Welfare Effects of Water Pricing in Germany

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Abstract

The observed two-part tariff price structure (consisting of a lump-sum price and a linear marginal price) for drinking water in Germany does not reflect the cost structure reported in the literature. Recovering marginal costs from a sample of 251 German counties, we see that there are positive price–cost margins, while lump-sum prices are too low. A price-structure readjustment along welfare-economic principles (marginal cost pricing; lump-sum price ensures cost recovery) would increase the mean consumer surplus by 0.037% of the local GDP or € 2.129 million per county, assuming a share of 15% variable costs in total costs.

1 Introduction

In Germany, water utilities and households are obliged to contract (Reif, 2002, Wackerbauer, 2003), so that virtually every household (99.24%)[1] is connected to the local public water supply grid. High mandatory standards and permanent quality control according to the *Trinkwasserverordnung* ensure that tap water is of homogeneous drinking quality nationwide.

[1] Computed using data provided by the Federal and State Statistical Offices (http://www.regionalstatistik.de/).

But there are increasing concerns about the economic efficiency of the water supply. International literature often focuses on problems of scarcity and rationing of water (see the recent survey by Worthington and Hoffman, 2008), while quite the contrary is the problem in Germany: Per capita water demand has decreased by 21% from 1991 to 2004. Due to the longevity of infrastructure investments (40 to 140 years), pipes and other network components are nowadays oversize. This oversizing decreases the technical efficiency and requires higher efforts to clean pipelines and ensure drinking-water quality (Leist, 2007, Reif, 2002, Wackerbauer, 2003).

Residential water supply is a natural monopoly with decreasing average costs and high fixed and sunk costs. German water suppliers are regulated to charge cost-covering prices, so that increasing costs translate into increasing water prices. Therefore, it is not surprising that the decrease in demand has been accompanied by an increase in the average price per cubic meter (1000 liters) of 15% (in real terms) from 1992 to 2010.[2] Increasing prices in turn induce households to save even more water. Leist (2007) calls this the "self-enforcing saving-circle" (p. 157). Fostering water consumption – e.g., by lowering the households' marginal price – would break the circle.

Economic theory predicts that welfare is maximized if the marginal price equals the marginal cost, but under natural monopoly, marginal-cost pricing is not cost-covering. Mandatory two-part tariffs that consist of a lump-sum price per household and a linear (or marginal) price per cubic meter ensure cost recovery. Literature hints at fixed-cost shares of 80%–90% in total cost (Reif, 2002, Leist, 2007, Schleich and Hillenbrand, 2009). Observed prices do not reflect this cost structure. In the sample used in this paper, the lump-sum price contributes only 4.4%–61.8% (mean: 25.4%) to total revenues. Another hint of suboptimal pricing is a court decision rejecting lump-sum prices that exceed 50% of the total average bill (Leist, 2007).

[2] Computed using data provided by the Federal Statistical Office (http://www.destatis.de/) and Bundesverband der Energie- und Wasserwirtschaft (http://www.bdew.de/). A household with a consumption of 80 cubic meters of tap water had an average annual bill of € 120.40 in 1992. Adjusted for inflation, the present value would be € 169.91 in 2010. The reported average is € 195.69.

The fundamental hypothesis of this paper is therefore that from a welfare-economic point of view, the price structure is inefficient: Lump-sum prices are too low, and linear prices are too high. Readjustment of prices along economic principles would be welfare-enhancing.

This paper provides estimates of the welfare loss that occurs due to inefficient water pricing. In the following section, I briefly sketch the theoretical concept underlying my analysis. In Section 3, I describe the data set and a few manipulations necessary in order to increase the number of observations. Data on costs is unavailable, but under a few assumptions, it is possible to recover fixed and marginal costs from the given data. This is done in Section 4. In Section 5, I estimate a demand function and discuss different specifications and techniques. In Section 6, I use the fitted demand function and the estimated marginal costs to predict water demand at marginal cost pricing as well as the welfare effects in terms of consumer and producer surplus. Depending on the imputed ratio of total variable costs to total costs and on the price elasticity of demand, the mean estimated annual welfare loss varies between € 444 thousand and € 2.14 million per county, or 0.004% to 0.04% of GDP. Before I conclude and provide policy recommendations in Section 7, I also discuss distributional effects of the suggested price-structure readjustment, as this study may also be seen as an example of the equity–efficiency trade-off.

2 Theoretical Background

Applied microeconomic partial-equilibrium analysis usually employs the changes of consumer surplus (ΔCS) and producer surplus (ΔPS) to evaluate welfare effects of price changes. For consumers, this method is only an approximation, because the theoretically sound concepts of equivalent variation (EV) and compensating variation (CV) require information about consumers' utility, which is empirically unobservable. For normal goods the relationship of these measures is $EV \leq \Delta CS \leq CV$, while the reverse relationship holds if the good is inferior. The difference between EV and CV is the result of the income effect, so that the difference between all three measures vanishes if income effects are negligible (see, e.g., Mas-Colell et al., 1995). On the supply side, producer surplus is not only an empirically feasible, but also a theoretically sound welfare measure, because the producers' decision-making is not affected by an income variable.

