay to improve the quality of drinking water across the planet.

To compare the average WTP of developed versus developing countries, we conducted a weighted analysis using sample sizes.

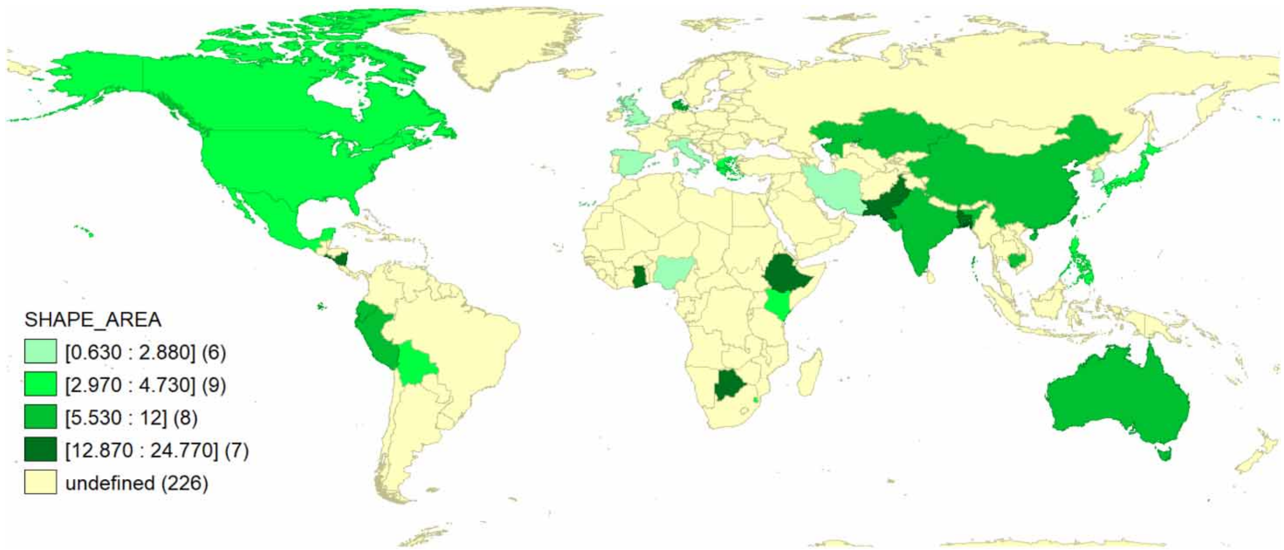

Figure 1 | Countries included in the meta-analysis. The WTP of each country was normalized to 2011 USD calculated at PPP.Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/wh.2021.268.

Table 1 | Studies in the meta-analysis – developing and developed countries

Country	WTP[a]	Study
Bangladesh	13.00	Gunatilake & Tachiiri (2012)
Botswana	16.53	Moffat *et al.* (2011)
China	7.84	Wang *et al.* (2015)
Ecuador	6.01	Roldán (2016)
El Salvador	16.64	Herrador & Dimas (2001)
Ethiopia	12.87	Hundie & Abdisa (2016)
Bolivia	3.09	Saz-Salazara *et al.* (2015)
Cambodia	12.00	Orgill *et al.* (2013)
Ghana	18.22	Amoah (2017)
India	7.67	Venkatachalam (2015)
Iran	0.63	Meibodi *et al.* (2011)
Kazakhstan	11.51	Tussupova *et al.* (2015)
Kenya	2.97	Amondo *et al.* (2013)
Mexico	3.26	Almendarez Hernández *et al.* (2013)
Nicaragua	16.68	Vásquez *et al.* (2012)
Nigeria	2.81	Ogujiuba *et al.* (2013)
Pakistan	24.77	Akram & Olmstead (2011)
Peru	9.19	Soncco & Armas (2008)
Philippines	4.57	Amponin *et al.* (2007)
Swaziland	4.27	Diamini (2015)
Australia	5.53	Cooper *et al.* (2018)
Canada	2.97	Appiah (2016)
Denmark	6.02	Hasler *et al.* (2005)
Spain	1.82	Saz *et al.* (2009)
United States	4.73	Mueller (2014)
Greece	3.29	Polyzou *et al.* (2011)
Italy	1.85	Beaumais *et al.* (2014)
Japan	3.04	Toshisuke & Hiroshi (2008)
Korea (South)	2.46	Kwak *et al.* (2013)
United Kingdom	2.88	Bateman *et al.* (2006)

[a]WTP as a percentage of the GDP *per capita* of each country. WTP was normalized to 2011 USD calculated at PPP. Data on 2011 GDP (PPP) *per capita* were obtained from WB (2019).

