The Monthly UnEconomist

Waste, Waste Generation, Source Reduction, Price Indexing & Variable Rates - We probably can't tell the score even with a scorecard!

Do we as a society produce more waste now than in the past? Total municipal solid waste (MSW), shown in Table 1, increased almost 2.5 times between 1960 and 1997. Per capita MSW grew from 2.7 pounds per person per day in 1960 to 4.5 by 1990, where it remained until 1995 when per capita waste dipped slightly and began to fluctuate at a lower level.

Over the same time period total consumer spending jumped by a multiple of 16.6. After adjusting for the 550% increase in consumer prices, real personal consumption expenditures (PCE), shown in Table 2, still increased by a factor of 3.6, much greater than the growth in either total or per capita MSW.

Table 1
MSW Per Capita

	MSW (000 tons)	Resident US Population (000)	MSW Per Capita (lbs/day)
1960	88,120	179,979	2.68
1970	121,060	203,984	3.25
1980	151,640	227,255	3.66
1990	205,210	249,907	4.50
1992	208,930	255,011	4.49
1994	214,180	260,682	4.50
1995	211,360	263,168	4.40
1996	209,190	265,253	4.32
1997	216,970	267,645	4.44

Source: Franklin Associates, *Characterization of Municipal Solid Waste in the United States: 1998 Update*, US EPA Report No. EPA530-R-99-007, July 1999.

This raises the question of whether we should be measuring waste generation on the basis of population or on the basis of economic activity per person. After all, it is presumably economic activity that generates waste, with higher per capita spending resulting in more waste per person, other factors being equal.

As shown in Table 2, MSW per thousand dollars of real personal consumption expenditure has actually declined rather steadily since 1960. Using waste per unit of real consumer spending as our measure of waste generation, how much of the waste generation decline since 1960 should be attributed to source reduction activities such as beverage container light weighting, backyard composting of organics, and other well recognized source reduction efforts?

At the same time, how much of the decline in waste generation should be assigned to other factors such as outsourcing of production to other countries or changes in consumer spending patterns to favor less waste intensive goods and services? Outsourcing of production, for example, means that MSW arising during production of goods and services would be generated outside the US, reducing US domestic waste generation for imported goods and services.[1]

Table 2
MSW per Thousand Dollars of Real Personal Consumption Expenditures

	MSW (000 tons)	Real PCE (millions of 1996 $)	MSW Per $1000 Real PCE (lbs)
1960	88,120	$1,494,400	117.9
1970	121,060	2,293,000	105.6
1980	151,640	3,169,400	95.7
1990	205,210	4,454,100	92.1
1992	208,930	4,603,800	90.8
1994	214,180	4,920,000	87.1
1995	211,360	5,070,100	83.4
1996	209,190	5,237,500	79.9
1997	216,970	5,433,700	79.9

Sources: Franklin Associates, *op. cit*., 1999; and US Department of Commerce Economics and Statistics Administration's STAT-USA/Internet, State of the Nation historical economic data available at STAT-USA's website.

This article attempts to shed some light on these tricky questions. To do so it is first necessary to take the reader on a slight detour through the theory of price indexing in order to illustrate some of the issues involved in creating aggregate indices. This discussion indicates why personal consumption spending is, in fact, preferable to population as a way to measure the rate of waste generation. It also reveals that measuring waste reduction in the aggregate is so difficult because it depends on being able to calculate accurate indexes for both prices and wastes.

This article concludes that it is probably more accurate and useful to measure source reduction for individual products or waste materials rather than in the aggregate. An example for yard debris generation shows how other important variables besides income -- for example, yard size and variable rate incentives -- enter into the source reduction calculation when analysis is conducted at the micro rather than the macro level.

The Consumer Price Indexing Problem

Are we better off now than we were at some previous time? This seemingly simple question has intrigued economists, among others, for decades. To avoid philosophical and empirical conundrums, that question is typically simplified to asking whether our real income or real consumer spending has gone up. Recent efforts to revise the cost-of-living adjustment (COLA) for social security, and the resultant acrimonious debate, highlighted the difficulties in adjusting income for changes in prices over time, revealing that in practice real income is itself an illusive concept.