The case of the German water supply industry differs in some details from the textbook case. First of all, the lump-sum price redistributes welfare from consumers to producers. Because of contracting obligations, households cannot avoid this payment, so that the lump-sum price causes no substitution effect and we can assume that the lump-sum price bears no deadweight loss. A second peculiarity of the German context is the linear sewage price that is charged per unit of fresh water by the wastewater management company. From the water supplier's perspective, this linear sewage price puts a wedge between producer and consumer prices. From the consumer's perspective, the linear sewage price is the price of a complementary good that must be consumed together with fresh water and cannot be unbundled. Therefore, the demand function depends on the sum of the linear prices of fresh water (p) and sewage (ps) – the full price is thus $pfull = p + ps$ – while the producer's revenue does not depend on sewage prices. If the linear sewage price reflects the marginal cost of wastewater management, this sewage-price wedge does not cause an additional deadweight loss. For simplicity, we will assume that this is the case.[3]

Analytically, the consumer surplus (CS) net of the lump-sum transfer is

(1a) $CS^0 = \int_{pfull^0}^{\infty} q(\overline{p})d\overline{p} - pl^0 \cdot h$ and (1b) $CS^1 = \int_{pfull^1}^{\infty} q(\overline{p})d\overline{p} - pl^1 \cdot h$,

where the index 0 represents the observed values and 1 represents the situation if the per-unit price for fresh water equals marginal cost, pl is the lump-sum price, and h is the number of households. Due to the contracting obligation, h is constant. For the determination of the net

3 The analysis does not suffer from this assumption. Quite the contrary: If marginal sewage prices were also above marginal costs, there would also be another deadweight loss and potential benefits to be gained from price-structure readjustment in the wastewater management industry.

producer surplus (i.e., after the lump-sum transfer), we assume constant marginal costs (see Section 4 for a justification of this assumption). The producer surplus is

(2a) $PS^0 = \left(p^0 - c\right) \cdot q\left(pfull^0\right) + pl^0 \cdot h$ and (2b) $PS^1 = \left(p^1 - c\right) \cdot q\left(pfull^1\right) + pl^1 \cdot h = pl^1 \cdot h$,

where c is the constant marginal-cost parameter. Under constant marginal costs and marginal-cost pricing, there will be no gross producer surplus (i.e., before lump-sum revenues), and the net producer surplus consists of the lump-sum payment only. The total change of welfare when switching to marginal-cost pricing (and adjusting the lump-sum price to ensure cost recovery) is easily determined as

$$
\begin{aligned}
\Delta WF &= CS^1 - CS^0 + PS^1 - PS^0 \\
&= \int_{pfull^1}^{\infty} q(\bar{p})d\bar{p} - pl^1 \cdot h - \left(\int_{pfull^0}^{\infty} q(\bar{p})d\bar{p} - pl^0 \cdot h \right) + pl^1 \cdot h - \left(\left(p^0 - c\right) q\left(pfull^0\right) + pl^0 \cdot h\right) \\
(3) \quad &= \int_{pfull^1}^{pfull^0} q(\bar{p})d\bar{p} - \left(p^0 - c\right) q\left(pfull^0\right) \qquad (p^1 \equiv c) \\
&= \int_{pfull^1}^{pfull^0} q(\bar{p})d\bar{p} - \left(p^0 - p^1\right) q\left(pfull^0\right)
\end{aligned}
$$

Equation (3) confirms that the lump-sum price component is irrelevant with respect to overall welfare, as it cancels out. The total welfare depends only on the demand function, the difference between price and marginal cost, and the sewage-price wedge.

The left-hand panel of Figure 1 depicts the situation in which the marginal consumer price $pfull^0$ exceeds the marginal costs of drinking water (c) and sewage treatment (cs). Area A represents the consumer surplus at price $pfull^0$. Area B represents the producer surplus. The deadweight loss is area C. Area D represents the sewage bill. The right-hand panel represents the situation under marginal-cost pricing. The gross consumer surplus increases by the area A′. There is no producer surplus anymore, and due to the increased use of fresh water, consumers have to pay an additional amount D′ for sewage.[4] To ensure cost recovery,

[4] Marginal costs of sewage treatment are assumed to be constant. For a justification of this assumption, see the remarks on the marginal costs of fresh water in Section 4.

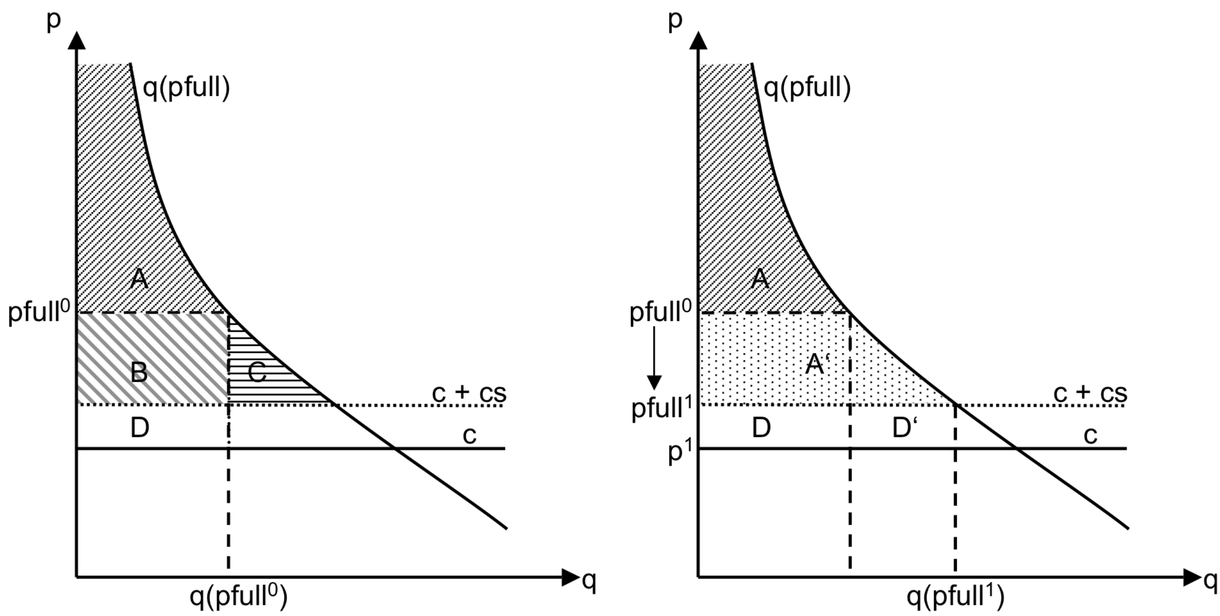

Figure 1: (a) Welfare under observed prices, (b) welfare under marginal cost prices.

producers have to be compensated for the loss of surplus B. The net consumer surplus (which is equal to the total welfare gain) is therefore $A' - B = C$.

