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Article

Unit pricing of municipal solid waste and illegal dumping: an empirical analysis of Korean experience

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Abstract Using a fixed effects panel regression model for count data on illegal dumping incidents in 16 provinces in Korea from 2001 to 2003 as reported by civilians to local government, we analyzed the effect of the unit pricing system on the propensity for illegal dumping. We found that a 1% increase in the unit price of a trash bag led to a 3% increase in the number of reports of illegal dumping. The policy implication is that charging households more for recouping waste disposal costs must be reconsidered and the incentive of compensation for recycling is more effective in curbing illegal dumping than the threat of enforcement.

Key words Municipal solid waste · Illegal dumping · Unit pricing

1 Introduction

It has been argued, particularly by the Korean government, that the generation of municipal solid waste has been greatly reduced through the so-called pay-by-the-bag system, which was introduced in 1995. It was reported that the total volume of waste generated was 58118 tons/day in 1994 and it had fallen to 47774 tons/day in 1995 (Kim 1998). Charging households by the bag has effectively increased the cost of discharging garbage and it seems to have contributed to having households discharge less. However, this also means effectively increasing the benefit of illegal dumping: ceteris paribus, households are presented with a stronger incentive to discharge illegally. Such illegal dumping, in addition to illegal incineration, creates large social costs. Thus, one is led to ask if the benefit of the pay-by-the-bag system could conceivably exceed the social cost. This article does not directly attempt to address this question, but measures the effect of the unit pricing scheme on the propensity for illegal dumping in Korea, and what implications this would have on setting policy.

This kind of quantity-based unit pricing has a relatively short history in most countries. In the United States, relatively few communities were using unit pricing programs in the 1980s. Yet by 1992, over 2000 basic autonomous units had such programs in place. By the end of the 1990s, this figure has grown to over 4000 (Miranda and Bynum 1999). A number of other countries, especially northern European ones, have been experimenting with their own programs for unit pricing. Reflecting this, a growing empirical literature has attempted to gauge household behavior under various unit pricing and recycling schemes in a range of countries and localities (Miranda et al. 1994; Fullerton and Kinnaman 1996; Kinnaman and Fullerton 1997; Nestor and Podolsky 1998; Miranda and Aldy 1998; Van Houtven and Morris 1999; Sterner and Bartelings 1999; Linderhof et al. 2001; Jenkins et al. 2003).

Fullerton and Kinnaman (1996) studied the effect of unit pricing using survey data from Charlottesville, Virginia, in the United States. They argued that this pricing program had little effect on the weight of garbage, but a substantial effect on volume, recycling, and illegal dumping. Van Houtven and Morris (1999), studying another program in Marietta, Georgia, also in the United States, found that unit pricing indeed significantly reduced curbside waste. Recognizing that a reduction in waste volume does not necessarily translate into a reduction in waste weight, some communities in the Netherlands have experimented with weight-based charges (Linderhof et al. 2001). Turning to the case of Korea, Hong (1999) analyzed the pay-by-the-bag system using over 3000 household survey data and found ambiguous evidence of success. Beyond the initial adjustment to unit pricing, it was found that a change in the price per bag had very little influence on the volume of garbage discharged. Moreover, Hong found evidence that volume-based charges led users to pack the bags intensively, such that volume reductions were not accompanied by significant weight reductions. In view of the results, Hong voiced concerns about illegal dumping, although this was a matter outside the scope of his analysis. Hong (2001) has also recognized the price effects of unit pricing on initial waste volume reduction, but the effects of later price changes were not addressed.

In this article, we explicitly examine the effect of the pay-by-the-bag system on illegal dumping. While acknowledging the accomplishments of the unit pricing system, Kim (1998) conceded that illegal dumping had substantially increased in the wake of the system's introduction. Yet, to date, we are aware of no studies that have tried to empirically examine the relationship between this system and illegal dumping. Obviously, this may be simply a result of the fact that illegal dumping is an activity that is difficult to measure satisfactorily. In light of Sigman (1998), a study of illegal waste-oil dumping in the United States, we used data regarding the reporting of illegal dumping by citizens to local governments and tried to gauge the effect of the unit pricing system on the propensity for illegal dumping. In 2000, a program called "report-prize" system was instituted in Korea in which individuals would receive monetary rewards for the reporting of illegal dumping. Although such reports obviously constitute only a fraction of the total number of illegal dumping incidents, we feel the data are indicative of the true population of such incidents. In this manner we have found that a 1% increase in the price of trash bags has caused a 3% increase in the number of reports, reflecting increasing illegal dumping.

