Incidence Analysis of a Unit-Based Garbage Tax

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1. Introduction

In 2003, the United States created over 236 million tons of solid waste. This averages to 4.5 pounds of waste per person per day.[1] It should not be surprising that the huge amount of waste created daily comes with negative externalities. Landfills leach chemicals into the soil and taint our water supply. Incinerators emit cancer causing toxins, such as dioxin, into the air. These results obviously provide disutility for individuals in society. Such externalities indicate a market failure; those who create waste are not internalizing all of the costs associated with their actions, and an inefficiently high level of waste is generated. Thus, government intervention is necessary. In theory, the most efficient means of intervening to bring waste creation to an efficient level is to implement a tax per unit of waste equal to the marginal external damage of the unit of waste. Though this may seem simple, measuring external damage is incredibly difficult if not impossible (Metcalf, 1999).

Other, more realistic methods of taxation have been employed with the goal of bringing waste creation to an efficient level. A weight-based tax would force each household to pay a tax per pound of garbage they create. This would be the first-best method of taxation as marginal external damage depends on volume after compacting at a landfill, or mass of garbage burned in an incinerator, which is best proxied by weight at the curb. Unfortunately, this method would be highly time-consuming and technologically advanced.[2] The costs may also make it economically impractical (Kinnaman and Fullerton, 1996).

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[1] Found at http://www.epa.gov/msw/facts.htm, March 2, 2006.
[2] "First-best" indicates a tax policy that leads to an efficient production of waste, thus households face the full cost of their disposal decisions (Fullerton and Kinnaman, 2002).

Two other methods, flat fees and quantity-based taxation, are currently employed in numerous municipalities. Flat fees are paid in monthly or quarterly bills to a private waste hauler or as part of a general local tax. Quantity-based taxation requires households to pay a unit based fee (a price per bag of waste) or subscribe to a certain number and size of trash bins that are emptied on a regular schedule. These policies are second-best because volume is inferior to weight as a proxy for marginal external damage. They also provide an incentive to escape the tax by compacting garbage into fewer containers, as opposed to environmentally friendly methods like recycling or reusing.

Whatever method of taxation is implemented, it will burden those who bear the tax. If the burden of the tax is not borne proportionally by each member of society, it is said to have a regressive or progressive distributional effect. A regressive tax is relatively more burdensome on the poorer members of society while a progressive tax is relatively more burdensome on the wealthier members (Pechman and Okner, 1974). It must be noted that despite the burden the tax may inflict, taxing an externality in this way increases welfare of society on net as it brings the production of waste down to an efficient level.

This paper specifically analyzes the incidence of a quantity-based tax. It investigates the effect of the "price-per-bag" garbage collection scheme that was implemented in Charlottesville, VA in 1992. Section 2 reviews the literature. Section 3 explains the theoretical model used to analyze the distributional effect of the unit-based tax. Section 4 presents the data, regression results, and incidence calculations. Section 5 discusses the results, and section 6 concludes.

2. Literature Review

Basic Theory

The burden of a unit-based tax depends on the portion of a household's income devoted to the tax. Generally, lower-income households dedicate a higher percentage of their income to consumption. If increased consumption leads to increased waste creation, then unit-based taxes would induce a larger burden on lower income households; thus they are regressive (Duff, 2003). This paper tests that hypothesis.

Applications of the Theory in Literature

Two categories of economic literature play an important role in the distributional analysis of solid waste taxation. The first category includes theoretical and empirical studies of solid waste management. This includes work that specifies the demand function, investigates the effects of market incentives (such as unit-pricing schemes), and establishes optimal government policies for efficient waste creation. The second category of literature considers the burdens of taxation and the means of measuring them. No formal overlap between these two genres has occurred. By combining methods and theory from both, this paper fills in the missing piece and analyzes the distributional effect of unit-based garbage taxation.

Literature that estimates the demand for garbage collection gives a glimpse of the likely distributional effect of garbage taxation. All demand functions incorporate income as an independent variable and can be used to estimate an income elasticity of demand.[3] If the income elasticity of demand for solid waste management is less than one, then it is considered a necessity. Therefore, a tax that is equal in monetary value for all who consume waste management services would most likely be regressive. Podolsky and

[3] The other common dependent variables in the demand functions are education, marriage, household formation, and race, price of garbage disposal, and recycling availability (Kinnaman and Fullerton, 2002).

Speigel (1998) find the highest income elasticity of demand, .55, while Hong, Adams, and Love (1992) find the lowest of .049. The majority of such studies find a value nearly half as large as the highest. Wertz (1975) finds elasticities of .279 and .272 on two different data sets, Richardson and Havlicek (1978) estimate .242, Rechovsky and Stone (1994) find .23 (for volume of waste) and .22 (for weight), and Fullerton and Kinnaman (1997) estimate .262. Jenkins (1993) gets closer to Podolsky and Speigel's high value with an elasticity estimate of .41.

However, concluding that the income elasticity of demand fully conveys the distributional effect of a tax relies on a strong assumption. It assumes that household behavior is a constant or at least that all households respond identically. On the contrary, households have options following an implementation or increase in a tax. They can respond by reducing their solid waste management needs through increased recycling efforts, purchase of goods with less packaging, or reuse of products they may normally throw away. Not all households will necessarily undertake these options in the same manner, and some may therefore escape more of the tax than others.