3 Data Set

Except for prices, the data source is the *Regionalstatistik* (http://www.regionalstatistik.de/), the official portal of Federal and State Statistical Offices for municipal-, county-, and regional-level data. All data in currency units (e.g., prices and income) are adjusted for inflation to 2010 levels, using the German consumer price index provided by the Federal Statistical Office. Data on water prices has to be requested directly from State Statistical Offices. Unfortunately, some offices are unable or unwilling to provide the data, so that this analysis makes use of data from eight out of the sixteen German federal states (cf. Table 1). Although access to municipal-level data has improved in recent years, many of the relevant (control) variables are available at the county level only. To maintain consistency, the unit of observation is therefore the county. If there is more than one water supplier in a county,[5]

[5] The supply area is usually congruent to the municipality. Exceptions stem from realignments of municipal borders, and can therefore mostly be found in East Germany. Many of these realignments took place there after the German reunification (Reif, 2002, Wackerbauer, 2003).

statistical offices report mean prices, weighted by the share of inhabitants who face the respective price.

Data on water quantities is available only for 1998, 2001, 2004, and 2007, while in most federal states the earliest observations on prices are for 2005, so that panel-data methods cannot be applied. Instead, data will be treated as pooled cross sections. There are only five states for which statistical offices provide observations on prices and quantities for the same year (highlighted green in Table 1). These five states have 108 counties, and for 101 of them the observations are complete. This number is unsatisfactorily low, so that I performed the following manipulations to increase the number of observations: In some cases quantity information is available for one year, and price information is available for the year after (highlighted yellow in Table 1). Carrying this price information one year backwards yields 70 additional observations. For two states, there is only price data for 2010, while the most recent quantity data is for 2007. Here, prices have been carried backwards three years (orange highlights in Table 1) to obtain 80 additional observations. After these manipulations, the data set consists of 251 observations.

The mean annual quantity of water consumed is 8.7 million m^3, ranging from 1.65 million m^3 to 85.7 million m^3. The mean annual lump-sum price is € 53.98, with a minimum of € 8.75 and a maximum of € 160.70. The mean per-unit price of fresh water (sewage) is € 1.77

	Schleswig–Holstein	Hamburg	Hesse	Baden–Württemberg	Rhineland–Palatinate	Saxony	Saxony–Anhalt	Thuringia
1998	q	q	q	q	Q	q	q	q
2001	q	q	q	q, pd, psew	Q	q	q	q
2004	q	q	q	q	Q	q	q	q
2005			pd, psew		Pd			pd, psew
2006			pd, ps					pd, psew
2007	pd, psew, q	pd, psew, q	pd, psew, q	q	Q	pd, q	q	pd, psew, q
2008			pd, psew			pd, psew	pd, psew	pd, psew
2009			pd, psew			pd, psew	pd, psew	pd, psew
2010	pd, psew	pd, psew	pd, psew	pd, psew	pd, psew	pd, psew	pd, psew	pd, psew

pd = price components of fresh (drinking) water; psew = price components of sewage; q = quantity of water delivered to consumers. Green: observation uses price and quantity observed for the same year; orange: observation constructed by carrying price information backwards one year; yellow: observation constructed by carrying price information backwards three years.

Table 1: Availability of information on price components and quantity

(€ 2.38) per cubic meter, ranging from € 0.77 (€ 1.02) to € 2.62 (€ 4.27). Table A in the Appendix provides descriptive statistics on all variables.

4 Computation of Marginal and Fixed Costs

The data does not contain information on marginal or fixed costs. Nevertheless, the specific economic and legal environment in the German water supply industry supports the plausibility of the following assumptions:

Assumption 1: Marginal costs are constant in quantity.

Marginal costs reflect the costs of water procurement, conditioning, and pumping. These costs are proportional to the quantity of water (Leist, 2007, Reif, 2002). Rudolph and Orzehsek (1997) conducted a case study on sewage treatment in Rostock, Germany, in which they use constant marginal costs to compute the effects of decreasing wastewater quantities on costs. While this literature also discusses the possibility of decreasing marginal costs, they agree that constant marginal costs are a plausible assumption for fresh water as well as for sewage.

Assumption 2: Water suppliers make no economic profits

In Germany, water supply and wastewater management are in the sphere of public responsibility. To fulfill their task, local governments can either run a firm with the municipality as majority owner or manage water utilities directly as a department of the municipal government. Independent of the legal form, public services must be priced just cost-covering. In economic terminology, publicly owned firms are legally bound to a zero-profit condition. If they make profits, they must decrease prices; if they make losses, they must increase prices (Leist, 2007).

By Assumption 1, the cost function is simply $C_i(q_i) = c_i \cdot q_i + C_i^f$, where $C_i(q_i)$ is the total cost of providing q_i cubic meters of water in county i, c_i is the marginal cost, and C_i^f is the fixed costs. Assumption 2 suggests that total revenues should be a sufficiently precise estimate of total costs:

(4) $C_i(q_i) = c_i \cdot q_i + C_i^f = p_i \cdot q_i + pl_i \cdot h_i$.

Separating $C_i(q_i)$ into $c_i q_i$ and C_i^f requires information about their shares in total costs. Assuming a share of variable costs equal to s_v, marginal and fixed costs can be computed as

(5a) $c_i = s_v \dfrac{C_i(q_i)}{q_i}$ and (5b) $C_i^f = (1 - s_v)\dfrac{C_i(q_i)}{h_i}$.

