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Analyzing the success of the volume-based waste fee system in South Korea

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ABSTRACT

For more than a decade, South Korea has been ranked first among the OECD (Organization for Economic Cooperation and Development) members in their municipal solid waste (MSW) recycling rate. One of the major contributing factors for its outstanding MSW recycling performance is the volume-based waste fee (VWF) system implemented in 1995. Despite the perceived success of VWF, there has been few research conducted that has sought to demonstrate the success of the policy in an empirical manner. Research conducted currently on VWF in South Korea tends to have limitations in empirical approaches and identifying the intervention effect of VWF on recycling performance. This study attempts to empirically test whether the adoption of VWF positively affected recycling performance in Korea over time. The findings suggest that although there was a dramatic increase of the recycling rate with the introduction of VWF in 1995, Korea's MSW recycling performance settled back again and showed the constant pace after the intervention. No significant differences in recycling rate were found between before and after 1995 period. In conclusion, implications and suggestions for both research and practice are proposed.

1. Introduction

For more than a decade, South Korea has been ranked first among the OECD (Organization for Economic Cooperation and Development) members in their municipal solid waste (MSW) recycling rate. In the most recent data released, in 2012, the MSW recycling rate of South Korea was 59.1% while the average estimated recycling rate of the other members was 24% (MOE, 2013a, 2014a; OECD, 2014). One of the major contributing factors for its outstanding MSW recycling performance is the volume-based waste fee (VWF) system implemented in 1995 (MOE, 2003, 2011). Focusing on the household MSW recycling in South Korea, this study investigates the effect of the VWF program. First, this study briefly discusses past research in household MSW recycling to argue that policy adoption perspective regarding waste management policies needs attention. Second, volume-based waste fee system (VWF) in South Korea is summarized and related research is reviewed to assess whether the effect of VWF on recycling performance in Korea has been sufficiently investigated. Recycling performance, in this study, is represented by recycling rates. Third, for the empirical analysis, the effect of the adoption of VWF on recycling performance is assessed by using segmented linear regression. Lastly, this study concludes by discussing the effect of VWF on recycling performance and offering implications for future research.

1.1. Past research in household MSW recycling

This study focuses on MSW recycling, meaning separate collection of potential recyclables from MSW. In recent household MSW recycling literature, there are two major streams of research. First stream is the studies related to household MSW recycling behavior, which focused on topics such as unit (quantity)-based pricing (Dijkgraaf and Gradus, 2004; Gellynck et al., 2011; Miranda and Aldy, 1998), household's willingness-to-pay (WTP) which measures how much households would pay to use curbside service (Hazra et al., 2013; Saphores et al., 2012), the effects of curbside recycling (Best and Kneip, 2011; Domina and Koch, 2002) the socio-psychological determinants of rural household recycling behavior (Tang et al., 2011), and the influence of demographic factors on recycling behavior (see Park and Berry, 2013; Saphores and Nixon, 2014 for further reference). In these studies, the unit of analysis was usually individuals because the main purpose was to study how various factors influence household recycling behavior and to suggest ways to increase recycling by affecting individual-level behavior.

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Next stream, related to the interest of this study, is composed of the studies focused on recycling policy rather than recycling behavior. Examples of topics include, varying effects of different types of MSW recycling programs (e.g., curbside, pay-as-you-throw, recycled product market) on recycling performance (Park and Berry, 2013), social cost for setting ineffectively high recycling policy goals (Kinnaman et al., 2014), recycling system policy reforms (Mo et al., 2009), sustainable MSW policy development (Moh and Manaf, 2014), MSW policy and administration in developing countries (Troschinetz and Mihelcic, 2009), and source-separated MSW policy implementation issues (Tai et al., 2011). In these studies, the main interest was the effectiveness of policies and the process of implementing it; thus the unit of analysis was usually policies rather than individual households.

Following the second stream of research in household MSW recycling, this paper departs from an individual-level analysis and investigates the MSW recycling rate (performance) from the pre- and post-policy adoption perspective. South Korea as a country is the basic unit of analysis because all provinces and local governments were legally mandated to implement VWF starting January 1, 1995.

