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Is there a garbage Kuznets curve? Evidence from OECD countries

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Abstract

This note examines the environmental Kuznets curve hypothesis for municipal solid waste in 33 OECD countries between 1995 and 2012. Wang's (2013) flexible polynomial model is utilized. The results show that there exists no inverted U-shaped Environmental Kuznets Curve relationship between per capita income and Municipal Solid Waste in OECD countries. Instead, they reveal a downward sloping relationship.

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1. Introduction

One of the main economic approaches to thinking about environmental quality is the Environmental Kuznets Curve (EKC) hypothesis. Briefly speaking, the EKC depicts the relationship between income per capita and any pollutant that reflects environmental quality. In this paper, we consider the case of Municipal Solid Waste (MSW), which is considered to be a local pollutant. MSW consists of different waste sources that include households and businesses. However, it excludes waste coming from sewage, construction and destruction activities (OECD 2018). The world's generation of municipal solid waste is about 1.3 billion metric tons per year, 50 percent of which is produced in Organisation for Economic Co-operation and Development (OECD) countries. By 2025, this amount is expected to reach approximately 2.2 billion tons per year (Hoornweg and Bhada-Tata 2012).

The focus on the EKC is reflected in a large literature within economics. In brief, the EKC hypothesis states that, at early stages of economic development, the pollution rate increases. However, at later stages, the pollution rate starts decreasing since economic activities will shift from polluting industries into service-based activities (Yandle *et al.* 2002). The first model on the EKC was established by Grossman and Krueger (1991) who study the effect of increased trade on environmental quality. Their results prove the existence of an EKC relationship for sulfur dioxide and smoke. Shafik and Bandopadhyay (1992) find similar results. The exploration of the existence of the Environmental Kuznets Curve continued over the last three decades, and intense research was conducted to verify the veracity of the hypothesis for different types of pollutants. Time-series, cross-sectional and panel data set estimations were implemented, while various studies relied on local, regional and global pollutants with different econometric techniques. The extensive research on the Environmental Kuznets Curve mainly relies on airborne pollutants such as carbon dioxide, sulfur dioxide and other greenhouse gases (Ekins 1997; Stern 1998; Stagl 1999; Dinda 2004; Stern 2004; Stern 2017). Few studies, however, use solid waste as the main pollutant in their EKC analyses due to the shortage of data. These studies provide mixed evidence. Lora *et al.* (2013) test the relationship between Gross Domestic Product (GDP) per capita and MSW in Colombia in 707 municipalities, from 2008 to 2011. The authors find results that are compatible with the EKC hypothesis. In addition to GDP per capita, factors such as population density and the elevation from the sea level are found to be significant in solid waste generation. Khajuria *et al.* (2012) use data from India, from 1947 until 2004, and find that the EKC relationship exists between economic growth and MSW. Mazzanti *et al.* (2009) use data from different Italian provinces, from 2000 until 2004. They find that the introduction of some explanatory variables, such as population, preserves the Environmental Kuznets Curve's regular shape. Yet, it loses some of its significance. Wang *et al.* (1998) examine the Environmental Kuznets Curve for hazardous waste in the US. Using a Tobit model for 3141 US counties in 1991, the authors prove that the EKC relationship holds for risky waste. Yet, some other studies fail to confirm the EKC hypothesis for solid waste. Seppälä *et al.* (2001) study the EKC for Germany, Japan, USA, Netherlands and Finland, from 1975 until 1994. The authors find that there is no EKC relation between direct material flows and GDP. In another study on 25 European countries, Mazzanti and Zoboli (2009) show that there is no Waste Kuznets Curve (WKC) trend. A study on 36 countries that include Mozambique and Australia shows a positive inelastic relationship between income per capita and municipal solid waste (Beede and Bloom 1995). In their study, Beede and Bloom (1995) show that population has a stronger effect on MSW than income per capita. De Groot *et al.* (2004) shows that the relationship in China does