Literature suggests $s_v = 0.15$ as a plausible value (Leist, 2007, Reif, 2002). I will refer to this case as the 15:85 scenario (15% of total costs are variable costs, 85% are fixed costs). A more conservative assumption is $s_v = 0.3$, or the 30:70 scenario, with 30% variable costs in total costs. Table 2 provides concise descriptive statistics of an evaluation of Equations (5a) and (5b) for both scenarios, and – for convenience – the corresponding statistics for observed prices in the last two rows. Notice that in the 15:85 scenario, the highest marginal cost is approximately of the same magnitude as the lowest linear price observed in the data. This is another illustration of the hypothesis that linear prices are currently too high.

		Minimum	Mean	Maximum
$s_v = 0.15$	c	0.17	0.38	0.78
	C^f	104.20	175.40	261.90
$s_v = 0.3$	c	0.33	0.75	1.56
	C^f	85.85	144.50	215.70
Sample	p	0.77	1.77	2.62
	pl	8.75	53.98	160.70

Table 2: Descriptive statistics on marginal and fixed costs in different scenarios

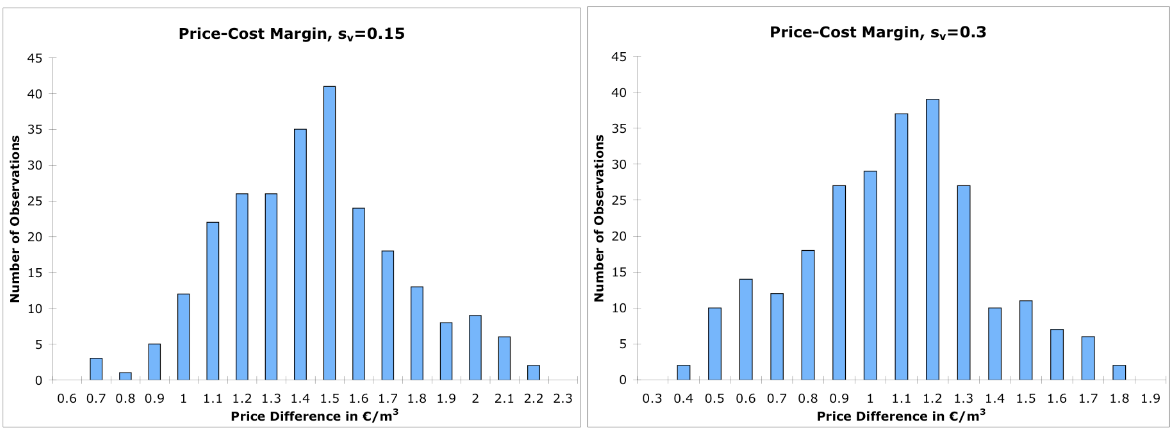

Figure 2: Price–cost margin in different scenarios

Figure 2 complements Table 2, visualizing the data as histograms. The left-hand panel displays price–cost margins ($p - c$) in the 15:85 scenario, and the right-hand panel displays them for the 30:70 scenario. Obviously, price–cost margins are of smaller magnitude if the variable-cost share is higher. Nevertheless, even in the 30:70 scenario, the observed linear prices strictly exceed the imputed marginal costs.

5 Variable Selection and Estimation of the Demand Function

Worthington and Hoffman (2008) provide a comprehensive survey of the empirical literature on residential water demand and discuss a number of different variables. A similar overview can also be found in Schleich and Hillenbrand (2009), who are the only ones to provide an empirical study of water demand in Germany. For conciseness, I do not repeat the discussion of all these variables and results of previous literature here, but refer to the comprehensive treatment in these two papers instead.

The regression model of the demand function is specified as

(6) $q_i = \alpha_0 + \alpha_1 \cdot pfull_i + \alpha_2 \cdot pfix_i + \beta \cdot x_i + \gamma \cdot D_i + \varepsilon_i$,

where the dependent variable q_i is the amount of water delivered to households and small firms in county *i*, $pfull_i$ is the the households' marginal price, pl_i is the annual lump-sum price per household, x_i are control variables, D_i are dummies for the federal states and years, and ε_i is the error term.

Due to the small sample size, I consider a rather parsimonious specification (regression III in Table 3),[6] in which x_i encompasses only the disposable annual income (*income*) and two variables that measure the market size: the number of households (*h*) and the average household size (*h_size*), that is, the average number of people living in a household. To

[6] Earlier drafts of this paper employed a richer model that included the variables considered by Schleich and Hillenbrand (2009). These variables hardly contributed to the explanatory power (measured by the change of the adjusted R^2), and the estimated coefficients were insignificant. The analysis benefits from dropping these variables, for two reasons: (1) Using less variables yields more degrees of freedom. (2) Due to missing values, some 90 observations had to be dropped. The parsimonious specification makes use of these observations. Estimation results for the richer model are available from the author upon request.

convince the critical reader that my data manipulation does not substantially alter the results, I also provide estimates that use the unmanipulated observations only (regression I) or that exclude those observations with a three-year gap between price and quantity (regression II).

