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"Effects of unit-based pricing on the waste collection demand: a meta-regression analysis"

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Abstract

We perform a meta-analysis of 21 studies that estimate the elasticity of the price of waste collection demand upon waste quantities, a prior literature review having revealed that the price elasticity differs markedly. Based on a meta-regression with a total of 65 observations, we find no indication that municipal data give higher estimates for price elasticities than those associated with household data. Furthermore, there is no evidence that treating prices as exogenous underestimates the price elasticity. We find that much of the variation can be explained by sample size, the use of a weight-based as opposed to a volume-based pricing system, and the pricing of compostable waste. We also show that price elasticities determined in the USA and point estimations of elasticities are more elastic, but these effects are not robust to the changing of model specifications. Finally, our tests show that there is no evidence of publication bias while there is some evidence of the existence of genuine empirical effect.

JEL classification: H23, Q52, Q53
Keywords: unit-based pricing, elasticities, meta-analysis.

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1. Introduction

The unit-based pricing (UBP) of residential solid waste collection has been implemented in many parts of the world, including municipalities in the United States, the EU, Japan and South Korea. Skumatz (2008) reports that these UBP-programs are available to about 25% of the US population and about 26% of communities in the US – including 30% of the largest cities in the US. Dijkgraaf and Gradus (2014) record that the percentage of Dutch municipalities using this system rose from 15% in 1998 to 36% in 2010 and Riezenkamp (2008) presented similar increases for other countries in Continental Europe. In Japan unit-charging programs for waste were available in 30% of municipalities in 2003 and, interestingly, South Korea had initiated a nationwide pay-as-you-throw (PAYT) program back in 1995 (see Sakai et al., 2008).

The increasing shortage of space and growing environmental awareness have forced many local governments to adopt such measures as UBP to reduce the amount of unsorted waste and to promote recycling. But whether UBP yields a net gain remains a somewhat contentious issue. While households may recycle more, compost more, and require less packaging from the stores, UBP might also encourage them to burn their garbage or to dump it on the roadside. Yet, Allers and Hoeben (2010) claim that if illegal dumping was a serious problem we would expect many municipalities to have abolished user fees. But this has not happened in the Netherlands, or apparently elsewhere, and as such there is no evidence, they conclude, of municipalities having become disillusioned with the effects of UBP programs.

The key questions that local municipalities seek a response to therefore are: Does UBP reduce quantities of waste and increase recycling, and if so, by how much? In most papers conducted to date this question is answered by estimating a price elasticity for unsorted waste (and a cross-price elasticity for recycled waste); however, the estimates reported differ markedly. For example, based on a survey at the municipal level, Allers and Hoeben (2010) found a high price elasticity (-1.77) for compostable waste and a combination of the weight and bin systems used by Dutch households. For the bin system in Portland (Oregon), Hong et al. (1993) reported a non-significant elasticity close to zero, a result that is more in line with Kinnaman (2006) who, based on an overview of the literature, claims studies "consistently estimate the demand for garbage collection services to be inelastic."

Despite the fact that the effects of unit-based pricing of waste have been widely debated in public economics, no systematic analysis has been conducted to date to explain why the reported impact of UBP diverges so much in the literature. In other fields, meta-regression analyses have been used to explain divergences in results in the empirical literature, thus providing new insights, for example, into the relationship between labor supply and wages (Evers et al., 2006), price and income elasticities of water demand (Dalhuisen et al., 2003), the limits to world population (Van den Bergh and Rietveld, 2004), privatization and costs (Bel et al., 2010) and inter-municipal cooperation and costs (Bel and Warner, 2014). In addition, these papers also provide a summary of the research results on these issues.

In this paper, we seek to fill the gap in the empirical literature on the effects of UBP by conducting a meta-regression analysis for unit-based pricing. In this way we are able to present a systematic analysis of the impact of various factors on the empirical estimates reported. Specifically, we use a sample of 65 price elasticities obtained from the literature on which to perform our meta-analysis, i.e., we regress the elasticities on the underlying study characteristics. We find that it is the substantial (or idiosyncratic) moderators – as opposed to the technical (or usual) moderators employed in meta-regression analyses – that have special importance for understanding the unit-based pricing elasticities. Thus, pricing waste on the basis of weight yields a high price elasticity; likewise, there is some evidence that pricing compostable waste and collecting it at the curbside does the same. Above all in countries in which waste is incinerated rather than landfilled, which is the case in most EU countries (see Riezenkamp, 2008), it can be argued that weight of waste (and not volume) is the relevant policy dimension.

