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Are Bottle Banks Sufficiently Effective for Increasing Glass Recycling Rates?

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Abstract: The Netherlands is a frontrunner in the EU regarding the circular economy. On a national scale, there are higher targets than the EU for different packaging materials as plastics, glass, paper/cartons, and aluminium. For glass, the government advocates a recycling rate of more than 90%. In 2017, the rate realised was 86%. To reach this 4% higher goal, the Human Environment and Transport Inspectorate wants to improve the collection infrastructure by increasing the number of bottle banks, with 800 by 2021. However, in the literature, an effectiveness analysis is lacking. Based on empirical evidence with data from 2007–2019, we show that increasing the number of bottle banks is not effective. Implementing a unit-based pricing system as a priced bag or container for unsorted waste can be more effective in achieving this goal, although this can have serious drawbacks.

Keywords: glass recycling; circular economy; waste infrastructure; local government; Netherlands

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1. Introduction

Lack of space and a growing environmental awareness forced Dutch governments to take measures in the 1980s and 1990s to stimulate recycling [1]. Separate collection of glass, paper and compostable waste became obligatory. With 46% of municipal waste recycled in 2016 the Dutch recycling rate is above the EU average of 38% [2]. According to the EU, 60% of municipal waste should be recycled in 2030. Nevertheless, the Netherlands increased the EU goal even further by demanding that 75% should be recycled in 2020 and that everyone should be allowed to have only 100 kg of unsorted waste per year in 2020 and only 30 kg in 2025. To achieve this goal, the separation and recycling of glass, compostables, paper, plastic, metals, beverage cartons, and textiles are crucial.

Most Dutch municipalities have an advanced infrastructure for curbside collection of unsorted waste and recyclables such as compostable waste and plastics, and easily accessible locations to bring glass bottles, paper, and textiles [1]. For glass, this is similar to most EU countries as “the vast majority of countries apply bring-point systems for the collection of glass” [3]. In addition, more and more Dutch municipalities have introduced unit-based pricing (UBP) systems for waste, as these unit-based pricing systems are effective in reducing unsorted waste and stimulating recycling. However, a drawback of unit-based pricing is illegal dumping, although data to verify this are not easily available. By 2019, 46 percent of all Dutch municipalities had implemented a unit-based pricing system. This share increased substantially from 16 percent in 1999 [4]. This is different to the United States, where in 2015, only 10% of municipalities had unit-based pricing or pay-as-you-throw [5].

For packaging materials such as plastics, glass, paper/carton, metals, and wood, separate goals for recycling are available [6]. Based on the European directive on packaging and packaging waste, packaging producers are responsible for reaching these targets and a so-called "green dot" company is in charge of meeting it (*Stichting Afvalfonds Verpakkingen*, referred to as the Afvalfonds). For example, for plastic, the EU target for re-use of plastic packaging is 55% by 2030. The Netherlands recycled 52% in 2018, only 3% below this goal. Home separation of plastic waste is quite expensive as it demands a separate collection infrastructure and storage and transport of low-density volumes [7]. Therefore, the Dutch Packaging Waste Fund ('Afvalfonds') stimulates postseparation of plastic waste as this results in a larger quantity per household and there are indications that postseparation is cheaper and its quality is higher [8]. Interestingly, since 2019, there are two tariffs for the packaging industry: one for normal plastics and a lower tariff for good recyclable plastics, which further stimulates the quality of plastic waste [9].

Based on life cycle assessments for packaging (Italian) wine, it can be argued that considering the whole life cycle of packaging materials, recycling glass has the highest greenhouse gas emissions impact compared with PET bottles [10]. Nevertheless, due to the great concern about plastic marine pollution, the demand for glass packaging has significantly increased since many people consider it more sustainable than plastic PET bottles [11]. Despite the effort to lower the weight of a glass bottle, in the Netherlands, the amount of packaging glass increased from 492,000 tonnes in 2015 to 508,000 tonnes in 2019 [12]. The Netherlands has an intensive network of public collection points or bottle banks for glass bottles and jars, and almost all Dutch households separate glass. Glass bottles and jars are almost infinitely recyclable and glass cullet recycled from waste bottles or jars is classified as a nondangerous waste [13]. Bottle banks are a way to avoid glass cullet from, for example, energy savings lamps, which contains some hazardous elements [13]. Therefore, this infrastructure will reduce costs for recycling glass and reduce energy consumption [14]. As far as we know, the effectiveness of increasing the number of bottle banks has not been investigated in the literature, but some papers describe the effectiveness of the availability of drop-off centres. In a comparison of recycling programs in US and Norway, [15] shows for both countries that drop-off recycling availability is positive and statistically significant in the glass recycling estimation. In general, drop-off options for glass appear much more common in Norway and drop-off recycling in Norway is less effective than in the US [15].