When estimating demand functions, endogeneity problems arise for a number of reasons. In the presence of endogeneity, the ordinary least squares (OLS) coefficient is biased towards zero (or downwards in absolute terms). Measurement error, simultaneity of price and quantity, and omitted variables are the most frequently discussed violations of the OLS assumptions. All these problems can be addressed using two-stage least squares (2SLS) estimation. Regression IV in Table 3 provides the results of the 2SLS estimation. However, the advantage of 2SLS over OLS crucially depends on the quality of the employed instrumental variables. With weak instruments, the IV estimator is biased, too. Obviously, an appropriate instrument must not be endogenous itself. It must be correlated with the (suspected) endogenous right-hand-side variable, and it must not have a direct effect on the left-hand-side variable. In our context, there are two suspected endogenous variables (*pfull*, *pl*), which means that we are looking for two or more instrumental variables[7] that influence prices, but do not directly affect demand. Since water utilities are publicly owned, local governments and municipal parliaments exert a direct or indirect influence on the price structure (Leist, 2007). The price structure has redistributive effects. For instance, families with many children use more water than single persons, so that a high lump-sum price combined with a low marginal price benefits families at the expense of single persons. But single persons and single parents bear the highest poverty risk in Germany (Strengmann-Kuhn, 2003). Political parties think differently about such redistribution, so that it seems reasonable to expect an influence of their political power on the price structure. The major parties are the CDU, the SPD, and – mainly in East Germany – Die Linke. While the CDU is

[7] 2SLS needs at least one instrument for each endogenous variable. A higher number of instruments improves the first state estimate that replaces the endogenous variable, but at the same time increases the risk of adding a weak variable, which would bias the 2SLS result. There is no general rule that suggests an optimal number of instruments (Wooldridge, 2002).

a rather conservative party that promotes the traditional family, Die Linke and (to a lesser extent) the SPD rather emphasize poverty reduction. The *Regionalstatistik* provides county-level data on election results for Bundestag elections. I include the shares of votes of the CDU (*cdu*) and Die Linke (*linke*) as instruments to capture the political influence on prices. Omitting the SPD and all the other parties avoids collinearity. In addition to political influences, I add the number of water collection facilities (*facilities*) as an instrument, because they are an integral part of the water supply grid and their maintenance causes fixed costs. Since these facilities are long-term investments that are neither dismantled nor newly constructed just because of a short-term fluctuation in water demand, they are exogenous at least in the short and medium term. As a fourth instrument, I include the share of groundwater in the total quantity (*ground*). According to Leist (2007), the costs of conditioning raw water to drinking-water quality mainly depend on the origin of the water. For instance, conditioning river water is more expensive than conditioning groundwater, but which type is used rather depends on the available natural resources in the local area than on the supplier's discretion.[8]

Some studies find the average price sensitivity instead of the marginal price sensitivity (see the references and discussions in the surveys by Arbués et al. (2003) and Worthington and Hoffman (2008)). Such results seem to occur mainly in markets with block tariffs, where consumers exhibit intramarginal effects if they move from one block to another, and average prices serve as proxy for marginal prices (Olmstead, 2009). Such tariffs are not present in our case. Econometrically, the average price does not add new information as compared to a specification that already includes the lump-sum price, the linear price, and the number of households, because the average price is constructed from these three variables and the quantity (which is included as the dependent variable on the left-hand side). Nevertheless, given the prominent place this issue takes in the literature, I provide robustness checks that include the average price (specifications V and VI).

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[8] The *Gebot der ortsnahen Wasserversorgung* urges water utilities to primarily use local resources and allows "imports" from neighbor areas only if the local resources are insufficient to guarantee reliable service.

Regression	I	II	III	IV			V	VI
Method	OLS[x]	OLS[xx]	OLS[xx]	2SLS[xx][9]			OLS[xx]	OLS[xx]
				second	first *pfull*	first *pl*		
Intercept	3.902***	3.865***	4.059***	4.506***	1.900	1.999	4.252***	4.281***
	(0.865)	(0.634)	(0.550)	(0.708)	(1.192)	(3.470)	(0.561)	(0.514)
pfull	–0.266**	–0.277***	–0.256***	–0.457***				0.703***
	(0.092)	(0.077)	(0.046)	(0.102)				(0.165)
pl	–0.013	–0.019	–0.011	0.041				0.085***
	(0.022)	(0.016)	(0.011)	(0.056)				(0.021)
pfull_avg							–0.315***	–1.028***
							(0.046)	(0.169)
h	0.979***	0.961***	0.988***	1.003***	–0.084	–0.084	0.99***	1.001***
	(0.117)	(0.089)	(0.070)	(0.079)	(0.137)	(0.447)	(0.072)	(0.066)
h_size	0.431***	0.467***	0.465***	0.543***	–0.084	0.038	0.450***	0.449***
	(0.122)	(0.093)	(0.083)	(0.096)	(0.208)	(0.821)	(0.089)	(0.087)
income	0.028	0.043	0.016	–0.011	0.028	0.260	0.013	–0.002
	(0.105)	(0.079)	(0.064)	(0.075)	(0.128)	(0.405)	(0.066)	(0.060)
schleswig	0.373***	0.304***	0.326***	0.308***	–0.092	–0.533.	0.262***	0.215***
	(0.057)	(0.055)	(0.039)	(0.078)	(0.088)	(0.286)	(0.043)	(0.040)
hesse_2004		0.355***	0.377***	0.438***	0.305*	–0.450	0.321***	0.285***
		(0.041)	(0.031)	(0.094)	(0.143)	(0.490)	(0.032)	(0.032)
hesse_2007	0.384***	0.311***	0.334***	0.399***	0.129.	–1.037***	0.280***	0.245***
	(0.052)	(0.042)	(0.031)	(0.094)	(0.076)	(0.277)	(0.033)	(0.032)
saxony		–0.085**	–0.086**	–0.091**	–0.044	–0.080	–0.061*	–0.010
		(0.029)	(0.029)	(0.033)	(0.041)	(0.111)	(0.024)	(0.020)
thuringia_2004		–0.044	–0.040	–0.085*	–0.139***	0.284*	–0.030	–0.005
		(0.035)	(0.032)	(0.038)	(0.041)	(0.115)	(0.028)	(0.029)
thuringia_2007		–0.059	–0.056.	–0.098**	–0.139***	0.267**	–0.038	–0.001
		(0.036)	(0.033)	(0.037)	(0.039)	(0.099)	(0.028)	(0.029)
baden_2001	0.359***	0.282***	0.309***	0.318**	0.124	–0.286	0.243***	0.208***
	(0.067)	(0.061)	(0.041)	(0.100)	(0.160)	(0.533)	(0.045)	(0.040)
baden_2007			0.274***	0.310***	0.126	–0.747*	0.219***	0.174***
			(0.034)	(0.078)	(0.089)	(0.310)	(0.036)	(0.034)
rhineland			0.248***	0.206***	–0.133.	–0.110	0.202***	0.163***
			(0.034)	(0.058)	(0.075)	(0.265)	(0.036)	(0.033)
facilities					0.048***	–0.051.		
					(0.009)	(0.029)		
ground					–0.013.	–0.051*		
					(0.007)	(0.021)		
cdu					–0.100	1.032***		
					(0.089)	(0.237)		
linke					0.130*	0.469**		
					(0.053)	(0.176)		
Adj. R^2	0.984	0.984	0.986	0.983	0.523	0.753	0.987	0.988
F (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BP[xxx] (p-value)	0.003	0.001	0.002	0.108	0.004	0.000	0.005	0.028
Observations	101	171	251	245	245	245	251	251