The rest of this paper is organized as follows. Section 2 presents an overview of the issues raised in the empirical literature regarding unit based pricing and elasticities. Section 3 explores the sources of variation in more detail by performing a meta-regression. Section 4 reports the meta-regression test and section 5 concludes and makes some suggestions for further research.

2. The empirical literature on unit-based pricing elasticities

To the best of our knowledge, the first study to calculate empirically the elasticity of the price of waste upon waste quantities was Wertz (1976). The estimation, which compared the quantities of waste for San Francisco, where a fee is charged on the number of containers put out, and the amount of waste for a subset of cities without such a fee, gave a negative elasticity of -0.15. Drawing on yearly municipal data, Skumatz and Breckinridge (1990) estimated an elasticity of -0.14 for Seattle (Washington) where a bin system is also employed. By simply comparing waste before and after the introduction of a bag-based UBP system in Perkasie (Pennsylvania) and Ilion (New York), Morris and Byrd (1990) found elasticities of -0.26 and -0.22. Finally, Jenkins (1993) estimated an elasticity of -0.12 for residential sector waste using pooled time series data for nine US communities.

Hong et al. (1993) evaluated the situation in Portland (Oregon) drawing on a large sample of households. Modeling the recycling and garbage collection services dependently, they showed that a disposal fee did not reduce the demand for solid waste substantially. Their price elasticity estimation was -0.03.[3] Interestingly, Strathman et al. (1995) also evaluated the situation in Portland, reporting a considerably higher price elasticity of -0.45 when using municipal and district data. As such, it would appear that municipal data gives higher price elasticity estimates

[3] As it was insignificant, they did not report the elasticity. By using the waste collection function (see Table 3) together with this equation and Table 1 for the sample mean of waste quantity and payment difference, the elasticity can be calculated. Similar derivations were made for Hong and Adams (1999) and Isely and Lowen (2007).

than those found for household data. Strathman et al. (1995, p. 71) suggest that measurement errors in the household survey might explain this difference.

Fullerton and Kinnaman (1996) employed a household survey in Charlottesville (Virginia), where they estimated a highly inelastic arc-price elasticity of demand for waste (measured in pounds) of -0.076, although it was still different from zero at the 5 per cent level. They also showed that the elasticity is much higher (-0.226) when measured by volume. Fullerton and Kinnaman (1996) point out that this can be attributed to the so-called "Seattle stomp", whereby garbage is stomped into a single container to avoid having to pay for multiple containers.

Podolsky and Spiegel (1998) claim that price elasticities can be influenced by other policy measures, including the introduction of curbside recycling programs, in a study conducted with a cross-sectional data set for 149 municipalities in five New Jersey counties. They estimate an elasticity of -0.39 when measuring the mean unit price and tons per capita of household municipal waste disposal for comparable unit pricing communities. Van Houtven and Morris (1999) evaluated a project in Marietta (Georgia) in which half the residents participated in a bag program and the other half in a subscription can program. Rather than pay a fixed monthly fee for collection, households paid a fee per unit of trash actually set out. Based on direct estimation and by estimating a logarithmic function, the estimates of the price elasticities were -0.14 and -0.15, respectively. Further, they also estimated the effect of different unit-based pricing programs using household data and found a larger elasticity (-0.26) for the bag system, but are aware that this might be due to selection bias in the household data.[4]

Further evidence for the case of Portland was reported in Hong and Adams (1999). Based on a household survey in which, importantly, waste was measured directly, volume and the number and size of cans were estimated using a probit model. But the authors found that the price differential did not influence the choice of can size. As such, they show that the price elasticity calculated at mean levels of waste is very low (-0.013) and only significant at the 90 per cent level. The first study to be conducted outside the US, as far as we can establish, was Hong (1999). The author studied municipal data from Korean cities implementing a bag-based system and simultaneously estimated a waste and recycling equation. He reports a higher elasticity (0.457) for recyclable than for non-recyclable waste (-0.154).[5]

Drawing on US municipal data, Kinnaman and Fullerton (2000) allow for price endogeneity. Although *a priori* the bias in the waste fee estimate when treating this policy variable as exogenous might be positive or negative, they show that previous studies with exogenous prices appear to have underestimated the effects of such programs on garbage and recycling totals. Kinnaman and Fullerton (2000) present one arc- and two point-elasticities for the UBP systems. The arc-elasticity resulting from a price increase from zero to the average fee charged in towns with user fee programs is -0.28, an appropriate estimate of the price impact of the introduction of user fees in a municipality. Assuming a linear demand curve, the authors calculate a point elasticity of -0.034 at an average price for all municipalities. However, as most towns in the