1.2. Volume-based waste fee system

Many Asian countries (e.g., Korea, Malaysia, Singapore) are now in the process of striving to simultaneously fulfill both economic and environmental goals and South Korea, in the area of waste management practices, is considered one of the countries implementing sustainable waste management practices (Agamuthu et al., 2009). In South Korea, public concern for environmental problems created by MSW has increased since the early 1990s, and this phenomena increased pressure on the Korean government to develop waste management policies such as a volume-based waste fee system (VWF) to reduce MSW waste and increase recycling (Seo et al., 2004). Consequently, the Ministry of Environment (MOE) conducted a pilot test of VWF in 1994 in a number of municipalities, and after the pilot program's success, VWF was implemented nationwide as of January 1, 1995 (MOE, 2011) (see Kim, 2002, for a comprehensive review).

The target groups for VWF are mainly households and small businesses (e.g., markets, shopping arcades) that produce less than 300 kg of waste per day. According to MOE (2011, p.16), the basic principles of VWF are as follows: (1) households (or small businesses) are required to purchase standardized plastic waste bags produced and sold by local governments, (2) wastes are to be put into the plastic bag and left for collection, (3) recyclables such as paper, plastic, and cans are collected from containers or bins placed near residences at no charge. VWF is still in effect nationwide in South Korea. The typical price of the waste bags in Seoul, which is the largest city in Korea, ranges from 0.05 U.S. dollars (52 KRW) for a 2 l bag to 1.8 U.S. dollars (1840 KRW) for a 100 l bag (SMG, 2013).

From the economic perspective, under the VWF system, it can be expected that because households are required to purchase waste bags to dispose of MSW, they will be motivated to recycle as much as possible rather than disposing of recyclables as waste to reduce the cost of purchasing waste bags. In fact, after the implementation of VWF, MOE (2011, p.19) reported that households and small businesses formed the consensus that "throwing out waste was like throwing out money..." and began to use products with less packaging and refill functions to reduce waste output.

VWF was regarded as highly successful in increasing recycling performance (Lee and Paik, 2011; MOE, 2011) and several past studies have sought to demonstrate the success of the policy in an empirical manner.

In 2011, MOE published a report that summarized the successes of VWF but only compared MSW generation and recycling mean values in the years 1994, 1998, and 2004 to claim that decrease in MSW generation and increased recycling are the results VWF adoption (MOE, 2011). Prior to the MOE report, several studies assessing VWF appeared in the Korean MSW literature. First, a study by Hong and Seonghoon (1999) conducted survey to more than 3000 Korean households and found that weight-based pricing system is more effective than VWF in inducing recycling but VWF was still a success because of reduced waste and increased recycling. Next, Oh, 2006 using Korean MSW data from 1990 to 2004 and descriptive statistics, argued that the positive effect of VWF on reducing waste is limited because such trend has been present since 1992 and the rate of reduction has decreased after the adoption of VWF. Following Oh's study (2006), Jeong and his colleagues (2007), using an interrupted time series analysis, compared the MSW generation and recycling amount of 15 provinces and metropolitan areas before and after the adoption of VWF. The panel data composed of MSW data of 15 regions was divided into two periods to form a control group (1992–1994) and a treatment group (1995–2004). The results revealed that the treatment group showed decreased MSW generation and increased recycling amount, supporting the positive effect of VWF. Although the presented studies assessed VWF in various aspects, their claim has a number of limitations that need to be addressed.