For glass, the focus of this paper, the European Union advocates a recycling rate of 75%. In 2017, the Netherlands recycled 86% of their glass, far above the EU goal [16]. Nevertheless, the Netherlands has set an even higher goal by demanding that 90% should be recycled in 2021, and the Human Environment and Transport Inspectorate (ILT) forced the Packaging Waste Fund to reach this goal by increasing the number of bottle banks by 800. However, an effectiveness analysis is lacking, and this paper tries to fill this gap by modelling the separate collection of glass waste per inhabitants as a function of the number of bottle banks. Similar to the seminal contribution in article [17], we correct also for unit-based pricing and a vector of socioeconomic characteristics, curbside frequency variables, and socioeconomic variables. This estimation model is used to understand which variables explain recycling success, and based on the confidence intervals, an extrapolation of 800 extra bottle banks is given. As far as we know, the effectiveness of increasing the number of bottle banks by using confidence intervals has not been investigated in the literature before.

The paper is organised as follows. In Section 2, data and methods are discussed. Estimation results for the basic model are given in Section 3, and in Section 4 we give a robustness analysis for the results of the basic model. Furthermore, an effectiveness analysis for increasing the number of bottle banks based on the estimation model of the basic model is given in Section 5. Finally, Section 6 contains some conclusions and a discussion.

2. Data and Methods

Data for the socioeconomic characteristics and the number of bottle banks per municipality are from the CBS (Central Bureau of Statistics). In our dataset, we have 14,323 bottle banks in 2019. As not all municipalities' data are available for each year, we calculated that we have, on average, 88% of the data for all bottle banks. If we have data for a municipality within a year, it reflects 100% of the available bottle banks in this municipality. Data on unit-based pricing and the amount of glass waste in kilograms per inhabitant come from the Netherlands Enterprise Agency. The total of separately collected glass waste in the Netherlands in 2019 is approximately 22 kg (49 pounds) per inhabitant. We have data for 454 municipalities for the period 2007–2019, with a total of 4284 observations. Further, data for glass waste is available from the Packaging Waste Fund for 2010–2017, and we used this data in the robustness analysis. This data can be more reliable as it is used to compensate municipalities and approved by an accountant. Nevertheless, the differences are small as the correlation between the data from the CBS and the Packaging Waste Fund is very high (i.e., 0.96). Furthermore, Statistics Netherlands (CBS) collects yearly information on the number of times in a year curbside collection of (unsorted) waste takes place. For the descriptive statistics, see Table 1.

Table 1. Descriptive statistics.

	Average	Max.	Min.	Std. Dev.
Glass in kg per inhabitant	22.11	45.24	8.00	4.50
Glass in kg per inhabitant (data Packaging Fund)	21.99	38.88	7.38	4.43
Bottle banks per 1000 inhabitants	1.08	4.85	0.03	0.44
Bottle banks per municipality	42.45	1277	1.00	66.26
Bottle banks per km^2	0.74	9.63	0.01	0.92
UBP: volume (dummy)	0.07	1.00	0.00	0.26
UBP: frequency (dummy)	0.23	1.00	0.00	0.42
UBP: bag (dummy)	0.06	1.00	0.00	0.23
UBP: weight (dummy)	0.05	1.00	0.00	0.22
Population density (inhabitants per hectare)	321	2946	13	406
Inhabitants	42,487	854,047	1498	61,646
Household size	2.37	3.55	1.66	0.19
Income (1000 €)	33.66	89.45	22.92	3.78
Elderly (%)	18.13	31.94	6.89	3.58
Ethnicity (%)	5.91	38.56	0.73	5.25
Dummy: low-frequency unsorted: 0–12 per year	0.08	1.00	0.00	0.27
Dummy: low-frequency unsorted: 13–17 per year	0.02	1.00	0.00	0.14
Dummy: few banks (<75% of average)	0.16	1.00	0.00	0.81
Dummy: very few banks (<50% of average)	0.02	1.00	0.00	0.10
Dummy: many banks (>125% of average)	0.34	1.00	0.00	0.71
Dummy: very many banks (>150% of average)	0.17	1.00	0.00	0.59
Dummy: inhabitants > 100,000	0.07	0.00	1.00	0.26
Dummy: inhabitants > 50,000	0.19	0.00	1.00	0.39
Dummy: inhabitants < 10,000	0.06	0.00	1.00	0.25
Dummy: inhabitants between 10,000–15,000	0.13	0.00	1.00	0.33

