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Should we blame the rich for clogging our landfills?

Itai Trilnick[1] and Alon Tal[2]

Abstract

Conventional wisdom often holds that relatively high consumption levels among the affluent contributes to the generation of high volumes of municipal solid waste (MSW). Comparing data from different cities in Israel suggests otherwise. Regression analysis reveals that aggregate per capita waste outputs of cities are only vaguely correlated with their socio-economic indicators. In fact, the apparent 'hedonic' waste of the richest cities, compared with the average ones, accounts for only about 2% of the total waste production. Israel's main economic area, the Tel Aviv district, produces a quarter more MSW per capita than other districts, suggesting a need for special attention by policy makers. A surprisingly strong predicator of MSW per capita is water consumption by municipalities, dedicated for public gardening. The trimmings of the municipal landscape constituting an unobserved fraction of total MSW data, are estimated to be responsible for 15% of Israel's MSW, making it an additional target area for consideration and intervention.

Keywords

Municipal solid waste, wealth, gardening waste, landfill, Israel

Introduction

This research sought to identify correlations between different socio-economic traits and waste generation. Assertions are frequently made about the sociological context of waste, reflecting popular and typically unfounded beliefs. For example, it is often said that rich families produce far more waste than poor ones, and therefore are mostly responsible for landfill capacity shortages and other solid waste problems in Israel. Other public beliefs attribute waste generation traits (high or low) to minorities. Nevertheless, as far as we could find, such assertions have never been seriously examined, especially not in Israel.

At an international level, the association between wealth and solid waste output is ostensibly obvious. With increasing economic activity and consumption of consumer products, it is typically assumed that waste outputs will also increase. Indeed, researchers have found statistical correlations between wealth and quantities of solid waste in different countries of Europe, where elasticity of waste generation relative to total consumption per capita reached up to 0.83 in Western European countries (Mazzanti and Zoboli, 2008). The notion of wealth-related waste generation brings Organisation for Economic Co-operation (OECD) statisticians, such as Blumenthal (2011), to present the trend lines of waste weight divided by gross domestic product when analyzing waste trends, so as not to compare different 'going rates' of waste across time and geographical locations with different wealth.

However, such international or inter-temporal comparisons have little relevance for policy makers in national governments. Given the growing awareness of the environmental effects of consumerism, it is useful to learn about the connection between waste generation and socio-economic traits, such as wealth, within countries. If rich people produce much more waste per capita than the poor, it might be effective to set user fees on a pay-as you-throw basis, connecting higher waste production with higher ability to pay. If waste output is weakly connected to wealth, a more universal fee or tax structure might be more appropriate. Generally speaking, identifying the socio-economic contexts of waste generation might help target sectors with higher waste output and tailor more efficient service and fee policies aimed at specific sectors based on waste generation rates.

Some attempts have been made to utilize a survey approach to find correlations between waste generation and socio-economic characteristics. In Abu Dhabi, 40 households were sampled repeatedly over a few months to construct a dataset of average waste outputs. A connection between wealth and waste generation per capita was found, with high income households generating 35% more waste on a per capita basis than the mean generation of all other households (Abu Qdais et al., 1997). Similar results were shown for the city of Moratuwa, in Sri Lanka (Bandara et al., 2007).

[1]Department of Agricultural and Resource Economics, University of California, Berkeley, USA
[2]The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sde Boqer, Israel

Corresponding author:
Itai Trilnick, Department of Agricultural and Resource Economics, University of California, Berkeley, CA, USA.
Email: itai.trilnick@berkeley.edu

Nevertheless, this survey methodology may present problems for policy makers: the sample might not be representative of the general population; members of surveyed households may produce substantial amounts of waste outside of their home as they purchase goods or services, creating unmeasured amounts of waste to be dealt with by the city; the data acquired might be influenced by seasonality, especially when food remains are a main component of waste; and survey results are not indicative in terms of the 'general picture' for policy makers, who need to address city-wide and national aggregated waste data.

Methodology

In Israel, extensive socio-economic data on local authorities are compiled and published by the Central Bureau of Statistics (CBS), including waste generation per capita per day in each jurisdiction. We used a recent database with 2011 figures (CBS, 2013). Regression analysis was performed, correlating different socio-economic characteristics of cities and towns to their waste generation data. These per capita per day figures are calculated by the CBS from the yearly total waste outputs of each city. They include not only household waste, but also the solid waste produced by businesses and gardening waste produced by local residences and public parks. Data about non-household sources of municipal solid waste (MSW) are important, as this waste is also the product of economic activities correlated with wealth. Moreover, yearly mean data help us dodge a possible challenge of seasonality in waste generation, as most surveys are either one waste sample per household or short timed repeated samples. This is important given the significant consumption of large summer fruits (e.g. watermelons), which affect waste volumes and weights (on a wet weight basis).