In the next section, we turn to the development of a simple theoretical model that focuses on the decision making of a typical household with regard to legal versus illegal waste disposal. In the third section, we introduce an econometric model and present empirical results. Lastly we make some concluding remarks and briefly discuss policy implications.

2 A simple theory

The objective of this section is to develop a simple theory from which we can draw an empirically testable hypothesis. We begin by considering the utility function of a typical household in a region such as $u = f(x, l, r, b)$ where x represents a composite numeraire good, while l, r, and b stand for legal disposal, recycling, and illegal dumping of garbage, respectively.[1] This typical household maximizes the utility function subject to its budget constraint: $x + p_l l + p_r r + p_b b \leq I$ where I represents the household's income and p_l, p_r, and p_b stand for the prices of legal waste discharge, recycling, and illegal dumping, respectively. The first price variable, p_l, means the price of the bag by which households discharge garbage legally. The second price variable, p_r, includes both the monetary cost of throwing wastes into recycling bins and the opportunity costs of time and effort in gathering, sorting, and returning recyclable goods, which is offset by the compensation received for those goods themselves and perhaps some intrinsic utility in participating in recycling efforts. Thus, the price may or may not be positive depending on the relative size of the costs and the compensation received. The third price variable, p_b, represents the expected fine from violating the law. More specifically, the expected fine is the probability of getting detected multiplied by the size of the fine imposed. That is, $p_b = p \cdot F(E)$ where p represents the probability of detection and E and F represent the government's enforcement efforts and the size of the resulting fine, respectively.

From the household's utility maximization problem, we can derive an individual demand function for illegal dumping as follows: $b = b(p_l, p_r, p_b, I)$. Summing horizontally all of the individual demand functions in a region, we can derive the regional aggregate demand function for illegal dumping, $B = B(p_l, p_r, p_b, n, \text{ri})$, which has an additional argument of the population size n. The individual income variable is replaced by the per capita income ri in the region. Obviously, the most critical variable in our analysis is the amount of garbage illegally dumped, the dependent variable, but we cannot easily observe it directly. Thus, following Sigman (1998), we used data on public reports of illegal dumping instead. Having recognized that the pay-by-the-bag system could benefit from greater community involvement in enforcement, the Korean

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[1] Illegal dumping here includes illegal incineration. The reported data we have used for illegal dumping included illegal incineration.

government started the so-called report-reward system in 2000. We analyzed the illegal practices as shown in the report data. The problem is that the report data do not include the quantity but only the number of cases of illegal dumping. Moreover, it does not cover all the illegal dumping incidents. In other words, the report is an incomplete count dataset.

In order to use the count data we need to understand how frequent a household discharges the total desired quantity of illegal dumping. The household should respond to the enforcement parameters by changing both the frequency and total desired quantity of illegal dumping. For an example, if the fines remain constant irrespective of the amount of dumping, the household would pack it more densely and make less frequent discharges to minimize the expected fines. Also, if the monitoring became more vigilant, the household would make less frequent discharges and probably a lower total amount of illegal dumping. Not all of the illegal incidents are detected and reported. We assume that only a proportion z of total illegal practices is reported and z is a number between 0 and 1. The amount of the monetary reward pz, per capita income ri, and population density pd we consider as the most important variables explaining the public's report propensity z. We assume that $\frac{\partial z}{\partial \mathrm{pz}} > 0$, $\frac{\partial z}{\partial \mathrm{ri}} > 0$, $\frac{\partial z}{\partial \mathrm{pd}} > 0$. As the income grows, people usually value the environment more and they tend to protect more strongly their environmental rights from illegal dumping and incineration. In addition, we can expect population density to have an impact on the public's reporting behavior. In more densely populated areas, for example, sensitivity to illegal disposal (especially illegal incineration) may be greater, and community monitoring may be more vigilant. In summary, z can be expressed in the following mathematical form: $z = z(\mathrm{pz}, \mathrm{ri}, \mathrm{pd})$. Finally, the reported number of illegal dumping incidents, B^{r}, is going to be just the "universal" illegal dumping incidents function B times the report propensity z as follows:

$$B^{\mathrm{r}} = B(p_1, p_{\mathrm{r}}, p_{\mathrm{b}}, n, \mathrm{ri}) \times z(\mathrm{pz}, \mathrm{ri}, \mathrm{pd}) \tag{1}$$

