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Role of plastics in decoupling municipal solid waste and economic growth in the U.S.

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ABSTRACT

Analysis of data from the US Environmental Protection Agency (EPA) on municipal solid waste (MSW) generation rates correlated to personal consumption expenditure (PCE) uncovers a decoupling event occurring between 1997 and 2000. A comparison of waste generation rates for each material category found in MSW reveals that plastics increased by nearly 84 times from 1960 to 2013 while total MSW increased only 2.9 times. The increase in plastic waste generation coincides with a decrease in glass and metal found in the MSW stream. In addition, calculating the material substitution rates for glass, metal and other materials with plastics in packaging and containers demonstrates an overall reduction by weight and by volume in MSW generation of approximately 58% over the same time period. A quantitative calculation of a scenario where plastics were not used in packaging and containers to replace glass, metal, and other materials demonstrates that MSW generation rate rises equally with PCE. Therefore, this study has determined that the increase of plastic use is a contributing factor to the decoupling of MSW generation from PCE.

1. Introduction

There has been a general trend regarding average MSW generation increasing with nominal Gross Domestic Product (GDP) of a region or country. The correlation has given rise to hypotheses that affluent societies consume more materials and resources and therefore, have a commensurately higher increase in MSW generation rates than less affluent societies. A more detailed inspection of the data indicates that actual MSW generation falls within a range of 2–6 lb per person per day (lb/person/day) over a range of GDP from $5000 to $110,000, respectively (Hoornweg and Bhada, 2012). This suggests that, regardless of region or income, there is a fairly consistent rate of material use that eventually is discarded as waste, applying a stress to the environment. Generally, more affluent regions or nations can counteract the environmental impact of development and waste generation by attempting to decouple MSW generation with GDP, productivity, standard of living increase or personal consumption expenditure (PCE).

Many developed and affluent nations have established material recovery programs (e.g. recycling) to attempt to decouple their continued increase in standard of living with an associated increase in MSW generation (Hopewell et al., 2009). The adaption of the Economic Kuznet Curve (EKC) to waste has resulted in a generally accepted Waste Kuznet Curve (WKC) (Fischer-Kowalski and Amann, 2001; Seppälä et al., 2001). The WKC has developed in the same way as the EKC describing a trajectory where initial increases of income per capita or GDP are directly correlated to increases in pollution or environmental degradation. Eventually, a transition begins where continued rises in per capita income result in a decrease in environmental degradation. Initially, there is a relative decoupling where waste generation rates rise more slowly than per capita income followed by an absolute decoupling where waste generation rates actually decline with a rise in per capita income.

A number of studies have been done on waste generation decoupling, mostly in the European Union (EU). In Europe, it is has been observed that decoupling potentially exists due to policy implementation, regulations, and tax penalties. Although the evidence is uneven, there does appear to be segments that experience a relative decoupling in recent years. However, a couple of studies (Cole et al., 1997; Seppälä et al., 2001) found no evidence of a transition to the inverted U-curve segment associated with a WKC.

A report by Mazzanti and Zoboli concludes that while there is no trend for waste generation (i.e. no observed WKC), policy directives in the early stages of implementation may work. They observe some early positive signals in favor of a relative de-linking for waste generation and associated landfill diversion (Mazzanti et al., 2006; Mazzanti and Zoboli, 2008). In another report by Mazzanti et al., they

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conclude that there is no relative WKC observed however there is evidence of absolute decoupling, specifically regarding wastes that are landfilled (Mazzanti et al., 2012; Mazzanti and Nicolli, 2011). Regarding landfill diversion, the decoupling observed is driven by factors related to structural (population density) and economic (opportunity costs) parameters.

A more specific analysis done by Montevecchi et al. investigates the effectiveness of environmental policy instruments to decouple waste generation using a case study in Slovakia. They find an absolute decoupling occurs primarily via policy and tax drivers but also recognizes that raising awareness and education campaigns appear to help (Montevecchi, 2016). Zorpas et al. determined that regardless of the wealth of a country or region, motivation is needed for the citizens to alter their behavior regarding waste impacts on the environment. The primary motivations were identified as tax penalties or financial incentives (i.e. income to the consumer) (Zorpas et al., 2014). Other cases studies find similar outcomes (Sjöström and Östblom, 2010).

Triquero et al. found that there is a combination of government and market based incentives that could improve regulatory framework to minimize waste. Implementing a proactive and preventive approach to enhance responsibility while involving all stakeholder groups could decouple waste generation from economic growth (Triguero et al., 2016). Finally, Poulios and Latinopoulos attempted to determine if a WKC relationship exists using time-series data over a 15 year-period from the Thessaloniki region of Greece. They uncovered evidence that enacted legislation related to waste management has not proven successful however, high gate fees and landfill bans had an immediate impact on waste diversion (Katsifarakis et al., n.d).

