Solid Waste Disposal and Its Relationship with Economic Development in Rural China

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Abstract

Applied a recently collected household data in 6 provinces in rural China, the purpose of this paper is to analyze solid waste disposal and its relationship with economic development in rural China. Domestic solid waste disposal per capita is about 1.07 kg/daily, or about 390 kg/year, and varies across regions and components. Major findings support the existence of the environmental Kuznets curves for domestic solid waste disposal with the estimated turning point of 17, 446 RMB per capita income.

Key words: Solid waste disposal, Per capita income, rural China

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Introduction

The relationship between economic growth and environmental pollution, both in theoretical and empirical perspectives, has been found to being characterized with the environmental Kuznets curve (EKC) (Andreoni & Levinson, 2001; Dinda, 2004; Egli & Steger, 2007; Grossman & Krueger, 1995; Kahn, 1998; Lieb, 2004; Stern, 2004). That says, pollution is rising with income at low income levels, but falling at higher income levels. The associated income threshold is labeled turning point. The theory has captured considerable attention from policymakers, environmentalists and economists due to the fact that the EKC hypothesis implies that pollution burden to a society will gradually diminish and disappear as the economy continues to grow, unless the emission level at the turning point goes beyond the irreversible line (De Bruyn & Heintz, 1998; Dinda, 2004; Song, et al., 2008). In developing countries, the EKC theory can herein provide a guideline for policymakers to prioritize when economic development against environmental protection.

Despite the existence of the EKC for some environmental issue, the empirical results on solid waste generation are, however, mixed. For example, some researchers found that EKC for solid waste does not exist and the waste generations grow with the income increase (Ma, et al., 2007). According to research on 25 European countries, Andersen et al.(2007) found that the amount of waste generated are expected to grow, albeit at a lower rate than the economic growth. Differently, most of research proved that the EKC for solid waste is existent (De Bruyn & Heintz, 1998; Dinda, 2004; Ichinose et al., 2011; Mazzanti & Zoboli, 2009; Song, et al., 2008;

Yang et al., 2003). Additionally, the turning point in studies which find the EKC has showed different turning point of solid waste generation across countries and studies. For example, the turning point for Japan's municipal solid waste is about 4.25 million Japanese Yen, 37.2 thousand dollar (Ichinose et al., 2011). The municipal solid waste in Italy reaches the highest point at the net income per capita of 24000 -27000 Euro (Mazzanti et al., 2008).

In terms of solid waste in China, many studies have pointed its severity and rapidly increasing speed (Wang, et al., 2011; Shen, J, 2006; Tang & Zuo, 2008; Song, et al., 2008; Yang, et al., 2003), but few have analyzed the waste-income relationship, particularly in rural areas. In 2007, solid waste from household daily living activities passed agricultural production pollution to become the top pollution hazard of rural environment in China (Tang & Zuo, 2008). The increasingly worsening problem has recently attracted considerable attention of local authorities and central policymakers. In 2007, the Chinese central government has launched a ray of policy measures to tackle these problems. Then, in the rural areas in China, are there EKC relationship between domestic solid waste discharge and per capita net income of farmers? If yes, what is the turning point? The purpose of this paper is to answer these questions.

The rest of this paper consists of the following several sections. Section 1 provides data description. Section 2 presents solid waste disposal and the descriptive analysis of the relationship between solid waste disposal and social-economic factor. Section 3 provides the econometric model and empirical results. Section 4 provides a summary of our results and discusses the directions of future research.

I. Data

The empirical analysis is based on a survey of 1118 rural households from 6 provinces in China, conducted by the authors in November through December 2010. The survey sample was stratified by a combination of geographic and social-economic factors. Provinces were selected largely by geographic location, including Jilin in the Northeast, Hebei in the North China, Anhui and Zhejiang in the East China, and Sichuan and Yunnan in the Southwest. In each province, we first ranked and evenly grouped all counties into high, middle and low categories according to per capita net income of rural residents in 2009, and then one county from each category was randomly selected. Within the county, we geographically located all townships into two categories, one near the county's capital and one in a remote area, and then randomly selected one from each category. Then, a complete random sampling method was used to select 3 villages in each township and ten rural households in each village for the survey. The total surveyed household number is 1118. Figure 1 shows the geographic distribution of the sampled counties.

The survey was carried out by well-trained enumerators with face-to-face interviews. The coverage of the survey instrument includes demographic and socio-economic characteristics of the household, the detailed information on the total solid waste disposal in a certain period, 8 sub-categories of wastes, and the methods that the households use to store and dispose solid waste. Information on several governmental projects related to rural waste production and disposal, and market issues on recyclable solid wastes such as glasses, metal and aluminum, papers and plastics were also collected. Household agricultural production related information and off-farm activities were also surveyed. In addition, a survey designed specifically for village leaders was conducted in each sampled village. The village leader survey collected information that can be used to double check the accuracy of observations from household and provided

additional knowledge that are relatively difficult to observe or measure at household level. Household solid waste disposal is defined to include almost all solid materials that are sourced from the household's daily living activities and disposed, including kitchen waste, plastics, papers, textile, leather, metal, ashes and so on. This definition is largely consistent Yang, R & Li's study (2006), but excludes any hazardous chemical and expired drugs.