From the CBS files, our variable of interest is defined as 'Residential, Commercial, and Gardening Solid waste' given in kg per capita per day for each local authority. However, an internal breakdown according to type of waste is unavailable. Our analysis includes CBS data for cities and smaller urban towns (defined as 'local councils'), while excluding the more dispersed agricultural communities located in 'regional councils'. We chose not to include them in our study because their idiosyncratic social and geographical traits produce a solid waste profile fundamentally different than Israel's urban populations, thus biasing results. Therefore, this analysis accounts for about 7 million persons, out of an approximate total population of 7.7 million in Israel in 2011. The equation derived was:

$$MSW_i = \alpha + \beta \cdot X_i + \varepsilon_i \quad (1)$$

where *MSWi* is the MSW per capita per day (kg) at local authority *i, Xi* is a vector of characteristics of that authority, and ε_i the random error. Ordinary least squares (OLS) estimation was applied to calculate linear estimators of the effects of socio-economic characteristics on waste output. Weights proportional to each authority's population were required for this regression, as the different MSW per capita values are averages of individual waste outputs in authorities with very different populations. Without the population weights, the effect of an observation from a small town would count exactly as the effect of an observation from a large city, affecting many more people. As the actual effect is the figure we are looking for, not weighting the observations would serve to bias the estimates (Angrist and Pischke, 2009).

Socio-economic data of each local authority were also taken from the CBS publication, with the vector defined as:

$$X_i = \{pop_i, jews_i, TLV_i, cluster_i, tax\_area_i, gard\_water_i\} \quad (2)$$

where *pop* is population size (in thousands). Although this analysis focuses on per capita waste generation, there might be economies of scale in waste production, for reasons such as economies of scale in business activities. Therefore, we included a control for city population.

Jews is a CBS variable defined as percent of 'Jews, non-Arab Christians, and people who are not classified by religion by the Ministry of Interior' in a population. This variable was chosen as cultural traits may affect waste production. In most cases, Arabs (Christian and Muslim) and Jews comprise almost 100% of Israel's population, with other groups (i.e. non-Arab Muslims) constituting only a small fraction.

TLV is a dummy variable indicating if local authority *i* belongs to the district (Hebrew 'Mahoz') of Tel Aviv, one out of seven districts in Israel. The city of Tel Aviv itself, with about 404,000 residents, is the economic capital of Israel and the country's main employment hub. An estimated 600,000 commuters arrive in Tel Aviv on a daily basis (TLV, 2013). A high commute rate to the city involves additional waste production to that of Tel Aviv's residents, both directly by the business activity in which commuters take part, and by the services rendered to these commuters (i.e. dining). This hypothesis can be confirmed by estimating equation (3):

$$MSW_i = \alpha + \beta \cdot TLV_i + \varepsilon_i \quad (3)$$

The estimates for β, with and without population weights (the latter to rule out the case of Tel Aviv size biasing its district's estimates), are significant, ranging from 0.45 kg to 0.65 kg per capita per day. The Tel Aviv district does generate more waste per resident than the rest of the country. It is also likely that the metro area of Tel Aviv, comprising nine additional cities and two towns, is affected by spillover effects from the unique economic traits of Tel Aviv itself.

Cluster is a ranking of authorities by the CBS. All authorities in Israel are divided into 10 different socio-economic clusters, using an aggregate score of many variables that mainly reflect the level of income and education of residents (CBS, 2009). These clusters are not equal in size and, accordingly, are not divided into precise 10% percentiles. Nevertheless, they are good proxies for socio-economic status, and are used extensively in research and regulation. Therefore, socio-economic differences, influencing waste outputs, might be found using this variable. Mathematically, the use of discrete clustered data as the independent variable (rather than using a continuous variable) will not bias the estimates, but might decrease their efficiency.

Table 1. Descriptive statistics of variables (see text for definition of acronyms).