We model the amount of (separate collected) glass per inhabitant as a function of the number of bottle banks (per 1000 inhabitants); the unit-based pricing system; and socioeconomic variables such as the number of inhabitants, household size, population density, income, share of elderly people, and ethnicity as follows:

$$GI_{it} = \propto_0 + \propto_1 \ BB_{it} + \sum \propto_{2j} \ UBP_{jt} + \sum \propto_{3j} \ SE_{jt} + \delta_i + \gamma_t + \varepsilon_{it}, \quad (1)$$

where GI_{it} is the (separated) glass amount in kilograms per inhabitant of municipality i in year t, BB_{it} is the number of bottle banks (per 1000 inhabitants) in municipality i in year t, UBP_j is a dummy with value 1 if municipalities choose an unit-based pricing system (with different payment systems based on volume (I), frequency (II), bags (III), and weight (IV)), SE_j are the different socioeconomic variables (i.e., population density (households per km^2), number of inhabitants (per 10,000) and its square, household size (inhabitants per household), yearly average income per household (€/1.000), share of elderly people (above

65 years), and ethnicity (defined as the share of nonwestern inhabitants)). Moreover, δ_i are the municipal fixed effects, γ_t is the vector with year dummies, and ε_{it} is the error term. All estimations are based on pooled ordinary least squares (OLS). For the estimate on the number of bottle banks, we also included confidence intervals, as [18] stresses the importance of confidence intervals to understand the economic interpretation of point estimates.

3. Results of the Basic Model

Table 2 shows the estimations for the basic model. From the estimations in Table 2, we can conclude that increasing the number of bottle banks has a significant but small effect on the amount of glass waste per inhabitant. This is in line with results for Czech Republic, where a higher density of collection points is considered an important factor for increasing the amount of separated waste per capita [19]. In the Netherlands, the total amount of bottle banks in 2019 was 16,260 and per 1000 inhabitants, this is 0.94 bottle bank. So, if the number of bottle banks increases by 800, as requested by ILT, the number of bottle banks per 1000 inhabitants increases by 0.05. Therefore, the (separated) glass amount in kilograms per inhabitant will only increase by 0.0174 (i.e., 0.29*0.05), which is 0.07%.

Table 2. Estimation basic model.

	Basis	
Bottle banks per 1000 inhabitants	0.35	(0.14) **
UBP: volume	0.26	(0.28)
UBP: frequency	2.23	(0.20) ***
UBP: bag	3.03	(0.37) ***
UBP: weight	0.97	(0.48) **
Population density	−0.001	(0.001)
Inhabitants/10,000	−0.06	(0.21)
$(\text{Inhabitants}/10{,}000)^2$	−0.001	(0.002)
Household size	−0.79	(1.47)
Income	0.02	(0.03)
Elderly	0.10	(0.06)
Ethnicity	−0.27	(0.08) ***
Constant	22.54	(4.03) ***
R^2	0.80	
Observations	4284	

Notes: **/*** mean significance at, respectively, 95%/99%, and standard errors are between brackets.

Unit-based pricing systems are more effective for stimulating the separation of glass. In particular, the bag-based system is effective for stimulating glass recycling. From Table 2, it follows that the increase in glass per 1000 inhabitants from having such a system is 3.03 kg. Compared with the average quantity of glass in 2019 (22.48 kg per inhabitant), this is an increase of 13%. If a frequency-based system or a weight-based system is chosen, then the increase is 2.2 and 1.0 kg extra, which in percentage is an increase of 10% and 4%, respectively. However, these systems can have some adverse effects such as administrative costs and illegal or illicit dumping. In particular, the bag-based system is effective for increasing separate collection of glass, but it has additional adverse effects as labour laws limit the number of bags each worker is allowed to carry per day.

First, the constant has a high explanatory power, which implies separating glass by citizens is already at a high level in the Netherlands, independent of the number of bottle banks and incentive structures as UBP. In terms of the socioeconomic variables, we found that only ethnicity is significant. Based on our results, nonwestern ethnic groups seem to recycle less glass. If a municipality has 10%-point more nonwestern people, the results indicate 2.7 kg less glass waste or 12% less recycling of glass. This is in line with [20]. Based on UK data, it was found that western ethnic groups have a stronger social norm to recycle. Note that this could be a result of a shorter learning process. However, on average, and especially for glass, the local recycling culture in the Netherlands and the UK has been built on for decades. This would suggest that this effect might evade over time. If we test this with our data by adding ethnicity times a trend, the coefficient is, however, not significant. We leave it as a topic for future research. The result for elderly people is contrary to the Czech Republic, where [19] found that a higher share of the population aged over 65 years results in less waste.

4. Robustness Analysis

In the robustness check, presented in Table 3, we firstly replaced the number of bottle banks per inhabitant by the number per km^2. Secondly, we included a nonlinear effect for the number of bottle banks per inhabitant. Thirdly, we included a dummy if a municipality has a low frequency of collecting unsorted waste.