On the other hand, to analyse the overall WTP according to various factors explained above, we tested different models. In model (1), we used as a dependent variable the natural logarithm of WTP (with standardized PPP values to 2011). This mechanism is found in several studies (Van Houtven *et al.* 2007; Groot *et al.* 2012; Kreye *et al.* 2014):

$$\log(\text{wtp}) = \beta_0 + \beta_1 * gdp + \beta_2 * hdi + \beta_3 * co2pc + \beta_4 * frwater + \beta_5 * waterfp + \beta_6 * dev_{ec} + \beta_7 * wtariff + \beta_8 * waterq + \beta_9 * corrup + \varepsilon$$

where log(wtp) is the natural log of each monthly WTP or the effect size; β_0 is the intercept or the estimated overall effect size; $\beta_{j=1,\ldots,k}$ are the coefficients for independent variables or attributes of each country (study); ε is the error term (see Table 2).

For the estimates, we used RStudio Version 1.1.463. From the package ‘weights’, we worked with the functions wtd.mean(), wtd.var(), and wtd.t.test(), which allow weighted estimates.

Table 2 | Means weighted by sample size

	All countries		Developing countries		Developed countries	
Variable category	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
WTP (1)	8.58	1.05	11.20	1.19	3.35	0.43
WTP/GDP (%)	2.54	0.49	3.75	0.56	0.10	0.01
GDP *per capita* (2)	16,863	2,990	5,845	1,031	39,140	1,602
HDI	0.705	0.027	0.610	0.017	0.898	0.008
CO_2 *per capita* (3)	4.74	0.98	1.55	0.54	11.20	1.11
Water footprint (4)	4,045	324	3,341	347	5,467	405
Fresh water (5)	13,579	4,181	8,685	3,114	23,474	10,230
Water tariff (6)	0.836	0.158	0.311	0.057	1.900	0.209
Water quality (%) (7)	92,406	1,715	88.9	2.16	99.6	0.135
[No] Corruption (8)	44.861	4.189	30.700	1.920	73.500	4.680
Population (9)	154.66	61.61	194.00	90.70	75.20	29.90
Sample size (10)	526.83	97.41	529.00	139.00	523.00	99.50

SE, standard error. (1) Monthly, in USD 2011 PPP; (2) yearly, USD 2011 PPP; (3) CO_2 emissions in metric tons *per capita*; (4) litres per day *per capita*; (5) renewable freshwater *per capita* in cubic metres per year; (6) tariff of 1 m^3 based on a consumption of 15 m^3 per month in USD; (7) water quality – proportion (%) of the population using improved drinking water sources; (8) corruption perception index; (9) millions of people – unweighted value; and (10) people – unweighted values.

3. RESULTS

3.1. Data collection

From our literature review of WTP studies, we selected 30 primary studies from 30 different countries. These studies used mostly (77%) face-to-face surveys. The sample sizes ranged between 120 and 3,000, with an average of 527 observations per study and an aggregate of 15,805 surveys, of which 10,575 (67%) corresponded to studies in developing countries.

As can be seen in Table 2, the statistical differences between the two groups of countries are very marked. Thus, for example, developed countries emit seven times more CO_2 *per capita* than developing countries, with consequent effects on water cycles. It is particularly noteworthy that when the monetary values are homologated (USD 2011 PPP), in absolute values, developing countries are willing to pay three times more than developed countries.

In the case of the water footprint, developed countries have an impact that, on average, exceeds 60% compared to developing countries. It is also notable that the former group has 170% more renewable freshwater available than the latter. Regarding tariffs, developed countries pay six times more than developing countries, which can be explained not only by income levels but also by the fact that they receive better-quality drinking water.

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Figure 2 shows the WTP of developing countries (green dots) versus developed countries (red dots). In addition to the obviously higher WTP of the former, their greater dispersion is confirmed in the corresponding box diagram in which the green dots correspond to the averages weighted by the sample sizes. The line represents the regression of these data, in which the slope shows the inverse relationship between these variables.