Significance codes: *** $p \leq 0.001$; ** $0.001 < p \leq 0.01$; * $0.01 < p \leq 0.05$; . $0.05 < p \leq 0.1$.
[x] Dummy for observations from Thuringia in 2007 (*thuringia_2007*) omitted to avoid collinearity.
[xx] Dummy for observations from Saxony-Anhalt in 2007 omitted to avoid collinearity.
[xxx] For 2SLS, the corresponding value refers to the Breusch–Pagan analog test (Wooldridge, 2002).

Table 3: Estimation results. All estimations in log-log form[10], heteroskedasticity-robust standard errors in parentheses

9 To estimate 2SLS, I use R's ivreg() from package "AER" and iv() from package "tonymisc". I additionally confirm the results using Stata's ivreg2. Results of the three estimation routines differ slightly in terms of standard errors, due to different heteroskedasticity correction methods. Reported results are those of ivreg() with standard White correction.

Results of regressions I, II, and III, presented in Table 3, show that the data manipulation does not severely affect the quantitative outcome of the estimation and slightly improves the significance. As the results were obtained using natural logarithms, the coefficients can be interpreted as elasticities. In all three cases, the marginal price elasticity is around –0.26, which is in line with the bandwidth of –0.25 to –0.75 reported by Worthington and Hoffman (2008) and similar to the OLS result of Schleich and Hillenbrand (2009), who find –0.24. The control variables for market size are consistently between 0.95 and 0.99 (number of households, *h*) and between 0.43 and 0.47 (average household size, *h_size*) and are highly significant. Income effects do not seem to be important: Both the disposable income (*income*) and the lump-sum price (*pl*) are insignificant. The bias from using ΔCS instead of EV or CV should therefore be minor.

Compared to the OLS coefficient of –0.26, the 2SLS (regression IV) price-elasticity estimate of –0.46 is larger in absolute terms, which is exactly the expected behavior. It is much lower than the 2SLS estimate (–0.75) of Schleich and Hillenbrand (2009), who find a remarkably high elasticity, given that water is a basic good. The market size coefficients increase marginally (from 0.99 to 1.0 for *h,* and from 0.47 to 0.54 for *h_size*) and remain highly significant, while the income variables (*income* and *pl*) remain insignificant.

Using the endogeneity test described by Wooldridge (2002) or the alternative test provided by Stata's ivreg2 (option: endog), exogeneity of *pfull* and *pl* has to be rejected at the 5% level. Sargan's nR^2 test and Hansen's J support the instruments' validity.[11] Anderson's canonical correlation test and the heteroskedasticity-robust Kleibergen–Paap test support the explanatory power of the instruments with respect to the endogenous variables.[12] The

[10] Some counties report zero catchment facilities, because the statistics count catchment facilities within county borders, and two counties catch all their water in neighboring counties. To be able to logarithmize anyway, the value one was added to this variable.

[11] H0: "The instruments are valid." Sargan nR^2: test statistic 0.081, *p*-value 0.960. Hansen's J: test statistic 0.051, *p*-value 0.975.

[12] H0: "The canonical correlation is zero." Anderson's CC: test statistic 19.38, p-value < 0.001. Kleibergen–Paap: test statistic 17.74, p-value 0.001.

instruments' relevance can be tested by excluding them from the first-stage regression. Their exclusion has a significant impact on the variance, which suggests that they are relevant[13]. Nevertheless, the instruments might be weak and bias the 2SLS estimator. The Stock–Yogo test assesses the 2SLS bias (due to weak instruments) relative to the OLS bias (due to endogenous regressors) (Stock and Yogo, 2005). In our case, the maximal relative bias is between 20% and 30%,[14] which is rather high, but still the best of all the alternatives that were tested in the research process.

The penultimate column (regression V) of Table 3 includes the average full price (*pfull_avg*) instead of *pfull* and *pl*. The estimated price elasticity of –0.32 is moderately larger (in absolute terms) than the elasticity obtained for *pfull*. This result is in line with Worthington and Hoffman's (2008) conclusion that all the different price variables they found in their survey result in price-elasticity estimates in the inelastic range. One should, however, avoid including the average price, the marginal price, the lump-sum price, and the number of households all in a single regression of log–log form, as regression VI in Table 3 illustrates: By its construction, the average-price variable implicitly puts $1/q$ on the right-hand side of the regression (while q is on the left-hand side). In log–log form, this specifies $\ln(q)$ as a function of $\ln(1/q)$. Since $\ln(q) = -\ln(1/q)$, the corresponding coefficient must become –1, which is indeed the case in the last column, where the coefficient *pfull_avg* is –1.03.