The problem of adjusting consumer income or spending for changes in the price level is analytically intractable because we the people change over time, and the goods and services we are offered in the marketplace constantly evolve. As a result, we continuously revise what we put in the shopping cart of goods and services we purchase each year. Trying to objectively compare well being today with well being in, say, 1990, then, involves comparing apples to oranges, to use a cliché that perfectly illustrates the problem for a hypothetical society that evolves over the ten year period from consuming only apples in 1990 to now consuming only oranges.

To understand the conditions under which computation of a consumer price index (CPI) would be straightforward, suppose that both people and marketplace offerings remained stable. Suppose further that each person had the habit of buying goods and services in fixed proportions, and that each always got the same relative share of the economy's total consumer spending.

In this very simplistic example, then, we could take the total amount of just one good or service purchased in some base year, say 5000 tons of apples in 1990, and compare that with the total amount of that same good or service purchased more recently, say 6000 tons of apples in 1999. The ratio of 1999 purchases to 1990 purchases would tell us how much real consumer spending went up.

Our real spending in this example is 20% higher. We know this because we assumed that each of us buys the same fixed proportions of goods and services each year. If in total we all bought 20% more apples, then in total we all must have bought 20% more of everything else as well.[2]

We can also use this apples index of real consumption to calculate the amount by which prices increased (or decreased) over the intervening period. To do this we would take total consumption purchases in 1999 and divide it by the total for 1990 to get total growth in consumer spending unadjusted for changes in prices. Dividing this unadjusted increase in consumption by the 1.20 growth in real consumption would give the amount by which consumer prices went up or down over the ten years, as indicated by how far above or below 1.00 the result is. If we then multiplied the result by 100 we would have our CPI for 1999 versus a base of 100 in 1990.

Unfortunately, real people in real economies do not exhibit such stable purchasing behavior, both because they change the relative amounts of various goods and services they buy, and because new goods and services are always coming onto the market while others whither away. In the real world one compromise solution to the price-indexing problem has been to pick a market basket of goods and services and use changes in its total purchase price to measure change in price level over time. This practice, of course, raises the possibility for endless debate about the composition of that market basket standard, and about when to throw out this or that item out of the basket and replace it with an offering only recently available in the market place. At the same time, it does provide a CPI which can be used to adjust consumer spending for inflation.

The Connection between the Consumer Price Index and Waste Generation

Surely the reader by now is wondering what the CPI has to do with the problem of measuring waste generation and source reduction. In fact the CPI has a great deal to do with measuring waste generation.

Consider substituting "waste per unit" for "price" and substituting "waste" for "consumer spending" in the discussion above. In the hypothetical economy that consumes everything in fixed proportions, the apple index of real consumption tells us how much more goods and services we consumed in 1999 versus 1990. We can use the known 20% increase in real consumption to adjust the change in total waste over the period 1990 to 1999 in order to hold constant the level of real consumer spending. The result is an index of how waste decreased or increased per unit of real consumption, i.e., an index of waste generation, just as the CPI is an index of how much prices went up or down per unit of real consumption.

Now consider the real world CPI which is based on a market basket of goods and services. Estimated real consumption is calculated by dividing total consumer spending on goods and services by the CPI.

In turn, if we divide total waste by this estimate of real consumer spending, we obtain an estimate of waste per unit of real consumption, i.e., an estimate of waste generation. These estimates for certain years over the 1960-1997 time period are shown in Table 2 and indicate that waste per $1000 of real PCE fell 32% between 1960 and 1997.

The Connection between Waste Generation and Source Reduction

In our simple fixed-consumption-proportions society it would be natural to equate the 32% fall in waste generation entirely with increased source reduction.[3] If the only difference in consumer spending between 1960 and 1997 was that the quantity of each good and service consumed went up by the same percentage, then the only way total waste would not grow by the same percentage would be for the amount of waste generated per unit for each good and service consumed to fall on average. This, of course, is usually what is meant by source reduction -- a decrease in the amount of MSW generated per unit consumed.