[4] See also footnote 13 in Van Houtven and Morris (1999).
[5] As the derivations are not provided, the standard error cannot be derived.

sample had not implemented a user fee program, the average price charged is low (see also Huang et al., 2011). The point-elasticity associated with the average fee in municipalities with user fee programs is -0.778, which should be useful for predicting the effect of a change in those municipalities that already implement user charges. Interestingly, the price elasticities reported are somewhat higher than those usually found in the literature.

Linderhof et al. (2001) conducted their study, based on a household panel survey of all inhabitants in Oostzaan, the first Dutch municipality to introduce a weight-based pricing system. In their analysis, they distinguish between compostable and non-recyclable waste, both of which are collected at the curbside in the Netherlands. As a result, they are able to estimate short- as well as long-run price effects for the amounts of both types of waste.[6] They find that the elasticity for compostable waste is four times as high as that for non-recyclable waste, as home composting has become more frequent thanks to the distribution of special composting containers. In addition, long-run elasticities are about 30% higher than short-run elasticities. Yamakawa and Ueta (2002) estimated the difference in the amount of waste collected in Japanese municipalities that had introduced a bag program, on the one hand, and those that did not operate a variable charging system, on the other. They report an arc price elasticity of -0.076 for 1985 and -0.061 for 1990.

Similarly, in the Netherlands, Dijkgraaf and Gradus (2004) evaluated a panel data set for all Dutch municipalities in order to evaluate the country's various systems.[7] To ensure the comparability of the Dutch experience with those abroad, three UBP-systems are identified (see, for example, Kinnaman, 2006). First, and the most common, is the bin (or the can) based system, where residents pay a fee each time their container is emptied at the curbside. A related volume-based program is the bag- (or tag-) based system, where residents purchase special bags, tags or labels to put on their own bags. In general, the bag-based system provides a more refined pricing system than the bin-based system, as the volume of the bags is significantly smaller than that of the can.[8] However, most municipalities that operate a bag-based system do not use it for compostable waste since there is an incentive for households to overfill these bags, making their subsequent handling difficult. In a weight-based pricing system, the collection vehicle weighs the can and matches this information with the owner's identity. As such, owners generating more waste pay a higher collection fee. On the basis of these different systems (weight, bag of unsorted, bag of unsorted/compostable and frequency/bin) eight point elasticities can be calculated.[9]

Based on municipal data for Massachusetts (US), Callan and Thomas (2006) also simultaneously estimated a waste and recycling equation and estimated a price elasticity of

[6] They distinguish between the two price effects by including lagged quantity as a right-hand variable in the regression.

[7] Four systems can be identified in the Netherlands (see Dijkgraaf and Gradus, 2004, 2009 and 2014; Allers and Hoeben, 2010): namely, weight, bag, frequency/bin and volume. In the volume system, however, households can only choose between different can types at specified review times (usually annual). As a result, the costs of a marginal increase in garbage are, in most cases, zero and so we do not consider the volume system in this international comparison.

[8] For countries that collect biodegradable waste separately, the bag-based system suffers the disadvantage that the waste is prone to the 'Seattle stomp' phenomenon (see Dijkgraaf and Gradus, 2014).

[9] Based on underlying estimation material (not published in the paper), we also estimate the standard error.

disposal demand of -0.582. The authors estimated a direct effect of -0.195 by holding recycling constant and an indirect effect of -0.387 as a result of increased recycling. Interestingly, Callan and Thomas (2006) show that the direct effect, which can be interpreted as the combination of illegal dumping and source reduction, is not significant, while the indirect recycling effect is significant. Isely and Lowen (2007) based their estimates on ten districts of the City of Grand Rapids (Michigan), for some of which they had daily data and so they were able to include fixed effects for months and districts. In 2004 they found a large increase in the per-unit garbage disposal fee and an estimated arc elasticity of -0.33. Gellynck and Verhelst (2007) investigated the implementation of a waste reduction plan for the Flemish region of Belgium, finding pecuniary incentives to be an effective instrument for reducing waste, with a price elasticity of -0.139. In this region of Belgium, two thirds of the municipalities introduced unit-based pricing (mostly via a bag system).[10] Based on a municipal panel sample for Japan, Usui (2008) estimated two waste equations one including the number of years that have passed since the introduction of the unit-based pricing the other without. On the basis of this, he calculated a point elasticity of -0.039 and -0.076 for the sample mean, where the former can be interpreted as the long-run elasticity and the latter as the short-run elasticity.[11]