Based on the cited studies, it is evident that factors such as policy and awareness can contribute to reduce MSW generation and landfill diversion but the US is driven by consumer demand and the cost of associated desired goods. Therefore, reduction in materials consumption in the US is not likely. Importantly, due to the lack of a national policy/directive or tax in the U.S. on MSW generation, the only implication for the decoupling between MSW generation and economic growth must be due to material stream changes. The biggest change in the composition of the MSW material stream over time has been in the plastics content, therefore, it is possible that the decoupling is correlated to plastics entering the consumer materials stream. This study has determined that the increase in plastic products across nearly all consumer sectors aligns with the possibility to yield lower cost consumer items and results in a decoupling of the waste generation to GDP and PCE. This is the first possible direct correlation where the substitution of one type of material (e.g. plastic for glass, metal, and other materials) enables the MSW decoupling that is pursued by policy or central actions. In this study, multiple pieces of evidence are presented that suggest a relative decoupling between MSW generation and economic growth, which in this case was defined by PCE. The MSW generation also serves as a surrogate for MSW disposal because there is assumed to be no accumulation of MSW at the individual or local level. In other words, all MSW generated is disposed (i.e. reused, recycled, combusted for energy recovery, and landfilled), according to the average rates for each part of the waste management hierarchy. An assessment of changes in the MSW composition in the US is also presented along with hypotheses as to why this MSW decoupling is occurring regardless of any specific policy or law implemented to reduce MSW in the US.

2. Materials and methods

The analyses conducted were based on public and internal data compiled by the American Chemistry Council (ACC) Plastics division, the US EPA, EREF, and the Earth Engineering Center at City College of New York (EEC|CCNY). This section provides a brief explanation of the primary calculations that were performed to identify correlations between the MSW material streams and MSW generation trends that are discussed in the Results and Discussion section of this study.

2.1. Volume calculations

Calculations were performed to determine the volume of MSW generated in the US over time. The volume of MSW was calculated using different methods and was crosschecked to compare the accuracy of final calculated reported values. One such method was based on the densities of material streams in MSW and the other utilized the volume-to-weight conversion factor for MSW provided by the EPA. For the first method, average densities reported in the literature of materials in MSW were used to convert the material stream tonnages to volumes (the material stream tonnages were calculated based on the percent material breakdown of MSW reported by the EPA for each given year). The total volumetric generation of MSW was calculated as the summation of the individual volumes of the material streams. The material densities that were used are shown in Table 1 and they are the average of reported low, medium, and compacted densities for each material.

The second method used a volume-to-weight conversion factor reported by the EPA in the April 2016 report, "Volume-to-Weight Conversion Factors". The conversion factor used was for "Uncompacted, Mixed MSW – Residential, Institutional, Commercial", which is reported to range from 250 to 300 lb per cubic yard (lb/yd^3); therefore, the average of the lower and upper bound, 275 lb/yd^3, was used in the calculations of this study.

An additional method that was employed to check the primary volume calculations used an average density of 0.18 ton m^{-3} obtained from data from the US EPA Landfill Methane Outreach Program (LMOP). The density estimation was determined combining US EPA data of actual tons landfilled (i.e. waste in place) amounting to 7,418,578,787 tons with the amalgamated average MSW density. The average MSW density was developed using a weighted average of each category based on a typical composition of MSW from years ranging from 1960 to 2013. A second calculation was performed to obtain the density of MSW by applying the formula, $0.305 \times \rho_{paper} + 0.061 \times \rho_{glass} + 0.107 \times \rho_{metal} + 0.066 \times \rho_{plastics} + 0.0142 \times \rho_{food} + 0.181 \times \rho_{yard} + 0.138 \times \rho_{other}$ to the waste stream densities in Table 1 and resulted in a value of 0.17 tons m^{-3}. These are in close agreement therefore, an average value of 0.175 tons m^{-3}. Please refer to Supplemental Information for further detail on the methodologies that were used to confirm volume generation of MSW in the US.

Table 1
Densities for each category of MSW[a]. *Source:* Waste Materials – Density Data, Environmental Protection Authority Victoria.

Category	kg m^{-3}	Tons m^{-3}
ρ paper	152	0.167
ρ glass	331	0.364
ρ plastics	101	0.111
ρ metal	130	0.142
ρ food	629	0.692
ρ yard	254	0.280
ρ other	93	0.103

[a] The densities reported in the table are different from physical material densities because they represent material densities in the waste stream. Therefore, factors such as moisture content and waste material compaction will contribute to variation from the physical material density.