However, in the almost forty years between 1960 and 1997, real world consumption patterns have changed dramatically, production methods have been transformed, and the relative amounts and types of goods and services produced overseas and imported into the US have increased substantially. This makes questionable any simple identification of the decline in MSW generation as being entirely explained by increased source reduction.

Nonetheless, the Environmental Protection Agency's recent report *National Source Reduction Characterization Report for Municipal Solid Waste in the United States*[4] proposes that changes in waste generation, as measured by MSW per million dollars of real PCE, during the 1990 through 1996 period should be entirely attributed to source reduction. As can be seen from the data in Table 2, MSW per $1000 of real PCE fell at an average annual rate of 2.04 pounds per year over the 1990 through 1996 period. But during the thirty years between 1960 and 1990 this waste generation measure also declined, only at the lower average annual rate of 0.86 pounds per year.

Given the larger annual decrease in waste generation rates during 1990 through 1996, it is plausible that source reduction did increase during the nineties. However, the EPA report provides no particularly persuasive or rigorous explanation for the report's assertion that the entire

2.04 pounds per year decline is the result of source reduction efforts. During a time of rapid change in consumer spending patterns (e.g., for services versus goods), relative prices (e.g., for consumer electronics versus housing), and the composition of imports versus exports (e.g., clothing versus software), more effort is required to extract the source reduction portion from the decrease in aggregate waste generation rates than just assuming that the entire decrease is caused by source reduction.

For example, we are presumably interested in distinguishing between reduction in waste per unit for each good or service consumed, and, say, a switch in consumer spending from heavily-packaged pet rocks to not-packaged hula hoops. The latter would reduce waste, purchase of all other goods and services remaining constant. It would also reduce waste generation if combined spending on hula hoops and pet rocks remained constant. But the reduction is entirely caused by consumer fads rather than any decrease in waste per pet rock or hula hoop.

Micro versus Macro Approaches for Measuring Source Reduction

Any attempt to measure source reduction for the entire US economy will inevitably encounter the sorts of analytical problems illuminated above. The indexing difficulty is of paramount importance. For prices and spending we forge ahead on heroic assumptions because economic policy decisions depend on being able to adjust economic data for inflation.

Is there a need for such heroic assumptions in order to measure source reduction? In the case of a product's price we cannot conclude that it has become more expensive unless we also know whether the standard for measuring price -- the dollar -- has itself changed in value. But a product's waste generation rate is based on a unit of measure -- weight -- that does not change over time.

So why resort to somewhat arbitrary indexes and indirect aggregation methods? Why not measure source reduction directly from the bottom up, one product or service at a time?

To illustrate the advantages of this approach, consider the yard trimmings component of MSW. Based on the estimates shown in Table 3, total yard trimmings in MSW increased over the thirty years between 1960 and 1990, but by 1996-97 had fallen back to about the 1980 level. Per $1000 of real PCE, yard trimmings waste declined throughout the 1960 to 1997 period, dropping by 1997 to 38% of its 1960 waste generation rate.

Table 3
Yard Trimmings Waste per Thousand Dollars of Real Personal Consumption Expenditures

	Yard Trimmings (000 tons)	Real PCE (millions of 1996 $)	Yard Trimmings Per $1000 Real PCE (lbs)
1960	20,000	$1,494,400	26.8
1970	23,200	2,293,000	20.2
1980	27,500	3,169,400	17.4
1990	35,000	4,454,100	15.7
1992	NA	4,603,800	-
1994	31,500	4,920,000	12.8
1995	29,690	5,070,100	11.7
1996	27,920	5,237,500	10.7
1997	27,730	5,433,700	10.2

Sources: Franklin Associates, *op. cit*., 1999; and US Department of Commerce Economics and Statistics Administration, *op. cit.*

Would it be reasonable to conclude that yard trimmings were source reduced by 62% between 1960 and 1997, or by 35% between 1990 and 1997? Macro methodologies for computing generation of yard trimmings per $1000 (or per million dollars) of real PCE, as laid out in the EPA report, cannot answer this question.