not follow the usual EKC shape, since solid waste increases at low and high levels of per capita income whereas it decreases at intermediate levels of per capita income. Yanrong *et al.* (2011) study the relationship between industrial solid waste and GDP per capita for the Henan province in China between 1993 and 2008. They find that income per capita and solid waste did not follow the usual EKC trend, since solid waste generation was decreasing with the increase in per capita GDP in the early stages of development. Only few studies are conducted on OECD countries. Yet, most of these studies do so without explicitly testing for the EKC hypothesis. An early study on 13 OECD countries between 1975 and 1990 shows that municipal solid waste increases monotonically with income (Cole *et al.* 1997). Another study on 30 OECD countries from 1980 until 2000 by Johnstone and Labbone (2004) shows that there exists a positive inelastic relationship between consumption expenditure and municipal solid waste. Karousakis (2009) uses time series and cross-sectional data from 1980 until 2000 to find the determinants of municipal solid waste for 30 OECD countries. The author concludes that GDP and urbanization have a direct positive effect on municipal solid waste generation.

In sum, the EKC hypothesis for MSW has mixed evidence. While some studies from developing countries find support for an inverted U-shaped EKC, some others do not. Older studies conducted on OECD countries fail to depict an inverted U-shaped EKC. However, they do so by simply studying the determinants of MSW generation and without explicitly testing the hypothesis. For this reason, this paper aims to fill a gap in the literature by examining whether the Environmental Kuznets Curve exists between GDP per capita and municipal solid waste for 33 OECD countries, and by explicitly testing this hypothesis using more recent data. The main aim of this paper is thus to provide new empirical evidence on whether economic development reduces MSW generation in OECD countries.

The paper unfolds as follows. Section 2 describes the data and the econometric model, and analyses the results. Section 3 concludes.

2. Model and results

2.1 Data

We use annual data covering the period from 1995 to 2012. We identify the following variables of interest: per capita Municipal Solid Waste (MSW) denoted by w, real GDP per capita denoted by y, population density denoted by p, urban population denoted by u, and energy intensity denoted by e. Data for per capita MSW is taken from the OECD municipal waste database (OECD 2018), whereas the data for all other variables is taken from the World Bank's World Development Indicators (WDI 2018). The data spans 18 years and 33 out of 36 OECD countries, excluding Australia, Canada and New Zealand due to the lack of data on one or more of the used variables. In our sample, MSW is measured in kilograms per capita per year. Real GDP has the year 2010 as the base year and is measured in US dollars. Population density is measured in people per square Kilometer of land area. The choice of population density as a control variable is based on prior studies that show a positive relationship between MSW and population density (Johnstone and Labbone 2004). We also control for urban population, which is the proportion of urban population in total population. Finally, we control for energy intensity, which is measured in Mega Joules per GDP, PPP (constant 2011 International $). Table I provides the summary statistics of the five variables. The mean of per capita MSW is about 486 kilograms per capita per year. GDP per capita

averages around USD 33,486 (constant 2010). As for population density, the average for the 33 OECD countries in our sample is around 139 people per square kilometer, compared to the world population density average between 1995 and 2012 which is about 49 people per kilometer square. Moreover, the average urbanization rate is around 75 percent, and energy intensity has an average value of 5.49 Mega Joules per dollar of GDP, noting that a higher value of the latter variable indicates a more energy intensive or more polluting economy.

Table I: Summary statistics

	MSW per capita	GDP per capita	Population Density	Urban Population	Energy Intensity
Mean	486.33	33485.76	139.73	74.67	5.49
Standard Deviation	129.44	21737.40	127.27	11.25	2.37
Minimum	245.60	5139.30	2.67	50.62	2.46
Maximum	829.43	111968.30	515.88	97.74	19.22
Number of Observations	581	594	584	594	594

Notes: Municipal Solid Waste (MSW) per capita is measured in Kilograms per year; Gross Domestic Product (GDP) per capita is measured in constant 2010 USD; Population Density is people per square Kilometer of land area; Urban Population is the proportion of urban population in total population; the Energy Intensity Level of Primary Energy is measured in Megajoules per 2011 USD PPP GDP.
Sources: MSW data is taken from the OECD (2018), whereas the data for all other variables is taken from the World Development Indicators (WDI 2018).