In Figure 3, we substitute the absolute value of the WTP for its relative value related to the GDP *per capita* of each country. With this transformation the dispersion decreases, which is confirmed in the box diagram on the right, particularly in the developed country stratum. The green dots in the box diagrams correspond to the weighted averages. In this case, it is worth highlighting the evident non-linear behaviour.

We applied Welch's *t*-test to compare the average WTP between developed and developing countries. This test fits the characteristics of this meta-analysis (independent samples, different sample sizes, and different variances), considering the sample sizes as weights.

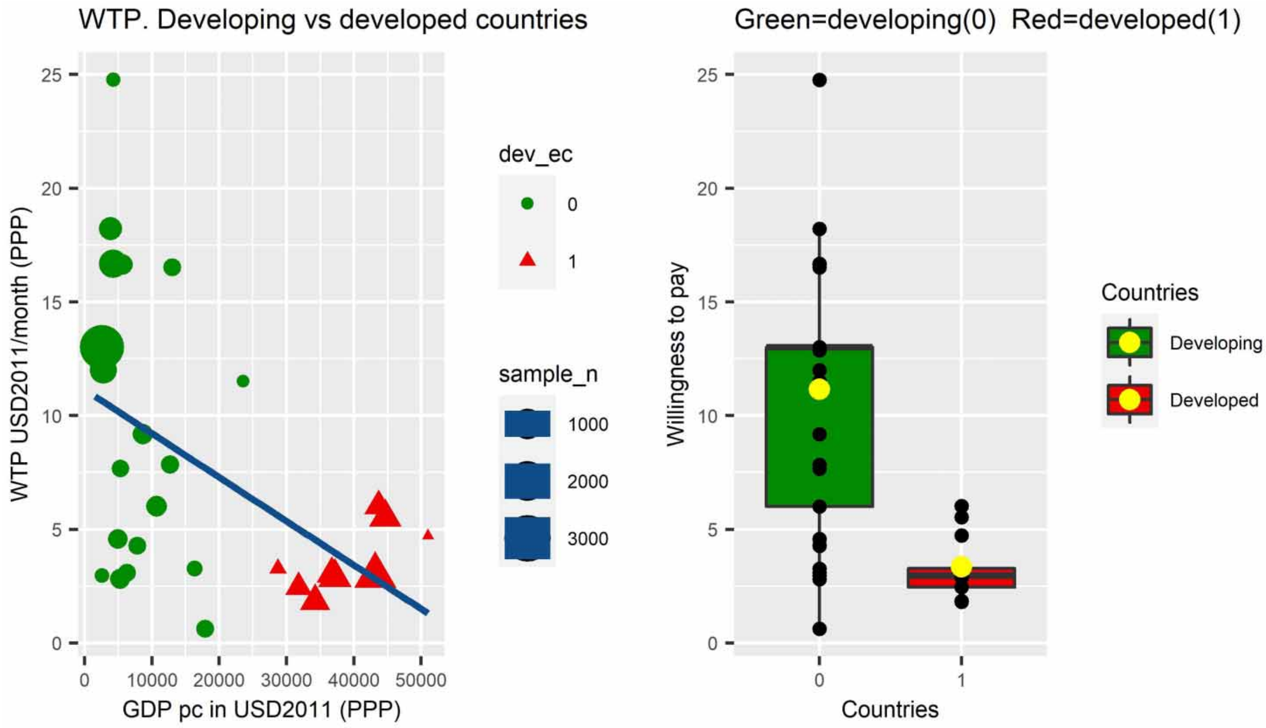

Figure 2 | WTP versus GDP in USD 2011 (PPP). Weighted by sample sizes. Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/wh.2021.268.