1. Direct Measurement of Source Reduction

Micro methodologies based on direct measurement of grasscycling, backyard composting, centralized composting and disposal quantities for yard trimmings provide more insight on source reduction opportunities and results. For example, the City of Seattle has conducted surveys of backyard composting and grasscycling. Seattle also maintains weigh scale information on curbside yard trimmings collections for centralized composting, and conducts regular composition studies on residential waste disposal. Combining these data allows one to conclude that Seattle source reduces 16.0% of residential yard trimmings, recycles (collects for centralized composting) 75.5%, and sends 8.5% to the landfill.[5]

2. Waste Generation and Source Reduction/Expansion Impacts Caused by Factors in addition to Real Income

A further example of the error in assuming yard waste generation and source reduction is explained solely by income comes from a study on garbage, recycling and yard waste collection rates and weights for cities, including Seattle, in the Puget Sound region of Washington state.[6] Statistical regression analysis of garbage and yard trimmings collection allows us to adjust yard waste per household for differences among cities and changes over time in important causal variables such as real income per household, yard size, and the charge for yard debris collection versus the charge for garbage collection. These statistical procedures show that, in fact, real income is just one of the variables driving waste generation for yard trimmings. Yard size and the charge for yard debris collection versus the charge for garbage collection turn out to be more important drivers of yard trimmings generation than household income.

The statistical analysis also provides an estimate of the source expansion impact of offering yard trimmings collection at no additional charge, i.e., bundling the costs of yard debris collection service into the fee charged for garbage collection. Those cities providing yard debris collection at no additional charge to garbage collection customers collect 13% more yard debris than they would if they did not offer yard debris collection for free.

This increase in yard debris waste generation is properly identified as source expansion, i.e., an increase in yard trimmings generation due to "free" yard trimmings collection while income, yard size, and other causal factors are held constant. Source expansion occurs in this case because households tend to reduce the amount of effort they expend managing yard debris at home (e.g., by grasscycling or backyard composting) when they are provided yard debris collection service at no charge.

At the same time, those cities that do charge a fee for yard debris collection incur a penalty in the form of decreased yard debris recycling and increased garbage collection quantities. Cities that charge at least as much for yard debris collection as they charge for the second can of garbage incur a diversion decrease that is more than twice as big as the source expansion from offering yard debris collection for free.

One elegant answer to this tradeoff between yard debris recycling and source reduction lies in a system like that used by Seattle. That city bans yard debris from garbage collection, effectively enforces that ban at the curb when garbage is collected, and at the same time imposes a separate charge for yard debris collection that amounts to only 25% of the fee for weekly collection of a second can of garbage. As indicated in the previous section, this system results in source reducing 16% of yard trimmings, while recycling 90% of the yard debris that is actually collected for centralized management.

Conclusion

These two examples for yard trimmings illustrate how source reduction can be directly measured by examining waste on a product-by-product basis. Other examples of readily measurable source reduction include beverage container lightweighting, reusable shipping containers, and selling CD's in just the jewel case rather than also wrapping the jewel case in a long paperboard carton. It is tempting to search for a macro methodology that estimates source reduction in the aggregate without actually having to examine changes in waste generation for each product and service consumed each year. But there is great potential for error in aggregate methodologies, especially the method based on real personal consumption expenditures that is promoted in EPA's National Source Reduction Characterization Report. Furthermore, source reduction is product and service specific. If there is need for a national index of source reduction, let it be computed by adding up source reduction successes and failures for all the goods and services we consume. The weight of waste per product or service unit consumed is a measurable concept. Why make source reduction into an aggregate abstraction?

About The Monthly UnEconomist

This monthly online newsletter available at www.SoundResource.com intends to provide insight and analysis on the everyday economics of recycling and the unpriced or underpriced environmental benefits of reducing waste disposal and replacing virgin-content products with products manufactured from recycled materials. Reader feedback is encouraged via email to info@ZeroWaste.com, and substantive comments will be published whenever they add to our understanding of recycling.