Variable	Obs.	Units	Mean	SD	Min.	Max.
Municipal solid waste	152	kg/capita/day	1.67	0.87	0.60	7.90
Pop		Thousands	39.67	82.57	1.20	804.40
Jews		%	66.37	46.21	0.00	100.00
TLV		1/0	0.08	0.27	0.00	1.00
Cluster		1-10	4.84	2.27	1.00	10.00
Tax_area		m^2/capita	2.83	2.57	0.00	16.55
Gard_water		m^3/capita/year	4.43	4.17	0.00	22.10

Tax_area is a variable indicating the area of business activity in authority *i*. It is calculated here by dividing the total area (in thousands of square meters) of commerce, hotels and banks for which municipal taxes are paid by the population (also in thousands), resulting in commercial area per capita in square meters. We chose this variable to approximate the effect of business activity on the difference in waste outputs. Areas defined as industrial were not included, as industrial waste is not included in the solid waste figures. However, it should be noted that industrial areas do generate, in addition to different sorts of industrial waste, some quantities of waste similar to MSW, produced in offices and other areas of factories. Some of this MSW-like waste might be collected and processed as regular MSW by municipalities, alongside residential and commercial MSW, yet no data specifying these quantities are available. Therefore, the assumption is that the ratio of MSW-like industrial waste in the MSW data is negligible .

Gard_water is the municipal water consumption for public gardening, in cubic meters per capita per year. This variable was chosen as bulky gardening waste is an unmeasured, but significant, component in the waste data of the CBS. While total MSW data are available, the CBS publication does not present the breakdown of each city's MSW to different waste streams. To our knowledge, no data comparing gardening waste of different authorities are presently available. However, water consumption for public gardening water is measured and included in the official figures, and might explain, at least part of, the differences in waste production resulting from gardening. Of course, given the Mediterranean climate where there is practically no rain for 7 months of the year, we assume that irrigation is positively correlated with waste outputs, and that the mean effect of one cubic meter of water (in terms of green waste generated) is the same in all authorities.

Table 1 presents the statistics about the variables of choice. Out of 201 local authorities in the database, 152 had no missing data on any of the variables used. The statistics presented are of these authorities only, whose data was used for the regression analysis.

The OLS estimation technique was used to derive the coefficients, describing the effect of each independent variable on MSW per capita per day. The latter is an aggregate variable, a type of variable calculated for each city and town as the mean for its population. The variance in population might create bias in the standard errors, which could, in turn, change the significance of the coefficients (Angrist and Pischke, 2009). Therefore, the standard errors were normalized using White's 'sandwich' matrix (White, 1980).

Table 2. Coefficients from estimation of equation (1). Standard errors in parentheses.

	MSW
Pop	0.00
	(0.00)
Jews	0.00
	(0.00)
TLV	0.26*
	(0.14)
Cluster	0.06**
	(0.03)
Tax_area	0.07*
	(0.03)
Gard_water	0.06**
	(0.03)
_const	1.01**
	(0.12)
Observations	152
R^2	0.48

* $P < 0.1$, **$P < 0.05$.

It is worthwhile emphasizing that no mechanism, by which MSW might change the independent variables chosen, is readily apparent. If statistical correlation is found between MSW and any of the variables of choice, the plausible causal effect (suggested in the independent variables description above) is likely to be unidirectional.

Results

The results are presented in Table 2. Population size and ethnicity were not found to be significant factors explaining the per capita generation of MSW. It seems that when other variables are held fixed, economies of scale do not apply in waste generation. Popular beliefs that there are differences in waste generation between Jews and Arabs also appear to be unfounded.

Each square meter of floor space defined as 'commercial' for municipal tax purposes (including retail store, offices and other non-industrial businesses) is responsible for 0.07 kg of daily waste production per resident. While the effects of commercial

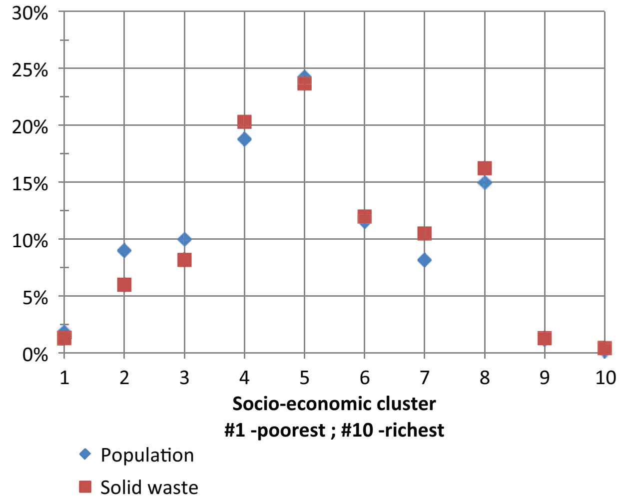

Figure 1. Shares of population and municipal solid waste of each socio-economic cluster.