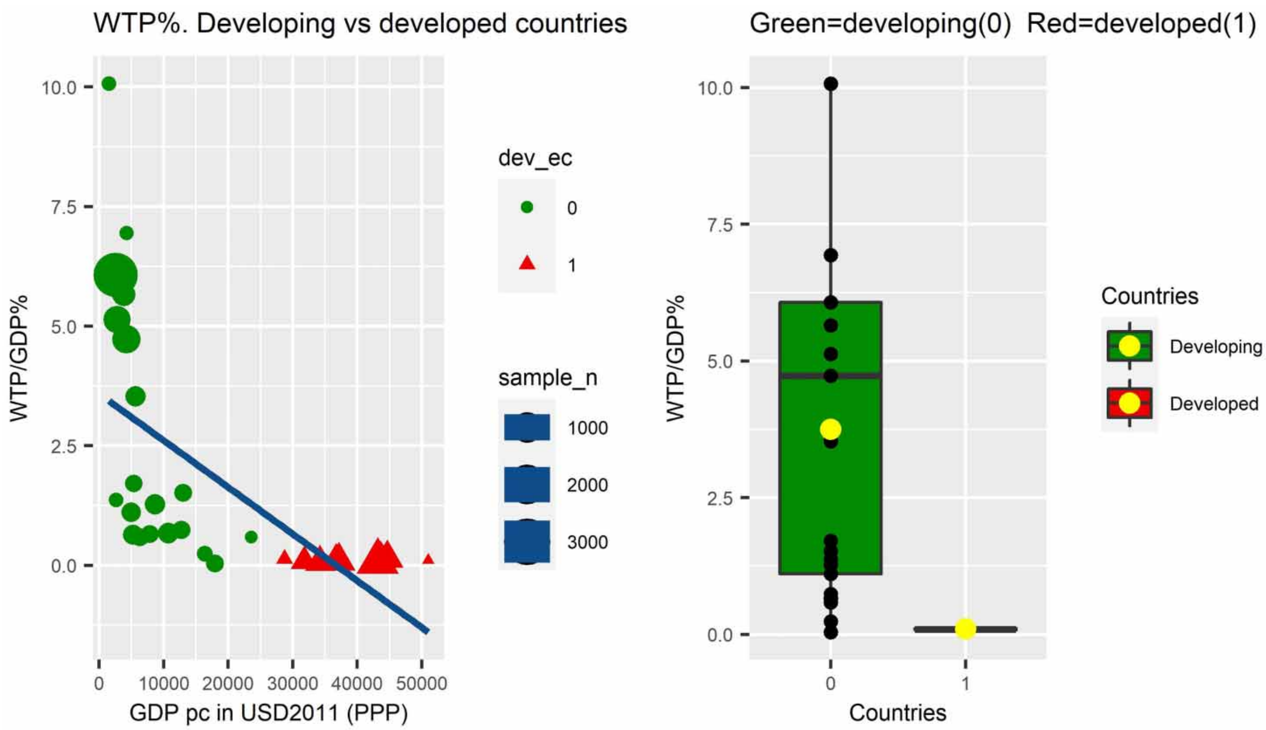

Figure 3 | WTP/GDP pc (%) versus GDP pc. Weighted by sample sizes. Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/wh.2021.268.

For the case of WTP in absolute values, when we tested whether the average WTP of developing countries is equal to that of developed countries, a difference of 7.82 USD was obtained, with a *p*-value of <0.01 (3.5e-06). We performed the same test considering the null hypothesis that the average WTP of developing countries is higher than that of developed ones, and the *p*-value was even lower (1.7e-06). Therefore, it can be concluded that statistically, on average, developing countries are willing to pay more than developed countries.

For the case of the WTP in relative values concerning the respective GDP *per capita*, in the case of the null hypothesis that the WTP% of developed countries is equal to that of developed countries, a difference of 3.65 percentage points was obtained, with a *p*-value of <0.01 (4.6e-06). For the same test but considering the null hypothesis that the WTP% of developing countries is higher than that of developed countries, the *p*-value was even lower (2.3e-06); therefore, it can be concluded that statistically, developing countries are willing to pay more, as a percentage of their income, than developed countries.

3.1.1. Correlations of interest

Table 3 shows some interesting correlations applying the variables weighted by the size of each sample (package 'weights' in R, weighted Pearson's correlations).

We can observe (in Table 3) that, both in absolute values (second column) and in relative values (third column), the average WTP shows inverse correlations with all variables, in both cases being higher compared to the HDI. It is important to highlight the fact that in primary studies, the correlation between WTP and HDI is usually positive, but the aggregation produced in this meta-analysis generates a negative correlation as a result.