Using a ten-year dataset comprising all 458 Dutch municipalities, Allers and Hoeben (2010) estimated the effect of different unit-based pricing systems on normal and compostable waste. The study distinguishes between municipalities using a UBP program, weight, bag or bin/frequency systems as well as a combination weight/bin system. As they also distinguish between arc and price estimations they obtain 20 elasticity estimates. Importantly, they argue that community-level studies do not usually take unobservable local characteristics with a potential influence on garbage quantities into account. For this reason, they propose a differences-in-differences approach (or fixed effects). In addition, they correct for the endogeneity of garbage prices, although they only found evidence of this in the case of compostable waste.

Based on a municipal sample in New Hampshire (US), Huang et al. (2011) showed that the point estimation of price elasticity can differ widely. As most towns in the sample had not implemented a user fee program and were charging a fee of zero per bag, their estimation at the mean price of the whole sample was very low (-0.096). When evaluated at the mean fee for towns with a user fee program, it was substantially higher (-0.62), and when a separate equation was estimated only for pay-as-you-throw (PAYT) towns it was higher yet again (-1.31), although the uncertainty increases somewhat as only 15% of the data are now taken into account. They also endogenize the introduction of PAYT systems and curbside recycling. In addition, the effect of a Heckman correction for possible sample selection bias was very small. Finally, Usui and Takeuchi (2013) evaluated the UBP effect of residential solid waste based on a large panel data set for Japan. They were also able to distinguish between long- and short-run price elasticities, but, interestingly, found hardly any differences between the two. To correct for possible endogeneity

[10] Six per cent of municipalities introduced a weight-based pricing system; however, they did not estimate this separately.
[11] He also estimated the equation without year fixed effects. However, as there is no reason not to include these effects and as the results are quite similar we do not include these estimation in our dataset.

they tested the inclusion of three proxy variables, including whether recyclable collection had changed during the last year. Based on their framework we can include eight observations for the price elasticity.[12]

Table 1 lists the 21 studies used in our analysis together with a number of important characteristics of these studies, including sample size, period of analysis, country and the number of observations each study contributes to the sample (total observations = 65).[13] We collected papers from academic journals published in the fields of Economics, Public Policy, Environmental Studies and Public Administration as well as from their online versions. We also collected unpublished papers available in large working paper collections, such as EconLit, GoogleScholar, Social Science Research Network, ResearchGate and Repec-Ideas. The database was constructed by the authors.

In the section that follows we give further details regarding the meta sample and an outline of its summary statistics. We then proceed to conduct the meta-regression and tests to differentiate the genuine empirical effect from publication bias. Note that we have 60 standard errors (SE) and, therefore, can use a total of 60 observations for our test of publication bias.

[12] As they assume a double-log equation for the waste function, the short-run elasticities can be directly obtained from the equations. To obtain an estimate for the long-run elasticities we take the average number of years since the introduction of the UBP system.

[13] As we have multivariate studies of factors explaining these elasticities we are obliged to exclude Morris and Byrd (1990) from our dataset as it simply compares the waste collection systems in two two US municipalities before and after the introduction of a UBP system.

Table 1: Studies with their main characteristics

number	Publication year	Authors	Year (data collection)	Sample size	Country		observ	SE
1	1976	Wertz	1970	10	USA	municipality	1	n.a.
2	1990	Skumatz/Breckinridge	1971-1987	16	USA	municipality	1	n.a.
3	1993	Jenkins	1980-1989 (vary)	600	USA	municipality	1	1
4	1993	Hong/Adams/Love	1990	2298	USA	household	1	1
5	1995	Strathman et al	1984-1991	95	USA	municipality	1	1
6	1996	Fullerton/Kinnaman	1992	75	USA	household	1	1
7	1998	Podolsky/Spiegel	1992	149	USA	municipality	1	1
8	1999	Van Houtven/Morris	1991-1994	624	USA	Munic/house	3	3
9	1999	Hong/Adams	Aug 1992-Jul 1993	8388	USA	household	1	1
10	1999	Hong	1995	3200	Korea	household	1	n.a.
11	2000	Kinnaman/Fullerton	1991	756	USA	municipality	3	3
12	2001	Linderhof et al	1993-1996	127581	Netherlands	household	4	4
13	2002	Yamakawa/Ueta	1985	130	Japan	municipality	2	n.a.
14	2004	Dijkgraaf/Gradus	1998-2000	1451	Netherlands	municipality	8	8
15	2006	Callan/Thomas	1990-1991	351	USA	municipality	1	1
16	2007	Isely/Lowen	2003-2005	456	USA	municipality	1	1
17	2007	Gellynck/Verhelst	2003	295	Belgium	municipality	1	1
18	2008	Usui	1995-2002	5307	Japan	municipality	2	2
19	2010	Allers/Hoeben	1997-2006	3605	Netherlands	municipality	20	20
20	2011	Huang et al	2000	200	USA	municipality	3	3
21	In press	Usui/Takeuchi	1996-2002	4644	Japan	municipality	8	8
							65	60