First, as shown in Fig. 1, where it shows the trend of Korea's MSW generation and recycling amounts from CY (calendar year) 1986 to 2012, the annual recycling rate in Korea had been exhibiting an upward trend before 1995; thus it is necessary to identify whether improved recycling performance is a result of an upward trend or of VWF. Scholars such as Oh (2006) and Jeong et al. (2007) have conducted either trend or time series analysis but missed to account for the policy intervention effect. Second, the annual MSW generation amount steeply declined from 1991 to 1995 and has been maintaining a steady trend since then (Fig. 2). The steep decline is the result of decreased generation of MSW materials such as food, paper, wood, coal briquette, and metal (MOE, 1996, p.5). The main contributors were food and coal briquette waste that decreased as a result of income increase which led to improved Korean household dietary life style and shift of popular heating system from coal briquette to gas and oil (Jeong et al., 2007). Accordingly, the effect of generated MSW on recycling performance has to be accounted for and this study does this by measuring performance by recycling rates rather than amount. VWF is a policy designed to minimize or prevent waste generation from household, and may not be directly related to improving recycling behavior. However, under VWF system, households are incentivized to recycle more to save plastic bag cost so that the recycled amount is inevitably affected. Thus, rather than following past research (e.g., Oh, 2006; Park, 2009) that assessed VWF performance by changes in generated MSW amount, this study uses recycling rate which measures the percentages of the recycled materials relative to the total MSW generation to capture the genuine pattern change as a result of VWF. Lastly, past research was limited in accounting for the effects of VWF over time. The MOE report (2011) selected only a few time periods (1994, 1995, 1998, 2004, 2007) for observation. A study by (Hong and Seonghoon, 1999) used cross-sectional data composed of responses from approximately 3000 Korean households. Oh (2006) used time-series data but only conducted descriptive analysis. Jeong et al. (2007) focused on comparing the control group (pre-VWF: 1992–1994) and treatment group (post-VWF: 1995–2004), but did not show the VWF performance in the first year (1995) of its implementation.

This study, resolving the limitations of past research discussed above, attempts to empirically test whether the adoption of VWF

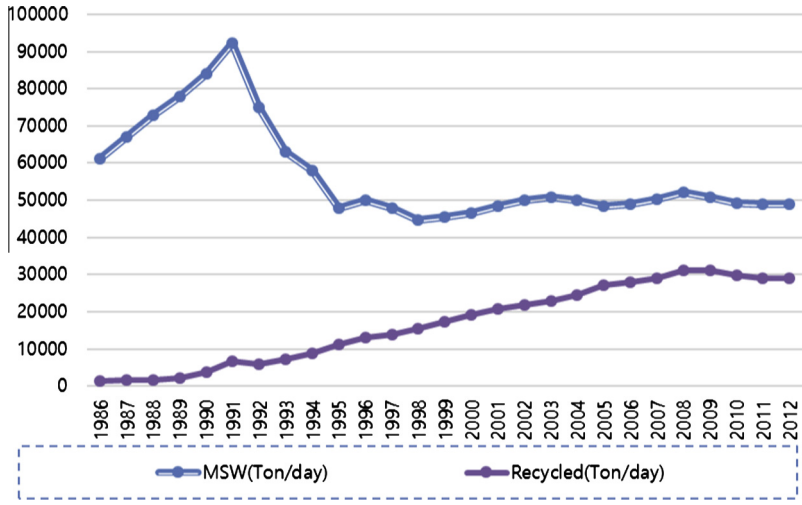

Fig. 1. MSW generated and recycled (1986–2012). *Source:* Ministry of Environment (MOE) (2014a).

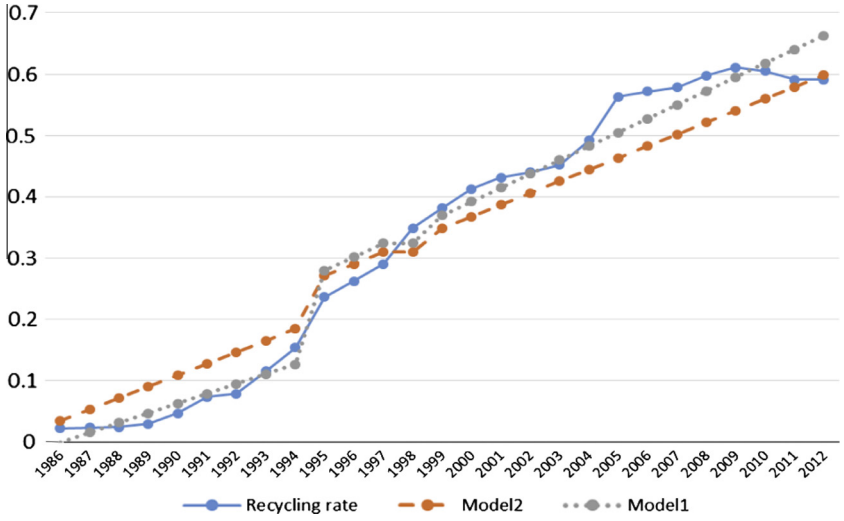

Fig. 2. Recycling rate and the fitted results (1986–2012).

positively affected recycling performance in Korea over time. Longitudinal data composed of pre-VWF and post-VWF annual MSW data is used. The major research interests are to compare the recycling performance of the pre-VWF and the post-VWF period and to identify the policy intervention effect of VWF. Recycling performance is represented by the MSW recycling rate.