Table 3. Estimation alternatives: banks per km^2, nonlinear, and low-frequency unsorted.

	Bottle Banks Per km^2	**Nonlinear**	**Low-Frequency Unsorted**
Bottle banks per 1000 inhabitant	-	0.56 *	0.31 **
(Bottle banks per 1000 inhabitant)^2	-	−0.06	-
Bottle banks per km^2	0.24	-	-
UBP: volume	0.27	0.27	0.25
UBP: frequency	2.25 ***	2.24 ***	2.25 ***
UBP: bag	3.03 ***	3.03 ***	2.89 ***
UBP: weight	1.00 **	0.99 **	1.07 **
Dummy: low frequency unsorted: 0–12	-	-	0.43 ***
Dummy: low frequency unsorted: 13–17	-	-	0.23
Population density	−0.002	−0.001	−0.001
Inhabitants/10,000	0.04	−0.06	−0.01
(Inhabitants/10,000)^2	−0.001	−0.001	−0.001
Household size	−0.79	−0.82	−0.74
Income	0.02	0.02	0.03
Elderly	0.10	0.10	0.11 *
Ethnicity	−0.27 ***	−0.27 ***	−0.25 ***
Constant	22.67 ***	22.53 ***	21.73 ***
R^2	0.80	0.80	0.80
Observations	4284	4284	4236

Note: */**/*** means significance at, respectively, 90%/95%/99%.

First, if we include bottle banks per km^2 instead of per 1000 inhabitants, we do not obtain a significant result for bottle banks. For the second estimation with a nonlinear effect for bottle banks, the linear coefficient is only significant at 90%. Furthermore, some Dutch municipalities decrease the frequency of collecting unsorted waste and hereby want to increase separation of recyclables such as glass. This is tested in the third estimations by including a dummy if unsorted waste is collected 12 or less times a year and a dummy if unsorted waste is collected between 13 and 17 times a year. Interestingly, when decreasing the frequency to twelve or less, we obtain a significant increase of glass of 2%. This is still substantially less than by introducing a unit-based pricing system. The result for bottle banks is significant, but somewhat smaller. It should be noted that the results the for unit-based pricing system and for ethnicity and elderly in these robustness analyses are similar to the results in the basic model, although elderly is significant at 90% in the third specification with a positive effect. To sum up, the results for the bottle banks are not robust with respect to significance Our basic result, a very small increase in separately collected glass, may thus even be an overestimation of the real effect.

In Table 4, three other alternatives are estimated. First, we include the glass data waste from the Packaging Waste Fund for 2010–2017. As these data are the basis for the fee the Packaging Waste Fund pays to municipalities and the fund claims that these data are more reliable, we use them in a robustness analysis. Second, as the number of bottle banks per 1000 inhabitants varies greatly between 0.03 (minimum) and 4.85 (maximum), we test whether the effectiveness of increasing the number of bottle banks depends on the density of the existing collection infrastructure. We include several dummies: few banks (if a municipality has less banks than 75% of the average), very few banks (if a municipality has less banks than 50% of the average), many banks (if a municipality has more banks than 125% of the average), and very many banks (if a municipality has more banks than 150% of the average). In the second estimation, we include few and many, and in the third estimation, very few and very many.

Table 4. Estimations, three other alternatives.

	Data Packaging Fund	Few/Many	Very Few/Many
Bottle banks per inhabitant	0.26 *	0.17	0.20
Bottle banks per inh × Dummy: few banks	-	−0.08	-
Bottle banks per inh × Dummy: very few banks	-	-	−0.23
Bottle banks per inh × Dummy: many banks	-	0.13	-
Bottle banks per inh × Dummy: very many banks	-	-	0.13
UBP: volume	0.47	0.238	0.25
UBP: frequency	2.51 ***	2.23 ***	2.22 ***
UBP: bag	3.83 ***	3.02 ***	3.02 ***
UBP: weight	0.65	0.96 **	0.99 ***
Population density	−0.003 ***	−0.001	−0.001
Inhabitants/10,000	−0.83 ***	−0.05	0.07
$(\text{Inhabitants}/10{,}000)^2$	0.005 **	−0.001	−0.001
Household size	−1.76	−0.83	−0.78
Income	−0.05	0.02	0.02
Elderly	0.01	0.10	0.10
Ethnicity	−0.26 ***	−0.26 ***	−0.27 ***
Constant	32.25 ***	22.76 ***	22.65 ***
R^2	0.88	0.80	0.80
Observations	3067	4284	4284

Note: */**/*** means significance at, respectively, 90%/95%/99%.