3. The meta sample

Our meta-sample is made up of the 21 studies identified as containing price elasticity estimates of the unit-based pricing of waste. These studies include a total of 65 observations of the elasticity of residential waste production with respect to price giving an overall average elasticity of -0.360 (see also Table 2).

There are many reasons as to why analyses conducted of the same phenomenon can present a marked variation in their empirical findings. Stanley and Jarrell (1989) classify them into three categories: (1) the uniqueness of the data set employed in each study; (2) biases induced by model specification; and (3) the different (statistical) methods employed. Given that here we undertake a meta-regression analysis to determine the pattern and diversity of findings in the empirical studies, it is important that we bear these points in mind when constructing our meta-sample.

We consider the variables describing the data sets used in each of the 21 studies. We define three moderator variables for the data base. First, it is quite common in meta regressions to construct a dummy variable *Year*, which takes a value of zero if the (average) year for the collection of data for elasticities is before a year (in this case 2000) and a value of one otherwise.

Second, we take the variable *Sample size*, which is specified in (almost) all the studies.[14] Third, we construct the variable *Municipality*, which takes a value of zero if the data collection took place at the household level and a value of one if the data collection took place at the municipal level. The descriptive statistics in Table 2 show that only 15% of the observations were made at the household level.

In addition, we consider three variables that describe model specifications. First, we construct the dummy variable *USA*, which takes a value of one if the study was conducted in the USA. Again, it is quite common to include such a moderator variable, and in our case it seems particularly relevant as UBP systems were first introduced in the USA. Second, we construct the dummy variable *Ex*, which takes a value of zero if some of the variables in the (estimated) waste function[15] can be treated as endogenous and a value of one otherwise. It will be recalled that some authors did in fact stress the importance of correcting for this endogeneity. Third, we construct the variable *Point*, which takes a value of zero if arc elasticity[16] is measured and a value of one otherwise.

Finally, we describe two variables to capture distinctive (statistical) or idiosyncratic methods. First, we construct as a dependent variable the dummy variable *Compostable*, which takes a value of zero if only the regular solid waste is analyzed, and a value of one if compostable waste is analyzed separately from regular solid waste. Second, we construct a variable *Weight*, which takes a value of one if a weight-based pricing system is analyzed and a value of zero if not. It is well known that a weight-based pricing system serves as a better incentive to reduce the amount of waste than a volume-based pricing system, which is affected by the compacting of garbage. However, by using *Weight* as a variable, we have to exclude six observations as the corresponding studies did not provide any information about it or the estimations included both weight- and volume-based systems.

Table 2 contains the descriptive statistics of these variables and the dependent variables in our meta-regression and the variables used in the meta-regression tests. In the next section we conduct the meta-regression.

[14] For studies without a given sample size, we were able to construct it.

[15] In most cases this is the price variable.

[16] An arc elasticity is defined as $\in = \frac{\Delta x}{\Delta p} . \left(\frac{p_1+p_2}{2}\right) / \left(\frac{x_1+x_2}{2}\right)$

, where p_1 and x_1 are the price and the waste before the policy change. In most cases this price is zero, but in Isely and Lowen (2007) an increase in price was evaluated. In all other cases we measure the variable as a point elasticity.