2. Methods and analysis

2.1. Data

South Korea annual MSW collection, treatment, and recycling data were collected from the Ministry of the Environment (MOE) in South Korea. MOE has been releasing an annual national municipal solid waste generation and treatment report since CY 1986 and the most recent data available was for CY 2012. The current study extracted data regarding MSW generation and recycled amounts from CY 1986 to CY 2012 (MOE, 2014a). MSW or residential waste, according to the Korea Waste Control Act, is defined as "Wastes except business wastes as substances that have become useless in human life and activities" (MOE, 2013b). Recycled MSW include materials such as paper, can, bottle, metal, plastic, textile, and other recyclable items depending on regional circumstances and is collected free of charge by door-to-door, collection bin, and designated area (e.g., collection center) services (MOE, 2003).

For the purpose of this study which tests the effect of VWF adoption, the dependent variable is the annual MSW recycling rate reflecting the recycling performance calculated by dividing annual MSW generation by the recycled amount.

2.2. Descriptive analysis

The results of the descriptive analysis are provided in Table 1. In the pre-VWF period, from 1986 to 1994, the average MSW generated was 72375.9 tons per day. After the implementation of VWF, from 1995 to 2012, the average MSW generated was 48834.6 tons per day, decreasing by approximately 32.5%. For the recycled amount, there was an increase of over 400% from 4409.9 to 23056.1 tons per day. Accordingly, the daily average recycling rate also showed a steep increase from 6.3% to 47%. In sum, from the pre-VWF and post-VWF periods, the generation of MSW decreased while the recycled MSW and recycling rates increased. Thus, it may seem that VWF contributed to the increase in recycled amount and rates. However, comparison of the mean values is insufficient for

Table 1
Descriptive statistics of variables.

		MSW (generated)	MSW (recycled)	Recycling rate (%)
Pre-VWF (1986–1994)	Mean	72375.9	4409.9	6.3
	SD	11276.5	2865.5	4.7
Post VWF (1995–2012)	Mean	48834.6	23056.1	47.0
	SD	1894.5	6665.2	12.7
Total	Mean	56681.7	16840.7	33.4
	SD	13014.0	10573.9	22.2

Note: MSW, recycled MSW (ton per day).

testing whether VWF is the major factor for the shift in recycling performance. The current study introduces segmented linear regression to empirically test the effects of VWF on recycling performance.

2.3. Segmented linear regression

The effect of the adoption of VWF on recycling performance is assessed by using segmented linear regression. In many cases, the auto-regressive integrated moving average (ARIMA) model, one type of interrupted time-series methods, is used to assess the impact of policy adoption because the variables affected by the policy will cause a break in the time-series trend and will depict how policy adoption or innovation may lead to non-incremental changes (Yang, 2007). Accordingly, ARIMA is appropriate for use in this study because the adoption of VWF creates an intervention in the time-series, and the main interest of this study is to test the non-incremental increase in recycling performance as a result of VWF. However, the minimum sample size (observation) for the ARIMA model is 50 (Liu, 2007) and the sample size in the current study is 27 (CY 1986–2012). In addition, although using a time-series is useful for detecting changes in levels or trends of the study variable, to assess whether intervention alone affected the dependent variable, to adjust for potential serial correlation, and to control for other effects, segmented linear is preferable (Lagarde, 2012; Wagner et al., 2002). For the reasons above, the current study uses segmented (piecewise) linear regression for the empirical analysis. For the purpose of simplifying the comparison of trends before and after adoption, the current study follows Lagarde's (2012) suggestion of an alternative specification of a segmented linear regression, which is

$$Y_t = \gamma_0 + \gamma_1 * \text{preslope} + \gamma_2 * \text{intervention} + \gamma_3 * \text{postslope} + \varepsilon_t \quad (1)$$