The results are similar to those of the basic model if we take the data from the Packaging Waste Fund. Only for the weight-based system, population density and inhabitants results are different: the first is no longer significant, and population density and inhabitants are now significant. It should be noted that the data for Packaging Waste Fund are for a smaller time-period (2010–2017), resulting in fewer observations. As [21] show, the use of the more refined weight-based system increased at the beginning of this century and, due to high administrative costs, decreased after 2005. However, the result for the bottle bank variable is robust. If we include a dummy for few or many bottle banks (or for very few or very many), we do not obtain even a significant result for bottle banks. Thus, we find no evidence that the effectiveness of increasing the number of bottle banks depends on the density of the existing infrastructure. For other variables, the results are similar to the basic model.

Finally, we also investigate several dummies for municipality size (see Table 5). There is some indication for the Netherlands that smaller and rural municipalities recycle more as they have more opportunities to place containers. However, [1] found a positive relation between municipality size and textile recycling. Therefore, we include dummies for small municipalities (<10,000 inhabitants), small and medium-sized municipalities (<10,000 inhabitants and inhabitants in the range 10,000–15,000), large cities (>50,000 inhabitants), and very large cities (>100,000 inhabitants).

Table 5. Estimation alternative models: size of municipalities.

	Small Municipalities	Small and Medium Municipalities	Large Cities	Very Large Cities
Bottle banks per inhabitant	0.32 **	0.32 *	0.37 ***	0.37 **
Dummy: inhabitants < 10,000	0.93 **	0.93 *	-	-
Dummy: inhabitants between 10,000-15,000	-	0.00	-	-
Dummy: inhabitants > 50,000	-	-	-0.19	-
Dummy: inhabitants > 100,000	-	-	-	−0.86
UBP: volume	0.25	0.25	0.26	0.26
UBP: frequency	2.21 ***	2.21 ***	2.22 ***	2.22 ***
UBP: bag	3.02 ***	3.02 ***	3.02 ***	3.02 ***
UBP: weight	0.88 *	0.88 *	0.98 **	0.97 **
Population density	−0.002	−0.001	−0.001	−0.002
Inhabitants/10,000	−0.07	−0.07	−0.06	0.00
$(\text{Inhabitants}/10{,}000)^2$	−0.001	−0.001	−0.001	−0.001
Household size	−0.95	−0.95	−0.80	−0.98
Income (€)	0.04	0.04	0.02	0.02
Elderly (%)	0.09	0.09	0.10	0.10
Ethnicity (%)	−0.27 ***	−0.27 ***	−0.26 ***	−0.26 ***
Constant	22.75 ***	22.75 ***	22.58 ***	22.95 ***
R^2	0.80	0.80	0.80	0.80
Observations	4284	4284	4284	4284

Note: */**/*** means significance at, respectively, 90%/95%/99%.

From these estimations, we see that for small municipalities with less than 10,000 inhabitants, the amount of separate collected glass is 0.9 kg (4%) higher. However, for municipalities with more than 10,000 inhabitants, this effect disappears. We have, therefore, indications that the effect of bottle banks might be larger in very small municipalities. For the overall effect in the Netherlands, this is only very marginal, as more than 99% of inhabitants live in municipalities with more than 10,000 inhabitants in 2019. Overall, we conclude from this robustness analysis that the effect on recycling of bottle banks is rather stable and there is no nonlinear effect.

5. Effectiveness of Increasing Bottle Banks

As the Human Environment and Transport Inspectorate (ILT) announced in 2017 that the Packaging Waste Fund should reach the 90% glass recycling goal by increasing the number of bottle banks by 800, we analyse the effectiveness for this year (see Table 6). In our dataset, we have 12,702 bottle banks in 2017. As we have missing data for some municipalities, extrapolating to the number of bottle banks for the Netherlands using the average number of bottle banks per inhabitant results in a total of 16,564. If the number of bottle banks increases by 800, as requested by ILT, the number of bottle banks per 1000 inhabitants increases by 0.05 to 1.02. From the estimation in Table 2, we can derive that the (separated) glass amount in kilograms per inhabitant will increase by 0.0164. If we consider the 5% uncertainty with respect to this parameter estimation, this will be between 0.0037 and 0.0290. So, on average, 800 extra bottle banks means an increase per inhabitants of yearly 21.83 kg to 21.91 kg, which means an increase in percentage of only 0.08%.

Table 6. Calculation of effectiveness of extra glass bottle banks.