The *UnEconomist* also analyzes northwestern and northeastern U.S recycling market prices for nine recycled materials (mixed paper, ONP, OCC, glass containers, tin cans, UBC, PET bottles, HDPE natural bottles, and HDPE colored bottles) tracked by graphs available online at www.SoundResource.com. These graphs are updated at least quarterly. *The UnEconomist* will from time to time report on the accuracy of the annually updated five-year recycling price forecasts that are also provided online for each of the nine materials.

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[1] The waste generation rate for each good or service, as discussed in this article, includes all MSW arising at each stage of the good's or service's production and consumption cycle. As is customary, MSW does not include agricultural, forestry, mining or industrial wastes.

[2] This footnote provides a symbolic demonstration of the assertions made in the text of this article. Let total consumption purchases in 1999 be symbolically represented by:

$$C(99) = \Sigma\, p_i(99)*q_i(99),$$

where $p_i(99)$ is the 1999 price of good or service i and $q_i(99)$ is the quantity of good or service i purchased in 1999.

The assumption of fixed proportions for each person's purchases, combined with the assumption of constant shares in total consumer spending, means that we can rewrite 1999 purchases for each good or service in terms of its proportionate relationship to a single good or service, say apples. This gives:

$$q_i(99) = \alpha_i*q_A(99),$$

where α_i is the fixed ratio representing the quantity of good or service i consumed per apple consumed.

Then we can rewrite:

$$C(99) = q_A(99)*\Sigma\, p_i(99)*\alpha_i\ .$$

Similarly, we can write 1990 consumption purchases as:

$$C(90) = q_A(90)*\Sigma\, p_i(90)*\alpha_i\ .$$

The only variables that can be different in the two equations are the quantity of apples purchased in 1990 and 1999, and the prices at which goods and services were sold in the two years. The ratio that, thus, measures the change in physical consumption of all goods and services between 1990 and 1999 is:

$$q_A(99)/q_A(90)\ ,$$

the amount of apples consumed in 1999 divided by the amount consumed in 1990.

Similarly, the ratio measuring the change in prices between 1990 and 1999 is:

$$\Sigma\, p_i(99)*\alpha_i/\Sigma\, p_i(90)*\alpha_i\ .$$

Thus, the consumer price index is based on a weighted average of prices in one year divided by the weighted average for prices in the base year, using the same weight for each good or service price in both years. In our simplistic example the appropriate weights are the fixed ratios representing the quantity consumed of good or service i per apple consumed.

[3] If total waste generation is given by an equation similar to the equation for total consumer spending, then:

$$W(99) = \Sigma\, w_i(99)*q_i(99),$$

where $w_i(99)$ is the waste generation rate in 1999 per unit of good or service i consumed. The fixed proportions assumption allows us to rewrite total waste as:

$$W(99) = q_A(99)*\Sigma\, w_i(99)*\alpha_i\ ,$$

using variables defined in footnote 1 above.

Following the reasoning laid out in footnote 1 we can then derive the ratio that measures the change in waste generation between 1990 and 1999:

$$\Sigma\, w_i(99)*\alpha_i/\Sigma\, w_i(90)*\alpha_i\ .$$

This ratio is the weighted average of waste generation rates in 1999 divided by weighted average waste generation in

1990, with the fixed proportions α_i for good or service i per apple serving as the weights in both years.

[4] United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, *National Source Reduction Characterization Report for Municipal Solid Waste in the United States*, EPA530-R-99-034, November 1999, pp. 76.

[5] Seattle Public Utilities, *On the Path to Sustainability, Technical Support Document, Volume 1: Recycling Potential Assessment/System Analysis Model*, forthcoming in 2000.

[6] See *The Monthly UnEconomist*, Vol. 1, No. 3, September 1999, and Vol. 1, No.4, October 1999, for more information on this study. This newsletter is available to registered subscribers at <www.soundresource.com>.