II. Solid Waste Disposal and Its Relationship with Economic Development

Situation of solid waste disposal in rural China

Surveyed data shows that domestic solid waste disposal is about 1.07 kg per capita per day in rural China (Table 1). It is very close to the survey data of Xie, et al. (2009), and even closer to Japan's municipal solid waste disposal (1.08kg), but a bit higher than our estimate based on the results of village-level survey data which is 0.9 kg (Huang, et al., 2012; Ichinose, et al., 2011). Solid waste disposal varies significantly across regions. Zhejiang, the most developed province, comes first at 1.19 kg per capita, followed by Jilin, Anhui, 1.17 kg and 1.12 kg respectively. However, solid waste disposal of Hebei, Sichuan and Yunnan is below the average level. Yunnan province gets the lowest value at 0.87 kg per capita.

From the aspect of component, Kitchen waste is the most important waste of rural domestic solid waste, whose proportion is 27.6%, also close to the Xie's data of 24.5% (Xie, et al., 2009). Metal waste is the second important part of rural domestic solid waste, accounting for 14.5% of total waste. The proportions of glass, paper textile, and plastic are 8.7%, 6.3%, 5.8% and 5.4% respectively.

There is also regional difference between different types of domestic solid waste. Zhejiang Province gets the highest kitchen waste proportion of total emission, reaching 36.9%; meanwhile,

Yunnan and Hebei get the lowest percentage, 23.8% and 15.3% respectively. The reason why some provinces have higher kitchen waste proportion may be different diet habits. Residents in Zhejiang province may consume more vegetables, fruits and aquatic foods that can generate more kitchen waste. The proportion of paper waste in all provinces is low, within 10%. The highest proportion comes Yunnan Province, accounting for 8.5%, while the lowest is Hebei, only 3.9%. Although the proportion of plastic waste is also within 10%, but there is significant differences between the various regions. Zhejiang gets the highest proportion of plastic waste, accounting for 8.0%, four times that of Hebei who comes lowest. There is much difference of metal waste proportion of total waste between provinces, varies from 9.7% to 20.7%. Compared with the above wastes, differences of glass waste between regions are minimum, from 7.1% to 11.6%. Throughout all regions, the proportion of waste textiles are below 8%, and the minimum is only 2.3% in Hebei, less than one third of Zhejiang.

Descriptive analysis of the relationship between solid waste disposal and economic development

Solid waste disposal is rising with income at lower income levels, but falling at higher income levels. The relationship between domestic solid wastes and income per capita may show an obvious inverted U-shaped curve. Through the analysis on the survey data, we find the inverted U-shaped curve of relationship between domestic solid waste disposal and net income per capita. According to annual net income per capita of farmers, we classified solid waste disposal data into seven groups, at a group interval of RMB 2,000. The result shows that, along with the growth of per capita annual net income, the waste disposal per capita first rose and then fell in the course (Table 2). We make the following assumption: the relationship between the solid waste disposal per capita of rural domestic solid wastes and income per capita shows an

obvious inverted U-shaped curve, and the turning point comes between 0.87~1.07 10^4 RMB net income per capita.

III. Econometric Model Specification and Estimation Results

Econometric model specification

The above descriptive statistical analysis has made certain judgment on the relationship between solid waste disposal and social-economic factors; however, this analysis takes into only the impact of single factor account, and does not analyze the results of the common functions of these factors from the perspective of integration of multiple factors. That is to say, in single-factor analysis, we fail to control the impact of other factors, and thus can not separate the impact of each factor on domestic solid waste disposal. Therefore, in order to grasp the relationship between domestic solid waste disposal and social-economic factor more deeply and accurately, we have established the following econometric model based on the household-level data of six provinces in China, which is set as follows:

$$\ln(y_i) = \alpha_1 + \beta_1 I_i + \beta_2 I_i^{\ 2} + \beta_3 Z_i + \varepsilon_i \qquad (1)$$

As the dependent variable, y_i denotes the ith household daily solid waste disposal (kg/capita/day). In the empirical analysis, we use the natural logarithm of y_i to reduce the impact of heteroscedasticity on coefficient estimates. On the right side of the model, there are series of independent variables. Most important, I_i is the household net income (10^4 rmb/capita), and $I_i^{\ 2}$ is the quadratic item of net income; Z_i is a vector of control variables. There is one policy variable about if the surveyed household has ever been trained on the solid waste disposal or not (1=yes; 0=no). Theoretically, households who use coal as living energy dispose more

waste than those who do not. So, we added one dummy variable in the model, which is valued 1 if the households uses coal as living energy, and 0 if not. Presence of seniors who are 60 years old or up in the household is included in the independent variables (1=yes; 0=no). Average education of the household (year) and population density of the village (1000 persons/km^2) are also considered as explanatory variables in the model. ε_i is error term that is assumed to be normally distributed.