Nr	Contents	Unit	Basis	+2SD	-2SD	Remark
1	Glass bottle banks 2017	2017 dataset	12,702	12,702	12,702	Measured
2	+800	Policy goal	13,502	13,502	13,502	Assumption
3	NL	Netherlands	16,564	16,564	16,564	Estimated
4	Inhabitants	2017 dataset	13,097,417	13,097,417	13,097,417	Measured
5	Inhabitants	Netherlands	17,080,000	17,080,000	17,080,000	CBS
6	Glass bottle banks now	Bottle banks per 1000 inhabitants	0.97	0.97	0.97	Measured
7	+800	Bottle banks per 1000 inhabitants	1.02	1.02	1.02	6+800/5
8	Effect on glass	kg per inhabitant	0.02	0.03	0.00	From estimation
9	Glass	kg waste per inhabitant 2017	21.83	21.83	21.83	Measured
10	% change	%	0.08	0.13	0.02	8/9
11	Necessary change	% waste	5.6	5.6	5.6	Assumption
12	Necessary change	kg waste per inhabitant	1.22	1.22	1.22	14*9
13	90% target	Bottle banks per 1000 inhabitants	3.47	1.96	15.20	12/8*800/5*1000
14	Idem	Bottle banks	59,348	33,503	259,649	13*5
15	Idem	Extra	42,784	16,939	243,085	14-3
16	Costs per bottle bank	Euro	7000	7000	7000	Assumption
17	Extra costs	Million euro	299	119	1702	15*16
18	Idem	Per tonne waste	14,418	5708	81,918	17/(12*5)

If we take into account that household or municipal packaging glass waste is about 5/6 of overall glass waste collected, and the 800 extra banks have an effect only on glass waste collected by municipalities, then the increase in household waste must be 5.6% to have an increase from 86% to 90% of overall target. In such a case, the increase in glass waste per inhabitant should be 1.22 kg (kg). In 2015, total glass waste was 410,000 tonnes divided between firms 68 (17%) and households 342 (83%) [22]. In 2017, total separated glass waste was 430,000 tonnes, which can be divided between firms 71,000 (17%) and households 359,000 (83%) compared with a total glass production of 500,000 tonnes [12]. For 90% recycling, the extra amount needed is 20,000 tonnes or 5.6% of household waste, as the extra bottle banks only have an effect on the amount collected with the municipal infrastructure. Based on the model in Equation (1), this means the extra number of bottle banks per 1000 inhabitants should be 3.47, which means an average of 59,000 bottle banks (or the interval 34,000–260,000 with 95% certainty). This means an increase of 43,000 bottle banks, nearly three times the current infrastructure, instead of the proposed number of 800 extra bottle banks. As we know, the Packaging Waste Fund uses 7000 euros as the proxy for costs of installing a bottle bank. Therefore, total costs will increase by 300 million euros—even if we take the lower boundary of the estimated effect of bottle banks on glass collection, this increase will be 120 million euros. Per (metric) tonne extra glass waste, costs are, on average, approximately 14,400 euro; if we take a lifespan of 15 years, the costs (without operating costs) are approximately 1000 euro per year. From these figures, it is very clear that increasing the number of bottle banks is not cost-effective. Although including external costs might increase effectiveness, the calculated costs are that high that our conclusion would then be the same in qualitative terms.

6. Conclusions and Discussion

In the Netherlands, a circular economy is high on the policy agenda. Glass is ideal for recycling since normally none of the material is degraded by reuse. Therefore, the Netherlands wants to raise glass recycling from 86% to 90%, while the EU target is 75%. The inspectorate ILT has ordered that the number of bottle banks should increase by 800 in 2021. Nevertheless, an effectiveness analysis is lacking, and this paper fills this gap. Based on the empirical analysis, there is an increase of only 0.07% and, to achieve their 90% target, the number of bottle banks should increase by 43,000. If the lower bound of the confidence interval is taken, this number is still 17,000, a doubling of the current infrastructure. Most Dutch municipalities have an advanced infrastructure of easily assessable locations to bring glass bottles and we found no evidence that extending this infrastructure will be cost-effective.

Introducing unit-based pricing systems such as the bag-, weight-, and frequency-based system is more effective, as the amounts of separated glass increase substantially. If a frequency-based system or a weight-based system is chosen, then the increase is, respectively, 11% and 10%. However, these systems can have some adverse effects such as administrative costs and measures needed to avoid illegal dumping. It seems that glass recycling is already at a high level in the Netherlands, and increasing the target far above the EU goal by increasing the number of bottle banks does not appear to be an effective option. As the social norm for glass recycling is already high in the Netherlands, there seems to be little room to improve it by extending the number of bottle banks. For other countries, there is more room to improve glass recycling. For example, there are now around 50,000 bottle banks in the United Kingdom [23]. Per 1000 inhabitants, this is 0.79 bottle bank, which is substantially below the Dutch average of 1.05 bottle banks per 1000 inhabitants.