The direction of the effect of per capita income on the reported number is not clear-cut, because on the one hand it reduces the reported number through the positive income effect on legal discharge by the bag (i.e., illegal dumping is an inferior good). On the other hand, it increases the reported number through the positive income effect on civilians' report propensity (i.e., environmental quality is a normal good). In contrast, the effect of population density on the reported number is clear in its direction because it implies more illegal dumping and also it makes the public more vigilant to illegal dumping and more tend to report. Finally the monetary reward has an ambiguous effect on the reported number. On the one hand, it makes the public more alert to illegal practices and more tend to report. On the other hand, the higher probability of illegal dumping being detected due to the public being more alert may reduce the number of illegal dumping incidents and less are reported. A similar argument may apply to the monitoring efforts by government officials.

3 Empirical analysis

3.1 Estimation equation and data

For an empirical estimation, Eq. 1 needs to be specified as having a specific functional form. We assume that the universal illegal dumping B and the report propensity z are all of an exponential function. This guarantees that the number of reports be positive. Among the independent variables in Eq. 1, the data for p_b (i.e., p and E) are hard to get, and we substituted the average fines actually imposed on the illegal dumping reported as its proxy, denoted by en. Also, we used the population of a region as a proxy for the total number of households discharging garbage in the region, denoted by pop. Incorporating these, we can finally present the following empirically estimable equation.

$$\mathrm{E}(B^{\mathrm{r}}_{it} \mid \theta) = \exp(\beta_1 p_{\mathrm{l}it} + \beta_2 p_{\mathrm{r}it} + \beta_3 \mathrm{en}_{it} + \beta_4 \mathrm{pop}_{it} + \beta_5 \mathrm{pz}_{it} + \beta_6 \mathrm{pd}_{it} + \beta_7 \mathrm{ri}_{it}) + \mu_i \quad (2)$$

where θ stands for the independent variables and the subscript i and t represent a region and a time period, respectively. We used a panel dataset, which covers 16 provinces in Korea from 2001 and 2003.

The dependent variable is the number of civilians' reports, which is provided by the Korea Ministry of Environment on its web site. $p_{\mathrm{l}it}$ as the price of a vinyl trash bag in region i and time t is set autonomously by the local administrative unit called "basic autonomous government," which in Korea is the city (*si*), county (*gun*), or ward (*gu*). While there are several different sizes of bags and so different prices, we use only the average price for 10- and 20-liter bags mainly because these bags are the most widely used by households and this approximation simplifies the analysis somewhat.[2] $p_{\mathrm{r}it}$, the price of recycling, captures the cost of the compensation that a household in region i at time t has received for 1 kg of recycled goods. However, there is no explicit pecuniary cost for recycling in Korea. It represents only the compensation received and it is, in fact, a negative number.[3] Papers, plastics, bottles, and cans are the primary recycled items and we used the annual average of the monthly prices for these items provided by the Korea Resource Recovery Corporation.[4] The weighted average of the item prices based on the proportion of each item in the wastes that households actually discharge is more accurate, but this information is very difficult to obtain, so

[2] The Korea Ministry of Environment publicizes the data annually at www.me.go.kr. We used this data in real terms measured in the 2000 constant Consumer Price Index published by the Korea National Statistics Office.

[3] Direct trade between households and recycling companies is rare in Korea. However, in the case of apartments, some compensation payments are given to "households autonomous meeting" and this is expected to increase the households' welfare.

[4] The price for recycled paper is the average of the prices for recycled newspaper and cardboard. The price for recycled plastic is the average of the prices for recycled polyethylene, polypropylene, and polystyrene. The price for recycled bottles is the average of the prices for white, brown, and dark green bottles. The price for recycled cans is the average of the prices for metal and aluminum cans. All are in real terms, 2000 constant.