activity are expected, this result is somewhat surprising. In a previous study, using 2009 data, no correlation was found between the *tax_area* variable and MSW. A suggested explanation of the lack of correlation at the time was the dominance of low waste-generating businesses (Trilnick, 2011). Of course, it is unlikely that the nature of a major city's business areas has changed in 2 years. The correlation found in the 2011 data, therefore, is probably the result of more thorough data gathering by the CBS, as solid waste has become a focus of attention of the Ministry of Environmental Protection in the last few years.

At the same time, residents of the Tel Aviv district appear to generate 0.26 kg of waste per day *more* than other residents in Israel. There is no reason to suspect that people in Tel Aviv area would generate such significant extra waste on their own, independent of their socio-economic status (which is held fixed by the cluster variable), or business area (controlled by the *tax_area* variable). Therefore, this surplus waste per-capita, beyond socio-economic characteristics, is best explained by the waste generated by services rendered to commuters and tourists.

Each socio-economic cluster adds about 0.06 kg of waste per capita per day, which extrapolates to a difference of 0.54 kg per capita per day between the poorest and richest. Annually, this difference amounts to 197.1 kg. However, as mentioned before, clusters are not even in the population. With only about 130,000 residents in the poorest towns (cluster #1), and about one tenth of that in the richest towns (cluster #10), most of Israel's population resides in average-sized middle class town and cities.

Figure 1 shows the share in the total population and total waste production of each socio-economic cluster. The data in Figure 1 were calculated using all observations, attributing the cluster average waste generation to the towns which were missing this datum. While the rich are, indeed, responsible for a larger share of total waste than their share in the population the difference may not be meaningful.

While the socio-economic cluster seems to have little influence on waste generation, water use for public gardening unexpectedly accounts for substantial differences between cities: each m^3 (per capita per year) of water consumed by the municipality for the purpose of public gardening seems to increase the daily MSW per capita by 0.06 kg. With an average per capita water consumption of 4.43 m^3, this influence amounts to an average of 96 kg per capita per year—about 15% of the average waste output per capita. While public gardening might be perceived as a luxury of sorts, thus correlated with wealth, the analysis controlled for wealth in the socio-economic score, which means that the effect of irrigation is independent of this scale. Indeed, many affluent communities have relatively modest public gardening, while other cities, with relatively modest socio-economic standing, have considerable public gardening. Accordingly, it would seem that the level of parks in an Israeli city may be a better predictor of solid waste generation than the income of its residents.

The constant term, which shows the baseline unexplained solid waste generation, was of 1.01 kg per capita per day. This constitutes a baseline waste per capita generation level for the poorest non-Jews, living outside of Tel Aviv district, with no commercial areas in their town and little, if any, municipal water consumption for public gardening. (Given Israel's arid climate, this implies virtually no public gardening.) Given that we included many socio-economic variables, this constant is likely to present an approximation of the average minimal amount of waste created by an average person in Israel. This is a substantial proportion out of the total mean waste output—about 61% of the mean waste output.

Discussion

To some extent, the results of this analysis come as a surprise. Popular beliefs about the effects of wealth, ethnicity and city size on solid waste outputs were found to be partially or completely false. Regarding the central question of this research: *the effect of wealth on solid waste*, we found that this effect is minimal. To emphasize this point, we calculated the total 'hedonic' waste generation by adding the partial effect of each socio-economic cluster on total waste generation. Calculating:

$$hedonic\_waste = \sum_{j=2}^{10}\sum_{i} 0.06*(j-1)*pop_{ji}*1000 *365 = 6.42*10^{8}\,Kg \qquad (4)$$

where j is the cluster and i are local authorities within each cluster, we are able to identify the yearly sum of waste added by the partial effect of the cluster variable (above the poorest cluster #1), or the total yearly extra waste generated as the result of differences between socio-economic clusters. The total solid waste output of Israel's cities and towns is about 1 million tons yearly. The result of the 'hedonic waste' calculation in equation (4) is surprisingly low, contributing only 15% of the total waste. This does not include the 'hedonic' waste of regional councils, which was not included in the estimation. However, regional councils only account for 9% of Israel's population, and their contribution to the total sum of solid waste generated is probably small.