The effectiveness of increasing the number of bottle banks has not been investigated for other countries, but some papers describe the effectiveness of the availability of drop-off centres. In a comparison of recycling programs in US and Norway, [15] suggested that convenience or reducing the effort it takes to recycle is more important for US households. Therefore, bottle bank effectiveness in the US may be different from Europe, although this requires an additional empirical investigation. In a comparison of recycling programs in El Paso (US) and Asturias (Spain), it is shown that El Paso has drop-off sites for packaging material while in the Spanish Principality of Asturias, curbside collection is more common. As a consequence, the time required to reach the point of disposal of waste is markedly lower in the Spanish case compared with the American case, while the separation rate for glass is 66.6% for the Spanish case, which is higher than the US case (40.4%). Based on these results, [24] advocated that in the US, efforts should be made towards increasing and dispersing the number of collection points and locating them close to population centres in order to reduce the time to reach them. However, based on 20 US cities, [25] indicated that drop-off recycling programs may increase households' intensity of recycling for glass, but the magnitude of the effect of these programs varies dramatically across different jurisdictions. Further, based on our analysis, it is not clear whether the cost of increasing the number of collection points outweighs the increased effectiveness of more collection points. Therefore, studies that provide insights on increasing the number of bottle banks outside the Netherlands are worthy areas of future research.

In addition, the debate on the impact of unit-based pricing on illegal disposal or waste tourism is still open, as data is not readily available. Interestingly, for Switzerland, there have been two recent opposing indications. [26] investigated whether the introduction of a unit-based garbage fee induces waste dumping in nearby communities, which do not implement such a policy and call it a "waste haven effect". Interestingly, it was found that there is some evidence for waste havens in a cross-section of 1752 Swiss municipalities. By contrast, in the Swiss city of Lausanne, [27] showed that four years after the introduction of a unit-based pricing system, illegal disposal remained a minor issue. Therefore, the issue of illegal or illicit dumping of unit-based pricing systems should be studied in more detail. Therefore, we advocate more recent and detailed data on illegal dumping.

It might be the case that decreasing travel distance is important to optimize glass collection. We could only measure this roughly by bottle banks per 1000 inhabitants or per km^2. It would be very interesting to have a more detailed dataset with GIS data to test this more explicitly. The same holds for explaining why some people do not engage in recycling. An interesting question for future research is also whether these people have a time issue, are not aware of the environmental consequences, or just do not care for them.

Finally, we recommend studies on the behaviour of the industry in terms of recycling of packaging material and lowering the use of single-use glass. Further, transport costs as well as environmental costs will lower if lighter glass or other materials such as plastics are used. Nevertheless, plastics have disadvantages as well. Most importantly, much of the separated waste is not recycled into new products. Substantial amounts are burned or even shipped to Asia. This leads to substantial plastic debris, as recent evidence has shown [9]. Therefore, for plastics design-for-recycling strategies, lowering the amount of mixed and contaminated plastics are important [9]. For glass, there are fewer indications for the importance of this. Some countries have a deposit system to stimulate recycling, and in the Netherlands, this is only used for beer bottles as such a system is costly. For flat glass used in construction and utilities, there can be some room for improvements. In [28], it is shown that the percentage of municipalities that collect flat glass separately increased from 17% in 2001 to 39% in 2010. In 2020, 87,500 tonne of flat glass was recycled in the Netherlands [28].