Before running regressions, we test for stationarity to avoid having spurious results. The Augmented Dickey Fuller (ADF) panel unit root test is applied since the data at hand is a panel. The null hypothesis in the ADF panel unit root test states that variables are not stationary. The results show that the p-value for the five variables is close to zero and that all the variables are stationary at level, at the one percent level of statistical significance. To control for country fixed effect, we use the panel fixed effect model in all our regressions.

2.2 Model and results

There is wide evidence in the EKC literature that utilizing the quadratic parametric model may lead to spurious results (Aslanidis 2009). In order to overcome this problem, our empirical model is based on Wang's (2013) method, which allows for flexibility in polynomial specifications without implementing a fully non-parametric approach. Our approach avoids spurious regressions resulting from the implementation of the pure quadratic form. Therefore, it yields more credible results as it explores a large array of polynomial relationships. In his model, Wang (2013) studies carbon and sulfur EKCs for 19 OECD countries by utilizing various non-linear transformations to check for the presence of an EKC. In line with Wang (2013), we express the EKC relationship between the pollutant and income using the following specification:

$$w_{it} = \alpha_0 + \alpha_1 y_{it} + \alpha_2 y_{it}^{\gamma} + \beta_1 p_{it} + \beta_2 u_{it} + \beta_3 e_{it} + \varepsilon_{it} \quad (1)$$

In equation (1), w_{it} represents the natural logarithm of MSW, y_{it} is the natural logarithm of GDP per capita, p_{it} is the natural logarithm of population density, u_{it} is the natural logarithm of the

urbanization percentage, and e_{it} is the natural logarithm of energy intensity; where i and t represent country and time respectively. γ represents a random polynomial power between zero and two, where one is excluded. The difference between any two consecutive values of γ is 0.1, following Wang (2013). The turning point of the EKC is when $y = \left(-\alpha_1/\gamma\alpha_2\right)^{1/\gamma-1}$, which exists under the following conditions:

a) when $\gamma \in (0,1)$: $\alpha_1 < 0$, $\alpha_2 > 0$ and $|\alpha_1| < |\alpha_2|$

b) when $\gamma \in (1,2)$: $\alpha_1 > 0$, $\alpha_2 < 0$ and $|\alpha_1| > |\alpha_2|$

This model allows us to detect the characteristics of the non-linear equations by choosing different values of γ.

We run 19 regressions using the fixed effect model. The results for the pure EKC relationship, excluding the controls, are presented in Table II below, while the 19 other estimates for the full specification given by equation (1) are presented in Table III. All estimations clearly indicate that there is no evidence in support for the inverted U-shaped EKC relationship between MSW and per capita GDP in the 33 OECD countries. Instead, plotting the fitted regressions in Tables II and II, within sample range, reveals the existence of a downward sloping relationship between the two variables.

Table II: Fixed effect estimates (without control variables)