Table 2. Descriptive statistics of variables used in meta-regression analysis and meta-regression tests

	average	SD	Max	min	Nº
Elasticity	-0.360	0.386	0.29	-1.770	65
Year	0.391	0.492	1.00	0.000	65
Sample	10160	30164	127581	10	65
Municipal	0.850	0.360	1.00	0.000	65
USA	0.317	0.469	1.00	0.000	65
Ex	0.500	0.504	1.00	0.000	65
Point	0.567	0.500	1.00	0.000	65
Compostable	0.267	0.446	1.00	0.000	65
Weight	0.237	0.429	1.00	0.000	59
Standard error	0.095	0.189	1.235	0.003	60
t-value	-9.701	11.997	6.920	-87.548	60
Degrees of freedom	10343	30225	124061	23	60

In the meta-regression tests to differentiate the genuine empirical effect from publication bias we also use the reported standard error, t-statistics and degrees of freedom (see section 5). Note, however, that this information is not available in all the studies. In some, the t-statistics are given, making the derivation of the standard error a straightforward task. In others, the model estimations and standards are given but not the standard error (SE) of the elasticity. In such instances we use the simplification suggested by Evers et al. (2006). For example, Callan and Thomas (2006) report the estimation of the elasticities, the estimation of the waste and recycling functions and the elasticity formulae. Applying the Delta method, a SE can be derived.[17] Similar derivations can be obtained for Strathman et al. (1995) and Linderhof at al. (2001). Additionally, degrees of freedom can be calculated from the sample size minus the number of regressors. Finally, we have 60 observations for SE and their t-statistics. Only in the case of seven observations is the t-statistic (in absolute value) less than 1.96.

4. <u>The meta regression</u>

The linear equation with which we estimate the influence of different study characteristics on elasticity can be stated as follows:

[17] We know from formula (5) in Callan and Thomas (2006) that $\in = \emptyset(\beta)$ p/W and so we know from the delta method that $\sigma_{\epsilon}^2 = \frac{p^2}{W^2} \lfloor \partial\emptyset/\partial\beta \rfloor \Sigma_{\beta} \lfloor \partial\emptyset/\partial\beta \rfloor'$, where p and W are the price and the amount of waste at the mean level (see equation (3.2) in Evers et al., 2006).

$$\epsilon_i = \alpha_0 + \alpha_1 Year_i + \alpha_2 Sample_i + \alpha_3 Municipal_i + \alpha_4 USA_i + \alpha_5 Ex_i + \alpha_6 Point_i + \alpha_7 Compostable_i + \alpha_8 Weight_i + \varepsilon_i \quad (1)$$

where ϵ_i is the elasticity reported and the moderator variables are as defined in the previous section (see also Table 2). We estimate equation (1) with OLS, correct the standard errors for potential heteroskedasticity, and adjust the correlation between observations in the same study.[18]

Table 3 shows the results from the estimation of the meta-regression equation (1). The estimation is conducted for an equation without *Weight* and one with *Weight* as a moderator variable. As explained in the previous section, in the latter case six observations have to be excluded, as the corresponding studies did not report whether the elasticity was based on a weight- or a volume-based pricing system.

Table 3. Meta-regression estimates

	Without weight		With weight	
Year	-0.2245	(0.0880)**	-0.1785	(0.0991)*
Sample size	-6.19 (E-06)	(1.04E-03)***	-3.34 (E-06)	(1.16E-06)***
Municipality	-0.1595	(0.1116)	-0.1322	(0.1104)
USA	-0.2390	(0.0910) **	-0.2831	(0.1098)**
Ex	0- 0.0036	(0.0720)	-0.0546	(0.0852)
Point	-0.2304	(0.1049)**	-0.2177	(0.1110)*
Compostable	-0.3756	(0.0918)***	-0.3305	(0.1081)***
Weight	--	--	-0.3746	(0.0484)***
Constant	0.2850	(0.1595)	0.2705	(0.1793)
R^2	0.3703		0.4460	
F	24.18***		38.29***	
N	65		59	

Year was found to be statistically significant in the equation without *Weight* and only weakly significant at the 10 per cent level when *Weight* is included. Thus, we obtain some evidence that later studies report a higher elasticity (in absolute values). *Sample Size* was significant in both equations at the 1 per cent level, indicating that the larger the sample the higher the elasticity (in absolute values). Taking both estimations into account, there is no indication that taking data from a municipal or a household survey impacts the results. *USA* was significant in both equations at the 5 per cent level, indicating that studies conducted in the USA present a higher elasticity (in absolute values). Based on both estimations there is no indication that the endogeneity issue

[18] In this case, it is assumed that the standard errors for each municipality are not independently and identically distributed, that there is an unknown correlation in $\varepsilon_{i,t}$ between municipalities in group i within t, but that groups i and j do not have correlated errors (see Nichols and Schaffer, 2007, for an explanation).

influences the results. *Point* was statistically significant in the equation without *Weight* and only weakly significant at the 10 per cent level when *Weight* is included. Thus, here too there is some evidence that point elasticities present a higher value (in absolute terms). It is worth noting that when *Weight* is included in the estimation, the significance of the *Year* and *Point* variables is weaker, falling from the 5 to the 10 per cent level.