The *water footprint* values can be interpreted as the water demand. It is therefore justifiable that the expected sign is positive; however, again the aggregation generates the opposite. Whereas the variable *freshwater per capita* can be interpreted as the supply of this internal renewable resource; thus, the negative sign is the one expected, due to the greater the availability of this resource, the lower WTP is understandable. In the case of *water tariff*, it can also be said that the negative sign of the correlation is the expected one since the higher the tariff, the lower the WTP people can assume. On the other hand, the WTP for improvement decreases if the current water quality is higher. The higher the *no-corruption* variable is, the less people are willing to pay, which, in principle, is the opposite of the expected sign.

3.2. Regression models

We evaluate different models in which we use as an independent variable the WTP in absolute values, relative values, as well as their logarithms. As for the regressors listed in Table 3, they show high correlations in some cases and warn of collinearity problems (Dormann Elith & Bacher 2013), with high correlation especially among the variables GDP, HDI, CO_2, and water tariff, so that in the models evaluated, we avoid including them together.

We use as criteria for evaluating regression models the coefficient of multiple determination R^2, obtaining the three models in Table 4 as the ones that best explain the variability of the meta-data. Moreover, we alternatively use the value of WTP as a dependent variable in three forms: (1) its natural logarithm (log(wtp)), (2) WTP as a percentage of GDP *per capita* (wtp_gdp),

Table 3 | Correlations between WTP and some variables of interest

	WTP	WTP/GDP (%)	GDP pc
WTP	1.0000	0.8399	−0.6695
WTP/GDP (%)	0.8399	1.0000	−0.7416
GDP *per capita*	−0.6695	−0.7416	1.0000
HDI	−0.6899	−0.8115	0.9618
CO_2 *per capita*	−0.6134	−0.6970	0.9389
Water footprint	−0.6133	−0.7070	0.6597
Freshwater	−0.2264	−0.3036	0.3833
Water tariff	−0.5428	−0.6164	0.8879
Water quality (%)	−0.2816	−0.3174	0.5590
[No] Corruption	−0.5043	−0.6374	0.9114

Table 4 | WTP meta-regression results

Dependent variable	(1) log(wtp%)		(2) wtp%		(3) log(wtp)	
Intercept	14.88	(0.00)***	29.19	(0.00)***	8.98	(0.00)***
Regressors						
log(gdp)	−1.76	(0.00)***	−3.59	(0.00)***	−1.20	(0.00)**
dev_ec 1	−0.65	(0.22)	2.39	(0.04)*	−0.95	(0.10)
hdi					4.03	(0.22)
waterq			0.05	(0.09)		
[No] corrup	0.03	(0.01)**	0.03	(0.22)	0.03	(0.01)**
R^2		0.9170		0.8547		0.6439
Adjusted R^2		0.9128		0.8314		0.5869
p-value		0.00		0.00		0.00

wtp% as a percentage of GDP *per capita*. The *p*-values are shown in parentheses. Each estimate is weighted by its underlying sample size. Significance codes: 0.00 '***', 0.001 '**', 0.01 '*', 0.05 '.', 0.1 ' ' 1.

and (3) its corresponding logarithm (log(wtp_gdp)), this last being the one that better presents R^2. We have also evaluated as regressor the natural logarithm of the GDP *per capita* (log(gdp)).

Only the second model includes the water quality regressor (*waterq*), although its coefficient is very small. The index *hdi* is included in the third model, but it is not significant. The variable *dev_ec* is only significant in the second model. The variable *no_corrup* is significant in the first and third models.

In all three models, the sign of the coefficient of the logarithm of GDP *per capita* is negative. Of the three models, the first one (1) is the most adequate to explain this functional relationship, explaining 92% of the variability of log(wtp%) according to its R^2. The function can also be expressed as follows:

$$\text{wtp\%} = e^{14.88-1.76*\log(\text{gdp})+0.03*\text{corrup}}$$

The most relevant aspect of our calculations is that all three models consistently reveal a negative coefficient for the logarithm of each GDP *per capita*, which implies that in countries with higher income, the population is less willing to pay for the improvement of its drinking water supply.

The fact that the three models present positive coefficients for the non-corruption index is also consistent, which can be interpreted as a symbol of confidence for cases in which the means of the collection can be adequately used, although the coefficient is relatively small.