In this model (Eq. (1)), Y_t is the MSW recycling rate at time t; time is a continuous variable in the format of a calendar year and indicates the period from the first year of observation (1986) to the last year of observation (2012). Preslope indicates time from the first period of observation to the year of the adoption of VWF (1995) and Postslope indicates time from the adoption of VWF to the last observation period. For other variables, γ_0 estimates the baseline value of the recycling rate at the beginning of the observation period; γ_1 estimates the level change of the mean of the annual recycling rate before the intervention (VWF); γ_2 estimates the level change in the annual recycling rate instantaneously after the intervention; γ_3 estimates the change in the mean of the annual recycling rate after the adoption of VWF. To measure the change in trends, γ_1 can be subtracted from γ_3 ($\gamma_3 - \gamma_1$). To conduct the analysis in Eq. (1), the necessary dependent variable (recycling rate) and independent variables (intervention, preslope, postslope) were created and presented in Table 2.

Table 2
Dataset and variables used in the segmented regression analysis.

Year	Generated MSW	Recycled MSW	Recycling rate (%)	Time	Intervention	Preslope	Postslope
1986	61072	1335	2.2	1	0	1	0
1987	67031	1562	2.3	2	0	2	0
1988	72897	1759	2.4	3	0	3	0
1989	78021	2275	2.9	4	0	4	0
1990	83962	3900	4.6	5	0	5	0
1991	92246	6786	7.4	6	0	6	0
1992	75096	5912	7.9	7	0	7	0
1993	62940	7233	11.5	8	0	8	0
1994	58118	8927	15.4	9	0	9	0
1995	47774	11306	23.7	10	1	9	1
1996	49925	13084	26.2	11	1	9	2
1997	47895	13907	29.0	12	1	9	3
1998	44583	15566	34.9	13	1	9	3
1999	45614	17394	38.1	14	1	9	5
2000	46438	19167	41.3	15	1	9	6
2001	48499	20922	43.1	16	1	9	7
2002	49902	21949	44.0	17	1	9	8
2003	50736	22938	45.2	18	1	9	9
2004	50007	24588	49.2	19	1	9	10
2005	48398	27243	56.3	20	1	9	11
2006	48844	27922	57.2	21	1	9	12
2007	50346	29116	57.8	22	1	9	13
2008	52072	31138	59.8	23	1	9	14
2009	50906	31126	61.1	24	1	9	15
2010	49159	29753	60.5	25	1	9	16
2011	48934	28939	59.1	26	1	9	17
2012	48990	28951	59.1	27	1	9	18

Note: generated MSW, recycled MSW (ton per day).

3. Results and discussion

The current study, using *Stata* 12, conducted a segmented linear regression analyses. The first regression (Model 1) shows the results without adjusting for first-order auto-correlation. In the first regression, Durbin and Watson (1950, 1951) test statistics of 0.713 indicated the presence of auto-correlation. Accordingly, in the second regression (Model 2), a Prais and Winsten (1954) estimator was used to correct for data auto-correlation. Table 3 provides the result of the two segmented linear regressions.

Model 1 indicates that all independent variables were statistically significant but because of the presence of auto-correlation, the current study focuses on Model 2 in which auto-correlation is corrected. The results from Model 2, correcting for auto-correlation, shows that all independent variables were statistically significant. The coefficient for Pre-slope and Post-slope were both statistically significant and indicated that, on average, the recycling rate for the two periods increased by 1.9% per year, meaning that the recycling performance was improving before the adoption of VWF and continued to increase in a similar rate after the intervention. As for the intervention variable, immediately after the adoption of VWF in 1995, the recycling rate increased by 6.8% implying that the intervention had a stronger effect on recycling performance compared to the average increase of the recycling rate by 1.9% both before and after the intervention.

Fig. 2 provides the graphical presentation of the raw data of annual recycling rates and the fitted results from Model 1 and Model 2. Consistent with the empirical results of the segmented regression analysis, from CY 1994 to CY 1995, a steep increase in recycling rates is observed. The increase occurred from CY 1994 to CY 1995 because the VWF was implemented on January 1, 1995 so that the recycling rate of CY 1995 actually incorporated the effect of the program from the first day to the last day of CY 1995. In sum, the recycling performance was already experiencing an upward trend before the adoption of VWF which had a strong and immediate impact on the dramatic increase of the recycling rate in CY 1995 and, after the intervention, recycling performance continued to improve. The findings suggest that although there was an instant and unprecedented increase of the recycling rate with the introduction of VWF in 1995, Korea's MSW recycling performance settled back to the constant pace after the intervention. No significant differences in recycling rate were found between before and after 1995 period. Thus, the current recycling rate may not be attributed to the introduction of VWF.