In the case of the variables capturing choices regarding the waste collection system, our results indicate that the moderator *Compostable* gives higher elasticities (in absolute values). It was found to be significant at the 1 per cent level in both estimations (i.e., with and without *Weight*). Introducing a separate collection and a fee for compostable waste is, as this outcome shows, therefore highly effective. The *Weight* variable is, likewise, very strong, being significant at the 1 per cent level. When the *Weight* dummy is set at 1, price elasticity (in absolute values) is substantially higher at -0.37.

Thus, overall, the meta-regression gives no indication that municipal data give higher estimates for price elasticities than those associated with household data. Furthermore, there is no evidence that treating prices as exogenous underestimates the price elasticity. There are, however, indications that price elasticities from the USA and point estimations of elasticities are likely to be higher (in absolute values), but these are weaker – albeit that they remain significant – when the *Weight* variable is considered in the estimation. Interestingly, the estimations indicate that price elasticity (in absolute values) increases with a rising number of observations. In line with sampling theory, it can be argued that studies with a larger sample size are more robust (see also Bel et al., 2010).

Furthermore, the dependency of the elasticities based on substantial moderators gives robust results. Elasticities based on the *Compostable* variable are considerably higher than those based on non-recyclable waste. In this case it seems that home composting has become especially important. Indeed, Dijkgraaf and Gradus (2004) report that a household's garden area is a prime determinant of the amount of compostable waste. Finally, elasticities based on weight-based pricing systems are considerably larger than those based on volume-based pricing systems.

5. Robustness tests

A major concern of any meta-regression model is the identification of any potential publication bias. Studies finding statistically significant relationships between the variables of interest are, it appears, more likely to be published, which might lead to incorrect conclusions regarding the effectiveness of a particular policy. To detect and correct for possible publication bias Stanley and Doucouliagos (2012) propose the funnel asymmetry test (FAT). This test estimates the relationship between a study's reported t-statistics and SE of its coefficients. We estimate the following equation:

$$T_i = \beta_0 + \beta_1 \left(\frac{1}{SE_i}\right) + \varepsilon_i, \quad (2)$$

where T is a study's reported t-statistic and 1/SE is the inverse of the standard error. Evidence for publication bias will be found when $\beta_0 \neq 0$.[19] Additionally, the coefficient β_1 provides an estimate of the true empirical effect of the parameter of interest. Equation (2) is estimated in Table 4. Furthermore, in line with Stanley (2008), to test the genuine empirical effect, we also conduct a meta-significance test (MST)[20] by estimating the following equation:

$$\log |T_i| = \gamma_0 + \gamma_1 \log(df_i) + \varepsilon_i, \qquad (3)$$

where *df* are the degrees of freedom of the estimate reported. Stanley (2008) argues that if $\gamma_1 = 0$ the genuine effect is disputable. These results can also be consulted in Table 4.

Table 4. Meta-regression tests (OLS)

Explanatory variables	FAT test Dep. Variable t-Statistic		MST: Dep. Variable: log (t-Statistic in Absolute Values)	
InversSE	-0.1164	(0.0647)*	--	--
Logdf	--	--	0.0442	(0.0741)
Constant	-3.2207	(3.1154)	0.6537	(0.2886)**
R^2	0.3660		0.0045	
F	3.24*		0.36	
N	60		60	

Recall that the FAT estimates the relationship between a study's reported effect and its coefficients' standard errors. Evidence of publication bias is found when the intercept is significantly different from zero (Stanley, 2008). Our FAT (Table 4) points to no evidence of publication bias, as the intercept is not statistically different from zero. It would appear that because the relationship between price and volume is so well established theoretically, very few papers today are likely to find a non-significant relationship. Indeed, the studies analyzed here typically deal with the dimension of the effect, rather than with the existence of the effect itself.