The ordinary least square (OLS) method is used for parameter estimation. We use two income variables to measure the potential relationship between household solid waste disposal and income, one is the family net income, and the other is its quadratic item. By doing so, we can empirically test whether the environmental Kuznets curve exists in Chinese rural household solid waste disposal. If the estimated parameter for income is significantly positive and significantly negative for the quadratic income, we say the relationship between solid waste disposal and income follows the EKC. Otherwise, it does not.

Estimation results

The estimated result of the relationship between solid waste disposal and social-economic is reported in Table 3. It is noted that the model specification provides the best goodness-of-fit. The estimated R-square is 0.11, suggesting that the models is fitted well given the fact of cross-sectional data and limited sample size. In addition, most control variables are significant and their signs are consistent with theoretical expectation. For example, whether the household participated in the training of solid waste disposal is found to be significantly negative in the model, suggesting an overall effectiveness of the policy in reducing waste disposal. The presence of senior members is found to be significantly and negatively related to solid waste disposal. One reason for the significance may be that presence of seniors can relax the household time

constraint in handling daily life activities that are believed to be the main source of solid wastes. Population density is positive and significant. The effect of population density in literature is mixed.

The estimated results indicate that the relationship between net income and the aggregated disposal level for solid waste is characterized with the Kuznets inversed-U shape, suggesting that per capita waste disposal is rising with income at lower income levels, but falling at higher income levels. This can be seen from the significantly positive estimator for variable income and the significantly negative parameter for its quadratic item. We can empirically calculate the income level at the turning point through formula $I^* = -\hat{\beta}_1 / 2\hat{\beta}_2$, where $\hat{\beta}_1$ and $\hat{\beta}_2$ denote the estimated parameter for net income and its quadratic item respectively. The calculation shows that domestic solid waste disposal reaches peak when yearly per capita net income rises to 17,446RMB. It is apparent that household disposals of the selected recyclable wastes are still on the upward sloping part of the curve in rural China, and it may take decades to cross from the upward to the downward, as the average net income per capita was only 5154 RMB throughout rural China in 2009 (National Bureau of Statistics, 2010).

Conclusion and Policy Implication

Based on a survey data consisting of 1118 representative rural households, this paper empirically analyzes solid waste disposal situation and its relationship with socio-economic factors in rural China, with particular focus on testing the existence of the well-known environmental Kuznets curve. Several major findings and their implications are remarked as follows.

First, domestic solid waste disposal per capita is about 1.07 kg/day, or about 390 kg/year. This level is close to municipal waste emission level (440 kg/year), and is also close to or has reached that of many developed countries (Japan, 390 kg, and the European Union, 256-660 kg) (Geng, 2010; Ichinose, D. et al. 2011; Vehlow, J. et al. 2007). With backward rural waste disposal facilities and management level, it means that the threat of solid waste disposal against the environment in rural China is much more serious than that of other developed countries. Therefore, the government should strengthen rural solid waste management without delay.

Second, domestic solid waste in rural China varies not just throughout regions, but also between different components. Zhejiang, the most developed province reaches the highest solid waste disposal at 1.19 kg per capita, and Yunnan province gets the lowest value at 0.87 kg per capita. Kitchen waste whose proportion of solid waste is 27.6% is the most important component of rural solid waste. Zhejiang also comes first in the kitchen proportion of total solid waste at the level of 36.9%, which is more than twice of that of Hebei. Consequently, the government should introduce different policies in different regions.

Third, the environmental Kuznets curve is empirically found for solid waste disposal. The turning point of estimated per capita net income is about 17446 RMB a year, which is far ahead of the current level, suggesting that the solid waste disposals in China's rural is still on the upward sloping part of the curve. While the inversed-U shape curves indicate that the waste disposal will gradually diminish as the economy continues to grow, policymakers and society have to realize that the waste disposal discussed in this study is flow pollution rather than stock pollution. The stock pollution resulted from their disposals should be paid enough attentions. Using any policy and marketing instruments which could significantly increase the recycling rate of these wastes are necessary.

Finally, household's presence of senior members in the family is found to be significantly related to solid waste disposal. As many rural households in China have tradition to have multiple generations living together, the finding may suggest that the waste disposal level at the turning point in rural China could be significantly lower than its counterpart in developed countries where young family often lives separately with their parents.