6 Evaluation and Discussion of the Welfare Effects

I use regressions III and IV to predict water demand and compute welfare effects.[15] The discussion will focus on a hypothetical readjustment of prices for the 15:85 and 30:70 scenarios outlined in Section 4. For illustrative purposes, I add two unrealistic scenarios: The 0:100 scenario makes the extreme assumption that water suppliers face fixed costs only and

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[13] First-stage *pfull*: F-value 9.060, p-value < 0.001; first-stage *pl*: F-value 5.009, p-value 0.001.

[14] Kleibergen–Paap Wald F–statistic, 5.377; Cragg–Donald Wald F-statistic 4.754; critical value ($p = 0.05$) for 20% (30%) maximal relative bias, 5.57 (4.73). Stock and Yogo (2005) provide only critical values for homoskedastic errors.

[15] To avoid biased welfare estimates, quantity prediction takes the error term into account.

therefore the optimal linear price is nil, yielding a flat-rate tariff for drinking water (with a linear sewage price, though). At the other end, the 40:60 scenario puts a limit to the hypothesis that this study is based on (marginal prices exceed marginal costs). Remember that there is an observation for which lump-sum price revenues amount to 61.8% of the total revenues, whereas the 40:60 scenario assumes that fixed costs amount to 60% of total costs. For this observation, readjustment of the price structure means lowering the lump-sum price and increasing the linear price. If this case were the true one (which, given the hints in the literature, is very unlikely), the argument I make in this paper would become invalid (at least for the mentioned observations).

Table 4 displays the computed effects. The first row displays the fitted demand function underlying the computation; the second row displays the scenario. The computed values are sample means, but also the sample minimum and maximum are given to illustrate the interval from which the mean is calculated.[16] Δp, $\Delta pfull$, and Δpl represent the differences between the hypothetical marginal cost pricing and the currently observed prices (in percent). Obviously, the price difference increases (in absolute terms) if the observed price structure is more distant from the hypothetical structure. Analogously, the predicted increase in water demand (Δq) increases in Δp (in absolute terms). The price-elasticity estimate under 2SLS is absolutely larger than the OLS estimate. Therefore, the predicted Δq and the welfare effects are larger when using the 2SLS results. Note that the mean price change (Δp) seems to be slightly different between OLS and 2SLS. Actually, the price change is (and must be) equal for each observation, but under 2SLS six observations drop out because of missing values for the instruments, so that the price change is different at sample means. In the 15:85 scenario, marginal cost pricing means lowering the linear price for drinking water by more than 78%. Given constant linear sewage prices, this means that the full price per cubic meter decreases

[16] Presenting standard deviations instead would veil changes of signs, which can serve as a quick plausibility check.

Scenario		OLS (Regression III) 0:100	15:85	30:70	40:60	2SLS (Regression IV) 0:100	15:85	30:70	40:60
Δp	mean	–100	–78.71	–57.41	–43.22	–100	–78.75	–57.50	–43.34
(in %)	(min; max)	(–100; –100)	(–83.30; –60.73)	(–68.61; –21.46)	(–58.14; 4.72)	(–100; –100)	(–83.30; –60.73)	(–68.61; –21.46)	(–58.14; 4.72)
$\Delta pfull$	mean	–42.94	–33.86	–24.78	–18.73	–42.82	–33.78	–24.75	–18.73
(in %)	(min; max)	(–71.10; –24.17)	(–58.84; –18.77)	(–45.85; –7.72)	(–37.44; 2.05)	(–71.10; –24.17)	(–58.48; –18.77)	(–45.85; –7.72)	(–37.44; 2.05)
Δpl	mean	505.90	415.00	324.10	263.50	511.60	419.80	328.10	266.90
(in %)	(min; max)	(61.80; 2 154)	(37.53; 1 816)	(13.26; 1 478)	(–2.92; 1 253)	(61.80; 2 154)	(37.53; 1 816)	(13.26; 1 478)	(–2.917; 1 253)
Δq	mean	13.81	9.66	6.30	4.38	38.52	28.45	20.17	15.31
(in %)	(min; max)	(6.07; 34.74)	(4.40; 23.00)	(1.91; 15.15)	(–0.49; 11.15)	(18.75; 90.31)	(11.93; 60.17)	(4.39; 40.74)	(–1.04; 30.92)
A′	mean	15 980	12 610	9 350	7 231	18 500	14 340	10 470	8 033
(in 1,000 €)	(min; max)	(2 589; 135 800)	(2 190; 106 600)	(1 076; 78 140)	(–926; 59 510)	(3 125; 151 700)	(2 354; 116 900)	(1 096; 84 010)	(–922; 63 100)
B	mean	15 200	12 160	9 131	7 109	15 220	12 200	9 186	7 174
(in 1,000 €)	(min; max)	(274; 130 300)	(214; 103 400)	(106; 76 570)	(–928; 58 670)	(2 741; 130 300)	(2 143; 103 400)	(1 063; 76 570)	(–928; 58 670)
C	mean	783	444	219	122	3 283	2 139	1 287	859
(in 1,000 €)	(min; max)	(86; 6,003)	(45; 3 576)	(2; 1 930)	(–16; 1 169)	(351; 21 460)	(210; 13 460)	(33; 7 856)	(6; 5 247)
C	mean	0.015	0.008	0.004	0.002	0.058	0.037	0.021	0.014
(in % of GDP)	(min; max)	(0.005; 0.041)	(0.002; 0.020)	(0.000; 0.010)	(–0.001; 0.006)	(0.020; 0.152)	(0.008; 0.107)	(0.001; 0.071)	(0.000; 0.051)
C	mean	3.74	2.09	1.00	0.54	15.15	9.73	5.75	3.79
(in € per capita)	(min; max)	(0.92; 10.12)	(0.40; 5.99)	(0.02; 3.25)	(–0.14; 2.00)	(4.62; 34.81)	(1.83; 23.49)	(0.29; 15.78)	(0.00; 11.58)

Table 4: Estimated welfare effects

by roughly one-third (–33.8%) of its current value. At the same time, the lump-sum price must increase by over 400% to ensure cost recovery. Depending on the elasticity estimate, this change in the price structure yields a predicted increase of water demand of 9.66% (OLS) or 28.45% (2SLS).