The findings offer implications for possible future research. The VWF system is based on enforced waste disposal by plastic bags sold by local governments; thus, there are no other legitimate options for households in disposing of MSW other than VWF. Accordingly, households are incentivized to recycle more to reduce the cost of purchasing designated waste bags. Nevertheless, results imply that while households may promptly respond to the newly introduced economic incentives, they may not function as a significant stimulus after a certain time period. In this sense, the alternative explanation may be attributed to altruistic, egoistic, and normative incentives that scholars such as Ewing (2001) claim to have a meaningful impact on recycling performance. Some studies such as (Tam and Tam, 2006) research regarding recycling in Hong Kong revealed that environmental attitude of citizens can be more crucial than strict waste management regulations for the sustainable environment. Furthermore, Lee and Paik (2011, p.1165) in their survey analysis to citizens of Seoul, discovered that citizens who are relatively older and wealthier participate in recycling activities more because they are "more exposed and sensitive to social concerns and economic issues". The authors went on to claim that more public education programs and advertisement for waste management policies will be necessary for increasing recycling participation. Consequently, future research may consider taking into account the other possible factors responsible for the high MSW recycling performance of South Korea rather than merely assuming that VWF played the vital role in improving recycling.

Table 3
Results of the segmented linear regression.

	Coefficient	Standard error	*t*-statistic	*P*-value
a. Model 1 (no correction for auto-correlation)				
Intercept γ_0	−0.017	0.023	−0.73	0.474
Preslope γ_1	0.016**	0.004	3.89	0.001
Intervention γ_2	0.130***	0.025	5.24	0.000
Postslope γ_3	0.023***	0.001	15.84	0.000
b. Model 2 (correcting for auto-correlation)				
Intercept γ_0	0.016	0.059	0.27	0.793
Preslope γ_1	0.019*	0.007	2.76	0.011
Intervention γ_2	0.068**	0.023	2.95	0.007
Postslope γ_3	0.019***	0.004	4.95	0.000

* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

4. Conclusion

The contribution of the volume-based waste fee (VWF) system of South Korea in increasing MSW recycling performance has been empirically tested to investigate whether nationwide enforced implementation of unit-pricing systems such as VWF may encourage recycling. Despite the highest increase in the South Korea annual recycling rate occurred immediately after the adoption of VWF, the findings of this study suggest that the introduction of VWF system has a positive impact but the effect of boosted recycling rate was temporary rather than constant.

The results of this study indicate the necessity for using other policy measures to further improve MSW recycling performance in South Korea. In recent years, MOE is promoting the policy orientation of 4R (reduce, reuse, recycle and recover) to strengthen recycling performance in South Korea (MOE, 2015b). For instance, the MOE introduced the extended producer responsibility (EPR) system in 2000, a policy that imposes recycling obligations to producers. EPR was first applied to packaging materials, lubricants, tires, fluorescent light bulbs, batteries, and electronic products. The EPR system was a success, resulting in 46% increase in quantity of the designated materials between the period of 2001 and 2008 (KEPB, 2010). In 2014, the MOE further expanded the scope of the materials to include various electronic devices and attempts to further apply the system to scrap cars in 2015 (MOE, 2014b). Other policy examples include disposable and over-packaged product control policy, free collection of household appliances waste, recyclable resources market for residential and business use (web-based) (MOE 2011, 2015a; KEPB, 2013).

While the proposed policies may positively affect MSW recycling performance, the MSW recycling rate of Korea has not shown major shift since the implementation of VWF. Therefore, using the methods proposed in this study, for the purpose of improving recycling performance by selecting the most effective program, multiple types of recycling programs can be compared against each other for their performance after adoption. However, since this study investigates only the South Korean case to evaluate the effect of VWF, further testing in other countries is required to increase generalizability to a broader group of countries.

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