Table 1. Summary statistics

Variable	Observations	Mean	SD	Minimum	Maximum
B^{r}	48	3705	3811	33	17139
p_{l}	48	270	97	155	547
p_{r}	48	211	7	200	227
en	48	22	12	3	52
pop	48	2975	2767	528	10165
pz	48	20	7	2	38
pd	48	2283	4091	92	17062
ri	48	12	3	8	21

SD, Standard deviation

we could only use the simple average. Moreover, it must be noted that the data is for wider regions and we applied the same price to all the subregions in a wider region. For example, the prices in Choongchong-kwon (a wider region) are identically applied to the subregions: Daejun City, Chungnam Province, Chungbuk Province, and Kangwon Province. There are four wider regions in total. en_{it} represents the fines actually imposed per illegal dumping incident reported in region i at time t (in thousand won). The fines include what government officials as well as private citizens have caught and imposed.

The remaining pz_{it}, pd_{it}, and ri_{it} are explanatory variables for the public's report propensity. pz_{it} is the prize (in thousand won) given per report, the data of which is provided in the Korea Ministry of Environment's website. pd_{it} is the population density of region i at time t (in persons per square kilometer). Finally, ri_{it} is the per capita income of region i at time t (in million won, 2000 constant). For the last two variables we used the data provided by the Korea National Statistics Office on its website (www.nso.go.kr). Table 1 contains a summary of the statistics for the data we used in our empirical analysis.

3.2 Estimation results

Assuming a Poisson distribution for the number of reports, we have estimated the coefficients in Eq. 2 by the method of maximum likelihood. We applied the Hausman specification test, and calculated the difference between the coefficients for fixed effect and random effect models, and its standard errors, as shown in Table 2.

To test the null hypothesis that the difference in coefficients is not systematic, we calculated the inverse of the difference between variance and covariance matrices for fixed and random effects models, and obtained –15.98 as the value for the test statistic. This means that we cannot apply the test because the asymptotic assumption for the Hausman test is not satisfied. That is, we cannot tell which of a fixed effect model or a random effect model is appropriate. Because the estimated coefficients for the parameters are very similar, we explain only the results for the fixed effect model (Table 3), although the same explanation can be applied to the random effect model.

Table 2. Difference in coefficients for Hausman test

Variable	Fixed effect model	Random effect model	Difference	Standard error
p_l	0.0112819	0.0005728	0.0000703	0.000
p_r	–0.0272039	0.0005317	–0.000096	0.000
en	–0.0164215	0.0005996	–0.0000314	7.78e–06
pop	–0.0006677	0.0000385	–7.83e–06	0.000
pz	0.0426751	0.0008546	0.000094	0.000
pd	0.0095916	0.0001799	0.0000475	0.000
ri	0.0814746	0.0057835	0.0004304	0.000

Table 3. Estimation results for fixed effects model

Variable	Coefficient	Standard error	z statistic	Probability
p_l	0.0112819	0.0005728	19.70	0.000
p_r	–0.0272039	0.0005317	–51.16	0.000
en	–00164215	0.0005996	–27.39	0.000
pop	–0.0006677	0.0000385	–17.33	0.000
pz	0.0426751	0.0008546	49.94	0.000
pd	0.0095916	0.0001799	53.31	0.000
ri	0.0814746	0.0057835	14.09	0.000

All the coefficients conform to the theory. However, some explanations are needed for the results for the size of population and regional income. The negative sign of the coefficient for pop is confusing, especially in light of the fact that overall the population size keeps in step with the population density. In other words, overall the areas with a bigger population density have a bigger population size also. The positive sign of the coefficient for ri implies that the income effect on illegal dumping is more than offset by the income effect on report propensity.