The last four rows of Table 4 display the welfare effects. For convenience, the labels follow Figure 1. The mean gross increase of consumer surplus (A′) is € 12.6 million (OLS) or € 14.3 million (2SLS) per county. The loss in producer surplus (B) that has to be compensated by increasing lump-sum revenues takes the largest share of A′ (some € 12.2 million under OLS as well as under 2SLS). So the mean net increase in consumer surplus (C = A′ – B) is € 444 thousand (OLS) or € 2.1 million (2SLS). Measured in percent of the corresponding local GDP, the net consumer surplus could on average be increased by 0.008% (OLS) or 0.037% (2SLS). Per capita, this amounts for € 2.09 (OLS) or € 9.73 (2SLS).

In the more moderate 30:70 scenario, the values are of smaller magnitude. The price adjustment would decrease the linear price by roughly 57.5% and increase the lump-sum price by roughly 325%. The magnitude of the estimated welfare effects reduces to some 50% (OLS) or 60% (2SLS) of the values in the 15:85 scenario.

Irrespective of the scenario or the estimation method, the suggested price-structure modification yields redistributive effects that policy makers should into account. The following rough calculation illustrates these effects: Currently, the mean lump-sum price is € 53.98 per year (see Table A in the appendix). Quadrupling this price to some € 216 might be considered an unbearable burden for single persons with low income. On the other hand, the decreasing marginal price benefits families with many children. In recent years, the average water consumption per capita and day was 122 liters (http://www.destatis.de/). The mean linear price is € 1.77 per cubic meter (see Table A in the appendix). Decreasing this price by 78% to roughly € 0.39 lowers this part of the annual water bill, *ceteris paribus,* by some € 61 per capita, so that a family of three would already be better off. Even if the price elasticity is taken into account (water consumption increases by roughly 30% to some 160 liters), the saving would be around € 55, and the family of three would still be better off.

7 Conclusions

Although a mean welfare gain of € 9.73 per capita or 0.037% of GDP seems rather small, the absolute value of € 2.1 million per county on average, as well as the maximum potential welfare gain of almost € 13.5 million, makes it worthwhile to reconsider current pricing structures in Germany's public water supply. Consumers would be the main beneficiaries of an alternative price structure that charges marginal-cost per-unit prices and lump-sum prices that cover the water suppliers' losses, because the additional welfare would be consumer surplus. There would, however, be a redistributive effect from single persons and families of two to families of three and more. Most policy makers are probably in favor of supporting families with many children, but this redistributive effect will be disadvantagous for single parents with only one child and single persons. These already bear the highest risk of poverty.

On the supply side, water utilities would experience a loss in producer surplus, but this loss would be fully compensated by additional revenues from a lump-sum transfer, so that their net surplus is unaffected. Still, municipal water suppliers would benefit from a shift away from per-unit prices towards higher lump-sum prices, because these revenues are certain, while per-unit price revenues are subject to fluctuations in demand.

The reader should keep some caveats in mind when interpreting the results of this study: Information on variable and fixed costs is unavailable, so it is not possible to provide "hard facts" as evidence for the claim that marginal prices exceed marginal costs. Instead, I can only provide hints from the literature, which reports fixed cost shares of 80–90% in total costs and court decisions that reject price structures with lump-sum prices that exceed 50% of the average total annual bill. It should also be noted that the available data is only aggregated and cross-sectional and that the number of observations is rather small.

Appendix

Variable	Description	Min	Median	Mean	Max	Std. Dev.	Observations
q	Water delivered to households and small firms (in m³ per year)	1,651,000	7,444,000	8,666,000	85,710,000	7,349,000	251
p	Marginal price of fresh water (in € per m³)	0.77	1.73	1.77	2.62	0.35	251
ps	Marginal price of sewage (in € per m³)	1.02	2.33	2.38	4.27	0.53	251
pfull	= *p* + *ps*	2.31	4.18	4.14	6.17	0.67	251
pl	Lump-sum price (in € per household and year)	8.75	41.80	53.98	160.70	38.40	251
pfull_avg	= *pfull* + *pl* / (*q* / *h*)	2.58	4.68	4.88	7.76	1.07	251
h	Number of households	17,840	79,220	98,140	883,000	76,150	251
income	Disposable income (in € per year and county)	572,500	3,070,000	3,750,000	40,280,000	3,266,997	251
inhab	Number of inhabitants	34,720	183,600	205,900	1,771,000	152,457	
h_size	= *inhab* / *h*	1.59	2.14	2.12	2.48	0.19	
facilities	Number of water collection facilities	0	41	51	201	44.34	249
gdp	GDP (in € per year)	1,092,000	4,431,000	6,105,000	83,650,000	7,572,452	
gruene	Election results for Bündnis 90/Die Grünen	0.0275	0.0732	0.0799	0.2617	0.0380	251
spd	...SPD	0.2010	0.3403	0.3414	0.5298	0.0530	251
cdu	...CDU/CSU	0.2037	0.3513	0.3510	0.5363	0.0634	251
linke	...Linke	0.0057	0.0450	0.0821	0.2968	0.0881	251
fdp	...FDP	0.0449	0.0995	0.0981	0.1793	0.0231	251
other	...other political parties	0.0186	0.0419	0.0475	0.1272	0.0211	251
ground	Share of groundwater in total caught water	0	0.741	0.678	1	0.306	245

Table A: Descriptive statistics (monetary values adjusted for inflation). Price data requested from German State Statistical Offices; all other data publicly available from the *Regionalstatistik* (http://www.regionalstatistik.de/).

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