We find some evidence of the existence of a genuine empirical effect (negative relationship between unit base pricing and volume of waste) because the coefficient for *InversSE* is negative and significant at the 10 per cent level. However, we need to remain cautious about the existence

[19] In some studies, when the SE contains some measurement errors, the square root of the sample size is taken as an alternative variable to test for publication bias. However, here that is not necessary, because the standard errors provide more robust results than those provided by the square root of the sample size (see also Stanley and Doucouliagos, 2012, box 4.10). We also run an estimation using t-values as the dependent variable for the full model (equation (1)). The results obtained show no relationship between the t-value and any of the moderator variables in the model (with the exception of USA in the estimation without weight). These results are available upon request.

[20] The MST is based on the statistical property that the magnitude of the t-statistic will systematically vary with the degrees of freedom if overall there is a genuine empirical effect (Stanley, 2008).

of a genuine effect, as this is not confirmed by the MST test; the coefficient of *Logdf* is not significant. However, it is worth noting that the information presented in Table 4 shows that results for the MST test are not as robust as those for the FAT.

6. Conclusions and suggestions for future research

The advantage of a meta-regression analysis is that it allows us to determine the impact of the phenomenon in question across a wide range of studies. Previous narrative meta-analyses, such as that conducted by Kinnaman (2006), show that the literature consistently estimates the price elasticity of the demand for garbage collection services to be inelastic. The meta-regression conducted here shows that this may be true, but that ultimately the elasticity depends on how the waste collection process is organized. A system is much more effective and price-elasticity is more elastic if waste collection employs a weight-based pricing system and if compostable waste is priced. Moreover, it seems that (early) estimations based on smaller sample sizes underestimate the price elasticity while there is no indication that the choice of sampling method or the endogeneity issue has influenced the results. Thus, from a policy perspective there seem to be strong arguments for introducing a weight-based pricing system or for pricing compostable waste. However, in this study we have not focused on administrative issues that might undermine weight-based pricing systems nor have we considered circumstances in which it might not be easy to price compostable waste, such as large cities with a high density of flats and apartments (see also Dijkgraaf and Gradus, 2014).

Although the meta-regression has provided some additional information, the magnitude of the price elasticity of the demand for waste remains unclear. For volume-based systems, for example, it would be interesting to distinguish further between bag- and bin-based pricing systems. In general, the bag-based system provides for a more refined pricing system, as the volume of bags is significantly less than that of a bin. However, as this dimension differs markedly from one system to another, we do not have sufficient data to explore this in a meta-regression. Additionally, intrinsic motivations and cultural issues can play a critical role in any assessment of household preferences for sorting waste (see for example Czajkowski et al., 2014). As Evers et al. (2006) suggest, one way of tackling this in meta-regression analyses is to use country dummy variables capturing differences in cultural preferences. However, given the limited amount of data available to us, we were only able to include one country dummy in our analysis, the USA. Significant values for the USA might be an indication that this country is better equipped to work with extrinsic motivation through price incentives. Yet, any general conclusions are hard to draw as the regional differences in the use of PAYT systems across the USA are large. For example, Skumatz (2008) shows that the states in the Northeast and the West of the USA, in particular, employ unit-based pricing schemes.

From an environmental perspective, of much greater concern is what happens if waste is reduced as a result of unit-based pricing. As typically there is no unit-based charge for (curbside) recycling, unit-based pricing also provides an incentive for households to divert their waste flows towards recycling collection. To deal with this issue, several authors have used cross-price elasticity, which measures the percentage change in recycling due to a percentage increase in the price of waste. For example, Isely and Lowen (2007) estimated a large cross-price elasticity of 1.16. At a 5 per cent confidence level their data did not reject the hypothesis that the decrease in garbage is completely shifted to recycling. Fullerton and Kinnaman (1996) calculated a cross-price elasticity for recycling of 0.073 at the mean level and found that approximately a third of the waste reduction effect can be attributed to recycling. As such, it would appear to be especially worthwhile undertaking a meta-regression analysis for cross-price elasticities. The studies reviewed in this article, however, do not provide a sufficient number of estimations to make such an analysis feasible, but it is the obvious direction for future research.

A further orientation for future research is to examine the differences between the short- and long-run effects. Recently, based on data at the municipal level in Italy, Bucciol et al. (2014) found that the effect of introducing a PAYT-system varies greatly with the initial level of sorted (or recyclable) waste ratio (SWR). They show that the effect of a waste fee is substantially lower when PAYT is implemented under a high SWR and as such PAYT-systems introduced at a later date are less effective. This seems to contradict the findings in Usui and Takeuchi (2013) where no (or very small) time effects are found and, therefore, the relationship between short- and long-run UBP-effects remains unclear.

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