The positive sign of the estimated coefficient for p_l implies that legal bag price increases tend to increase illegal dumping. This does not necessarily mean that overall waste generation did not decrease. With illegal dumping increased, overall waste generation may have decreased at the same time, for example, if recycling had substantially increased with the increase of legal bag price. However, the result demonstrates that the government should be cautious in its policy evaluation. Even though less waste has been generated overall after the policy introduction, it has been done at the cost of an increase in illegal dumping. From Eq. 2 we know that the legal bag price elasticity of reports on illegal dumping is just $\beta_l \cdot p_l$. Evaluating this at the sample mean of p_l, it amounts to 3.05 with a standard error of 0.15. This means that a 1% increase in the price of a legal bag leads to about a 3% increase in reports of illegal dumping practices. However, this does not necessarily mean that the illegal dumping itself would also increase by 3%, firstly because the legal bag price change might influence the report propensity, and secondly because the government officials' enforcement activities might change in accordance with the legal bag price change.[5] In the same manner, the recycling price elasticity of reports on illegal practices, $\beta_2 \cdot p_r$, can be computed at a sample mean of p_r of 5.74 with a standard error of 0.11, which means that a 1% increase in the compensation for recycled goods leads to about a 6% decrease in the reports of illegal dumping incidents. Again, the recycling price elasticity of illegal dumping is not necessarily 5.74 for reasons similar to those given regarding the legal bag price elasticity of illegal dumping. Additionally, illegally dumped wastes contain some amount of materials independent of the compensation for recycled goods like inedible foodstuffs. It is notable, however, that the recycling price elasticity of reporting, 5.74, is much greater than the enforcement elasticity of reporting, $\beta_3 \cdot \text{en}$, evaluated with the sample mean of en of 0.36 with a standard error of 0.01. This implies that the incentive of compensation for recycling is more effective than the penalty of enforcement in restraining illegal practices. The coefficient of pz is positive, suggesting that the monetary rewards are eliciting the desired effect of a greater number of reports.

4 Conclusions

The pay-by-the-bag unit pricing system was introduced to provide households with an incentive to reduce the generation of wastes and enhance the portion of recycling among wastes discharged. Although several authors have acknowledged the initial effect of the unit pricing system at the time of its introduction, they have also argued that an additional increase in the price of legal disposal has a minimal effect. While reducing the overall volume of wastes, the price increase tends not to significantly reduce the weight of such waste and also tends to induce illegal dumping. We have addressed this issue by attempting to quantify the effect of the unit pricing system on illegal dumping in Korea.

We ran a panel regression with regional fixed effects. We found that a 1% increase in the legal bag price led to a 3% increase in the number of reports of illegal dumping. We also found that a 1% increase in the compensation for recycled goods led to a 6% decrease in the number of reports of illegal dumping. With caveats we interpret these to imply that the legal bag price increase induces illegal dumping and the compensation for recycled goods dampens illegal dumping significantly. Additionally, we found that the compensation for recycled goods has a greater effect on the number of reports of illegal dumping than government enforcement activity, implying that the incentive of compensation is much more effective in checking illegal dumping than the threat of enforcement.

The policy implication of our analysis is clear. The marginal effect of an additional increase in the legal bag price on overall waste generation is minimal, as

[5] The government officials as well as civilians monitor illegal waste dumping. As a final manager of national waste generation and treatment the government may design an optimal mix of legal bag price, report prize, monitoring probability, and fine schedule. For example, with a change in report prize there may be substitution between civilian and government official monitoring. However, this is beyond the scope of the analysis in this article.

other authors have argued. Moreover, as we have shown, the price increase induces illegal dumping significantly at the same time. Considering the critical damage caused by improper dumping or burning, we might say that the marginal benefit of increasing prices for legal bags may well be outweighed by the marginal cost. In light of this conclusion, the overall increase in the price of legal bags just for the sake of recouping waste disposal costs as the Korean government has done recently must be reconsidered. In addition, because a higher incentive for recycling is implied to be more effective in curbing illegal dumping than increasing enforcement efforts, the government resources should be readjusted toward promoting recycling, and, furthermore, the government enforcement efforts should be differentiated across different areas. More enforcement resources should be allocated to sparsely populated rural areas than to densely populated metropolitan areas.

This study has many limitations. First, we have estimated the effect of legal bag price on the number of reports, but not on the volume of illegal dumping. To measure the quantity of illegal dumping, we need to understand how often the violators illegally dump their optimal amount. Second, we have not taken into consideration the illegal dumping detected by government officials. There may be a systematic relationship between the monitoring efforts of civilians and those of government officials. Lastly, the data on compensation for recycled goods needs to be more accurate for the individual regions. These issues are all left for future projects.

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