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References

1. Dijkgraaf, E.; Gradus, R.H.J.M. An EU recycling target: What does the Dutch evidence tell us? *Environ. Resour. Econ.* **2017**, *68*, 501–526. [CrossRef]
2. Eurostat. Waste Statistics: Statistics Explained. *Press Release*, 3 May 2021.
3. Seyring, N.; Dollhofer, M.; Weissenbacher, J.; Bakas, I.; McKinnon, D. Assessment of collection schemes for packaging and other recyclable waste in European Union-28 Member States and capital cities. *Waste Manag. Res.* **2016**, *34*, 947–956.
4. Gradus, R.H.J.M.; Dijkgraaf, E. Poorer and less political fragmented Dutch municipalities take tighter waste reduction decisions. *Waste Manag.* **2019**, *88*, 328–336. [CrossRef] [PubMed]
5. Gradus, R.; Homsey, G.; Warner, M.; Liao, L. Which US municipalities adopt Pay-As-You-Throw and curbside recycling? *Resour. Conserv. Recycl.* **2019**, *143*, 178–183. [CrossRef]
6. Gradus, R. Kritische reflectie op huishoudelijk afvalbeleid in circulaire economie: Ondoelmatigheid tiert welig. In *Verduurzaming en nu de Kosten nog: Essaybundel Raad Voor Openbaar Bestuur*; van Nijendaal en, G., Leurs, B., Eds.; Rob-Rfv: Den Haag, The Netherlands, 2018; pp. 104–128. Available online: https://www.raadopenbaarbestuur.nl/ (accessed on 2 May 2021).
7. Gradus, R.H.J.M.; Nillesen, P.H.L.; Dijkgraaf, E.; van Koppen, R.J. A cost-effectiveness analysis for incineration or recycling of Dutch household plastic waste. *Ecol. Econ.* **2017**, *135*, 22–28. [CrossRef]
8. Dijkgraaf, E.; Gradus, R.H.J.M. Post separation of plastic waste: Better for the environment and lower collection costs? *Environ. Resour. Econ.* **2020**, *77*, 127–142. [CrossRef]
9. Gradus, R. Postcollection separation of plastic recycling and design-for-recycling as solutions to low cost-effectiveness and plastic debris. *Sustainability* **2020**, *12*, 8415. [CrossRef]
10. Simon, B.; Amor, M.; Földényi, R. Life cycle impact assessment of beverage packaging systems: Focus on the collection of post-consumer bottles. *J. Clean. Prod.* **2016**, *112*, 238–248. [CrossRef]
11. Ferrara, C.; De Feo, G. Comparative life cycle assessment of alternative systems for wine packaging in Italy. *J. Clean. Prod.* **2020**, *259*, 120888. [CrossRef]
12. Afvalfonds ('Packaging Waste Fund'). *Verpakkingen in de Circulaire Economie: Recycling Verpakkingen Nederland 2019*; Afvalfonds verpakkingen: Leidschendam-Voorburg, The Netherlands, 2020.
13. Furlani, E.; Tonello, G.; Maschio, S. Recycling of steel slag and glass cullet form energy saving lamps by fast firing production of ceramics. *Waste Manag.* **2010**, *30*, 1714–1719. [CrossRef] [PubMed]
14. Chao, C.; Liao, C. Approaches to eliminate waste and reduce cost for recycling glass. *Waste Manag.* **2010**, *31*, 2414–2421. [CrossRef] [PubMed]
15. Kipperberg, G. A comparison of household recycling behaviors in Norway and the United States, Environ. *Resour. Econ.* **2007**, *36*, 215–235. [CrossRef]
16. Afvalfonds ('Packaging Waste Fund'). *Verpakkingen in de Circulaire Economie: Recycling Verpakkingen Nederland 2017*; Afvalfonds verpakkingen: Leidschendam-Voorburg, The Netherlands, 2018.
17. Fullerton, D.; Kinnaman, T.C. Household responses to pricing garbage by the bag. *Am. Econ. Rev.* **1996**, *86*, 971–984.

18. Romer, D. In Praise of Confidence Intervals. *AEA Pap. Proceeding* **2020**, *110*, 55–60. [CrossRef]
19. Slavík, J.; Pavel, J.; Arltová, M. Variable charges and municipal budget balance: Communicating vessels of the waste management. *J. Environ. Manag.* **2020**, *275*, 109976. [CrossRef] [PubMed]
20. Abbot, A.; Nandeibam, S.; O'Shea, L. Recycling: Social norms and warm-glow revisited. *Ecol. Econ.* **2013**, *90*, 10–18. [CrossRef]
21. Dijkgraaf, E.; Gradus, R.H.J.M. Waste management in the Netherlands. In *Handbook on Waste Management*; Kinnaman, T., Takeuchi, K., Eds.; Edward Elgar Publishers: Cheltenham, UK, 2014; pp. 287–315.
22. Afvalfonds ('Packaging Waste Fund'). *Verpakkingen in de Circulaire Economie: Recycling Verpakkingen Nederland 2015*; Afvalfonds verpakkingen: Leidschendam-Voorburg, The Netherlands, 2016.
23. Bottle Bank Celebrates Birthday. BBC News, 6 June 2007. Available online: http://news.bbc.co.uk/2/hi/uk_news/england/south_yorkshire/6724099.stm (accessed on 2 May 2021).
24. Jenkins, R.R.; Martinez, S.A.; Palmer, K.; Podolsky, M.J. The Determinants of Household Recycling: A Material-specific Analysis of Recycling Program Features and Unit Pricing. *J. Environ. Econ. Manag.* **2003**, *45*, 293–318. [CrossRef]
25. González-Torre, P.L.; Adenso-Díaz, B.; Ruiz-Torres, A. Some comparative factors regarding recycling collection systems in regions of the USA and Europe. *J. Environ. Manag.* **2003**, *69*, 129–138. [CrossRef]
26. Erhardt, T. Garbage in and Garbage out? *On Waste Havens in Switzerland. Environ. Resour. Econ.* **2019**, *73*, 251–282. [CrossRef]
27. Carattini, S.; Baranzini, A.; Lalive, R. Is Taxing Waste a Waste of Time? Evidence from a Supreme Court Decision. *Ecol. Econ.* **2018**, *148*, 131–151.
28. Available online: https://www.vlakglasrecycling.nl/ (accessed on 2 May 2021).