However, it should be noted that this 'hedonic waste' estimate includes the 'hedonic' waste of many, rather poor, authorities from low socio-economic clusters. In fact, 'hedonic' waste of the richest clusters 8–10, the wealthiest 16% of the population, is $1.84 * 10^8 Kg$ —only 4% of the total waste. When calculating the 'hedonic' waste of clusters 8–10 as the extra waste they generate above cluster 5, the mean cluster, it adds up only to $8.01 * 10^7 Kg$ —2% of the total waste amounts.

The source of this result cannot be a negligible difference between socio-economic clusters, as Israel was recently ranked fifth in wealth inequality among the 34 countries of the OECD (OECD, 2013). The notion of wealthy, consumerist elites clogging landfills with the by-products of their excess income appears to be inconsistent with observed actual waste generation patterns in Israel. If consumerism is, indeed, a cause of excess waste, its effect seems to spread rather evenly throughout the entire population of Israel.

Acquitting the rich of the charge of excess waste generation has additional implications for environmental policy. For instance, it could provide an argument against 'pay-as-you-throw' waste reduction programs, which have been discussed in Israel in the past, but never implemented. Today, charges for waste collection and treatment are included in the municipal property taxes, which are set according to the floor area of residential properties. 'Pay-as-you-throw' schemes, with residents paying a fixed charge per kg of waste, are commonly justified by the 'polluter pays' principal: the more waste generated by the household, the more it will pay in waste charges. However, if baseline waste generation is high, and the difference in per capita waste outputs between rich and poor is small, such linear charges on waste could be seen as a regressive tax. This follows from the notion that, in Israel, household income and household size are negatively correlated. Therefore, poor, large households would pay a higher nominal charges than rich households under a 'pay-as-you-throw' policy, as they are larger in size and produce a similar per capita waste quantity. This approach, suggested by Savradlov et al. (2005), is supported by our findings. The social shortcomings of such a 'pay-as-you-throw' scheme might offset, partially or completely, its environmental benefits.

Another surprising finding was the effect of municipal water consumption for gardening, producing about 0.06 kg of solid waste per capita per day for each cubic meter of water consumed per capita yearly. Similar to the previous calculation of 'hedonic waste', the total yearly effect of this water consumption can be estimated.

$$garden\_waste = \sum_i 0.06 * gard\_water_i * pop_i * 1000 * 365 = 6.26 \cdot 10^8 Kg \quad (5)$$

Surprisingly, the often disregarded gardening waste accounts for about 15% of Israel's MSW. Policy makers seeking solid waste reduction should pay greater attention to the contribution of public parks and gardens, and prioritize on-site compost programs.

Conclusions

Solid waste presents a significant environmental and management challenge to municipalities, with the associated collection, treatment infrastructure and regulation constituting a considerable societal expense. While the literature describes differences in solid waste generation between countries, little attention has been directed at the implications of socio-economic disparities for domestic waste disposal policy making. Israel's experience suggests that myths about socio-economic influences on individual waste generation are still prevalent among environmental organizations and even high-level policy makers.

A statistical analysis of waste generation in 152 cities and towns of Israel, of diverse socio-economic characteristics, calls many of these assumptions into question. Widely used socio-economic clusters, ranking local authorities by direct and indirect wealth indicators, proved to have little correlation with MSW generation per capita. Results show that the effect of wealth is only responsible for about 2% of the total waste outputs, when considering the difference between the richest cities of Israel with the mean. We found no observable difference between large and small urban settlements, or ethnic backgrounds of residents.

One surprising factor contributing to waste generation, estimated to be responsible for about 15% of total solid waste, is water used for public gardening. Policy makers may want to consider reductions in city gardening or shifts to vegetation which required less trimming help reduce municipal waste production.

The most significant variable correlated to MSW generation was found to be a dummy variable for the Tel Aviv County, Israel's economic centre and main commuting area. The cities in this county, as with all other cities in Israel, are responsible for collection and treatment of all the waste generated in their jurisdiction. While they benefit from taxing businesses and activities associated with their central role in Israel's economy, it should not be taken as granted that these taxes (regulated by the central government) are high enough to finance adequate waste management, suitable to the additional volume of waste generated as by-product of this relatively high economic activity Future research and policy making should address thoroughly the waste concentration in Tel Aviv county, and determine if its management deserves special attention and funding from the national budget.

Conflict of interest

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