4. DISCUSSION

In addition to obtaining a WTP value that summarizes the results of the primary studies, our hypothesis for this study was that developed countries are willing to pay less than developing countries for improvements in their household water supply. Although primary studies often conclude the opposite, i.e., that the higher the household income, the greater the WTP for improvements in water quality, our results confirm that at the aggregate level of this meta-study, the opposite occurs.

We used 30 case studies across the world, corresponding to 20 developing countries and 10 developed countries. One study was selected for each country, and a single estimate was used from each study, as recommended by Nelson & Kennedy (2009) to avoid the *dependency* problem.

We found that on a global level, household WTP is sensitive to the level of development of each country, which can be measured from economic growth through GDP *per capita* or from the HDI, which is considered a more appropriate indicator of development. In both cases, it was found that with greater development or growth, households are willing to pay less for improved domestic water use, confirming our hypothesis.

This conclusion differs from that obtained in a meta-analysis by Van Houtven *et al.* (2017) in which they had a similar objective, although some methodological differences may explain the divergent results. On the one hand, the cited authors do not include cases from developed countries in their analysis, and on the other hand, they do not anticipate the problem of dependency since they use multiple estimates from the same study (e.g., 17 case estimates from Altaf *et al.* (1992) in Pakistan) and several studies from the same country (e.g., they include three studies from Pakistan). Furthermore, in our case, we use WTP as a percentage of GDP *per capita* (income), which further accentuates the inverse correlation we found.

A possible explanation for the fact that the results of our meta-analysis show this inverse correlation, in contrast to the primary studies, can be found in the different levels of improvement required and in the respective tariffs. It should be remembered that this inverse correlation does not imply causation, which, if there is one, would not correspond to the WTP on GDP *per capita*.

Regarding the levels of improvement, we must consider that in each primary study the respondents share approximately the same water quality deficiency, while in a meta-analysis the cases may differ significantly in this respect. For example, in the study by Appiah (2016) in the province of Alberta in Canada, it was found that people were willing to pay to ensure they did not have water outages, even though the results indicated that over the past 10 years respondents had, on average, only experienced one short-term water outage.

In contrast, in a case study in Ethiopia, Hundie & Abdisa (2016) confirm that the city of Jigjiga has a critical water supply problem, as 'the pumps and all the pipelines also need a replacement'. Furthermore, according to households' perceptions regarding the current water supply and quality, 84% stated that water quality is poor and 83% that quantity is also poor. Thus, although low incomes in developing countries influence the amount of WTP, their high requirements for improvement are more influential, leading to a higher relative WTP. In any case, it would be useful to have an indicator that accounts for the water quality of each primary study, a factor that we have not been able to determine. However, we can only speculate on this point based on reports from different institutions.

Less developed countries often have significantly deficient drinking water systems. The fact that households in these countries are willing to pay a greater part of their income to improve the quality of this service makes it possible to investigate options outside the frequent state protectionism in these economies, albeit partially.

On the other hand, we can also speculate on the influence of the high tariffs on drinking water paid by households in developed countries. As we see in Table 2, on average, they pay six times more than households in developing countries, which suggests that with such a level of tariffs, these households may feel that they are already paying enough for good quality service, with no need for additional value, or perhaps a minimum WTP.

For our estimates, we use the sizes of each sample as weights. Although we did not include this in the results, we also used unit weights and the populations of each country, in all cases with similar conclusions. These options are second alternatives to the more appropriate weighting of variances, which is unfortunately not reported in most of the primary studies used in our study, coinciding on this point with van Houtven *et al.* (2017). We, therefore, suggest that in general, future work on WTP should incorporate this measure and additional information to allow compliance with the Havránek *et al.* (2020) guidelines. In any case, it is worth noting that, according to Marín-Martínez & Sanchez-Meca (2010), some studies have even shown that weighting by sample size yields more accurate results.

To overcome these methodological limitations in meta-analysis studies on water, the collaboration of researchers and journals that address this issue is necessary to be able to learn from the experiences of works in medicine and psychology that do it better in these cases.

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DATA AVAILABILITY STATEMENT

All the data used are available from the sources cited in the variable descriptions and in the list of primary studies.

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