$\gamma \in (0,1)$	α_0	α_1	α_2	Conditions		R^2
				$\alpha_1 < 0$, $\alpha_2 > 0$	$\|\alpha_1\| < \|\alpha_2\|$	
0.1	176.50***	2.13***	-152.27***	No	Yes	0.489
0.2	90.48***	2.37***	-68.23***	No	Yes	0.488
0.3	61.80***	2.69***	-41.41***	No	Yes	0.488
0.4	47.46***	3.11***	-28.85***	No	Yes	0.487
0.5	38.85***	3.70***	-22.06***	No	Yes	0.487
0.6	33.12***	4.58***	-18.30***	No	Yes	0.487
0.7	29.02***	6.05***	-16.65***	No	Yes	0.486
0.8	25.94***	8.99***	-17.40***	No	Yes	0.486
0.9	23.55***	17.81***	-24.62***	No	Yes	0.486
$\gamma \in (1,2)$	α_0	α_1	α_2	Conditions		R^2
				$\alpha_1 > 0$, $\alpha_2 < 0$	$\|\alpha_1\| > \|\alpha_2\|$	
1.1	20.07***	-17.47***	12.77***	No	Yes	0.485
1.2	18.77***	-8.65***	4.66***	No	Yes	0.484
1.3	17.66***	-5.71***	2.28***	No	Yes	0.484
1.4	16.72***	-4.24***	1.26***	No	Yes	0.484
1.5	15.90***	-3.39***	0.75***	No	Yes	0.483
1.6	15.18***	-2.77***	0.47***	No	Yes	0.483
1.7	14.54***	-2.35***	0.30***	No	Yes	0.482
1.8	13.98***	-2.04***	0.20***	No	Yes	0.482

1.9	13.47***	-1.79***	0.13***	No	Yes	0.482
2.0	13.02***	-1.60***	0.09***	No	Yes	0.481

Notes: * significance at the 10% level, ** significance at the 5% level, *** significance at the 1% level

Table III: Fixed effect estimates (with control variables)

$\gamma \in (0,1)$	α_0	α_1	α_2	Conditions		R^2
				$\alpha_1 < 0,\ \alpha_2 > 0$	$\lvert\alpha_1\rvert < \lvert\alpha_2\rvert$	
0.1	253.51***	3.09***	-218.82***	No	Yes	0.225
0.2	130.07***	3.45***	-98.18***	No	Yes	0.223
0.3	88.91***	3.90***	-59.66***	No	Yes	0.222
0.4	68.32***	4.52***	-41.62***	No	Yes	0.221
0.5	55.97***	5.37***	-31.86***	No	Yes	0.220
0.6	47.74***	6.65***	-26.46***	No	Yes	0.219
0.7	41.86***	8.79***	-24.11***	No	Yes	0.218
0.8	37.44***	13.06***	-25.22***	No	Yes	0.217
0.9	34.01***	25.88***	-35.74***	No	Yes	0.216

$\gamma \in (1,2)$	α_0	α_1	α_2	Conditions		R^2
				$\alpha_1 > 0,\ \alpha_2 < 0$	$\lvert\alpha_1\rvert > \lvert\alpha_2\rvert$	
1.1	29.02***	-25.39***	18.58***	No	Yes	0.214
1.2	27.15***	-12.57***	6.79***	No	Yes	0.213
1.3	25.56***	-8.30***	3.33***	No	Yes	0.212
1.4	24.20***	-6.16***	1.85***	No	Yes	0.211
1.5	23.03***	-4.88***	1.10***	No	Yes	0.211
1.6	21.99***	-4.03***	0.68***	No	Yes	0.210
1.7	21.08***	-3.41***	0.439***	No	Yes	0.209
1.8	20.27***	-2.96***	0.29***	No	Yes	0.208
1.9	19.55***	-2.60***	0.19***	No	Yes	0.207
2.0	18.90***	-2.31***	0.13***	No	Yes	0.207

Notes: * significance at the 10% level, ** significance at the 5% level, *** significance at the 1% level

3. Conclusion

Our results reveal a decreasing relationship between GDP per capita and MSW per capita, which suggests the absence of an EKC relationship and indicates that higher economic standards may lead to less MSW generation. This finding could be explained by the presence of enhanced environmental regulations in more developed countries. It could also be due to the major role of waste-management industries, in the selected OECD countries, in MSW long-term abatement. However, we should be cautious about extrapolating these results to future trends in developing countries as further studies are required.

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