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Table l Per capita solid waste disposal and its composition in Rural China

	Zhejiang	Jilin	Anhui	Hebei	Sichuan	Yunan	Total
Solid waste disposal per capita per day (kg)	1.18	1.17	1.12	1.04	1.03	0.87	1.07
Proportion of the following wastes							
Kitchen waste	36.9	28.3	29.7	15.3	31.8	23.8	27.6
Paper	7.2	6.5	6.5	3.9	5.3	8.5	6.3
Plastics	8	6.7	6.4	1.9	3	6.5	5.4
Metal	20.7	15.2	21.4	6.7	9.7	13.7	14.5
Glass	9.8	7.5	11.6	7.1	7.1	9.3	8.7
Textile	7.2	7	7.1	2.3	4.9	6.2	5.8
Others	16.2	34.6	23.3	64.1	42.1	37.3	36.4
Total	100	100	100	100	100	100	100

data source: authors' survey

Table 2 Relationship between social economic characteristics and domestic solid waste disposal

	net income per capita (10^4 RMB)						
	below 0.27	0.27-0.47	0.47-0.67	0.67-0.87	0.87-1.07	1.07-1.27	above 1.27
Solid waste disposal (kg/capita/daily)	0.97	0.95	1.13	1.21	1.27	1.07	1.17

data source: authors' survey

Table 3 Econometric results of effects of social-economic conditions on domestic solid waste disposal

	Per capita solid waste disposal (kg/day)
Social-economic conditions	
Net income per capita ($10^{4/}$capita)	0.321
	(2.78)***
Square of net income per capita	-0.092
	(1.93)*
Control variables	
Trained on the solid waste disposal or not? (1=yes; 0=no)	-0.304
	(2.13)**
Presence of senior in household (1=yes; 0=no)	-0.167
	(3.66)***
Use coal as living energy or not? (1=yes; 0=no)	0.38
	(5.56)***
Population density (1000 persons/km^2)	0.638
	(1.98)**
Average education of the household (year)	-0.012
	(1.19)
County dummy	Not reported
Constant	-0.186
	-1.58
R^2	0.11
Observation	1, 118

Notes: t-value in parentheses; * p<.1, ** p<.05, *** p<.01

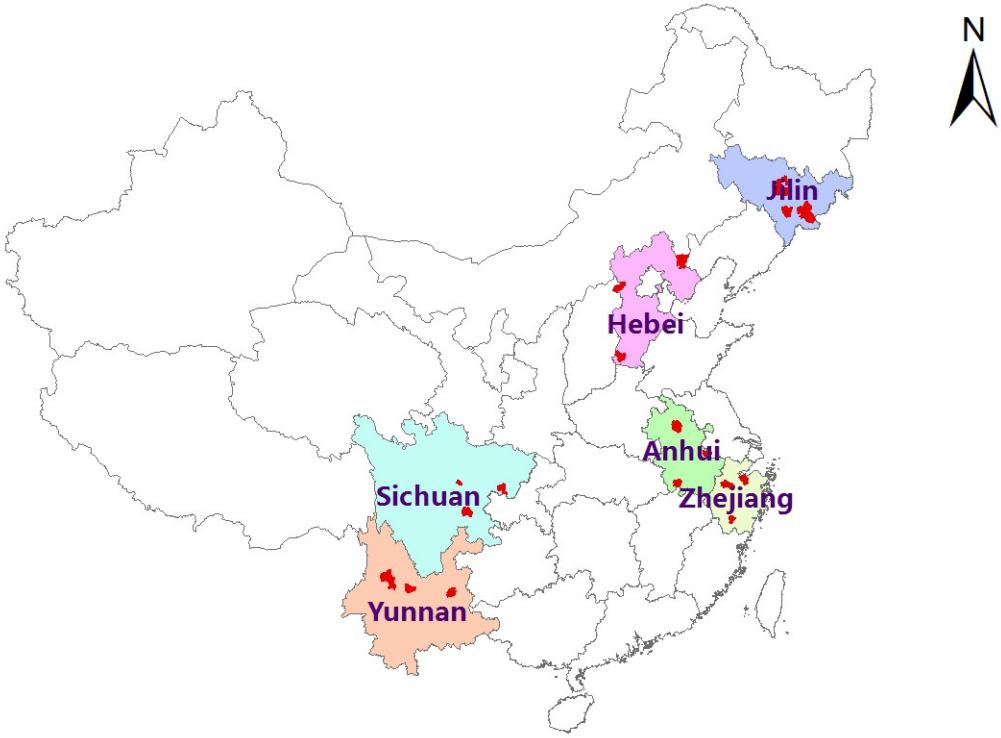

Figure 1. Distribution of Sampled Counties