Such household response is represented by the price elasticity of demand for solid waste. Jenkins (1993) finds a price elasticity of demand of -.12; Wertz (1976) estimates that it is -.15. However, these estimates come from cross-sectional community level data and do not analyze responses for differing income levels.

When specific data about the behavior of households of differing incomes before and after a tax implementation is available, the distributional effect can be clearly identified. West (2004) and West (2005) estimate behavior responses using the Consumer Expenditure Survey and analyze the distributional effects of vehicle emissions taxes. West (2004) compares the distributional effects of a uniform miles tax with an emissions tax.

She finds that greater price responsiveness among low income households mitigates the regressivity of both taxes.

However, when it is impossible to know the exact behavioral response of a household or individual to a tax increase, behavior is often held constant for ease of analysis. This method is used in Metcalf (1999) to argue that a shift toward "green taxes" will reduce the regressivity of the federal tax system. One must note that this type of analysis leaves something to be desired in the face of a negative externality. Generally, taxes are imposed to reduce the behavior that creates these externalities, such as driving and creating garbage. If the goal of the tax is to alter behavior, assuming constant behavior misses the point altogether.

As stated before, no distributional analysis (incorporating behavioral responses) of quantity-based garbage taxation has been completed. However, Kinnaman and Fullerton's (1996) research provides the perfect opportunity to analyze tax incorporating such a response. This natural experiment occurred in Charlottesville, VA in 1992 when an $.80 tax was placed on each 32 gallon bag or can of garbage collected. Kinnaman and Fullerton weighed and counted the bags and cans for 75 households before and after the implementation. Then, they estimated the effect of this tax on the weight of the garbage, the number of containers, the weight per can, and amount recycled as a function of household income and demographic variables.

Kinnaman and Fullerton do not formally analyze the incidence of the tax. However, their calculations suggest regressivity. They observe that, after the tax, the lowest income group creates .55 containers of waste per person while the highest income group creates only .46 containers per person. This suggests that the tax consumes a larger portion of the poorer households' incomes.

The literature that analyzes tax incidence generally uses a common set of assumptions. When analyzing a specific tax on a service or good, the tax is assumed to be fully borne by the consumer (Pechman and Okner, 1974, West, 2005, and Metcalf, 1999). Making this assumption markedly simplifies a distributional analysis. It allows the distribution to be measured with respect to uses of income and ignores any effect on the sources of income.[4] This assumption is discussed further in section 3. Additionally, the effects of the tax are considered distributionally neutral (Browning, 1979) allowing the assumption that members of society benefit from the government's expenditure of the tax revenue as if they had allocated the funds themselves. This assumption allows us to disregard the possibility that different groups in society, whether wealthier or poorer, may benefit more from government spending.

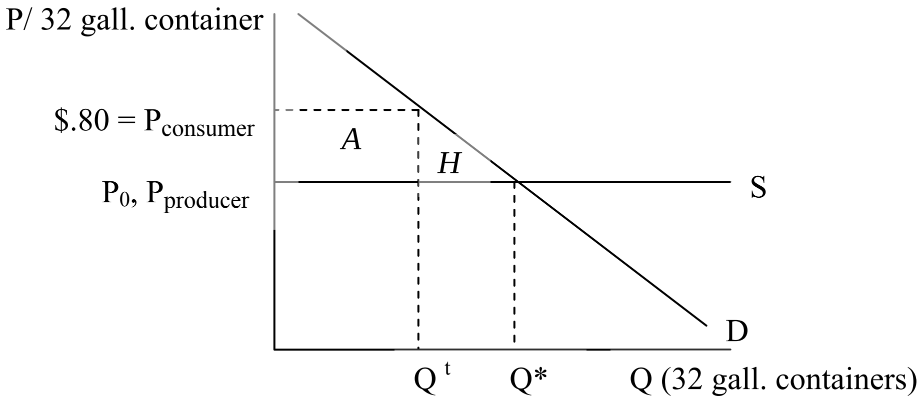
Considering that taxes on waste management (alternatively considered fees for service) are currently employed in society, a distributional analysis of such policies is crucial. This paper modifies the demand specification and data set used in Fullerton and Kinnaman (1996) to complete a formal analysis of the incidence of a unit-based tax. It maintains the commonly used simplifying assumptions discussed above. In doing so, this paper fills a void in the economic literature on solid waste management.

3. Theoretical Model

Modeling the incidence of this unit-based tax is quite straightforward, especially when done in a partial equilibrium framework. A partial equilibrium analysis focuses on one single market, the market for garbage collection, and ignores all implications for other markets. As mentioned earlier, this model assumes the burden is borne by the consumers only. This is synonymous with the assumption that supply is perfectly elastic. In other

[4] For further explanation of uses of income and sources of income considerations see Browning and Johnson (1979).

words, suppliers can provide any quantity of garbage collection that is demanded at the given price. This assumption is realistic if suppliers face a constant cost per unit of production because they have a number of nearly perfect input substitutes in the production process and no capacity limits. However, consumers cannot respond as flexibly. In the short run, while recycling and composting cannot negate all household waste creation, garbage collection is a necessity; demand cannot be perfectly elastic. Thus the market for garbage collection is represented as follows:

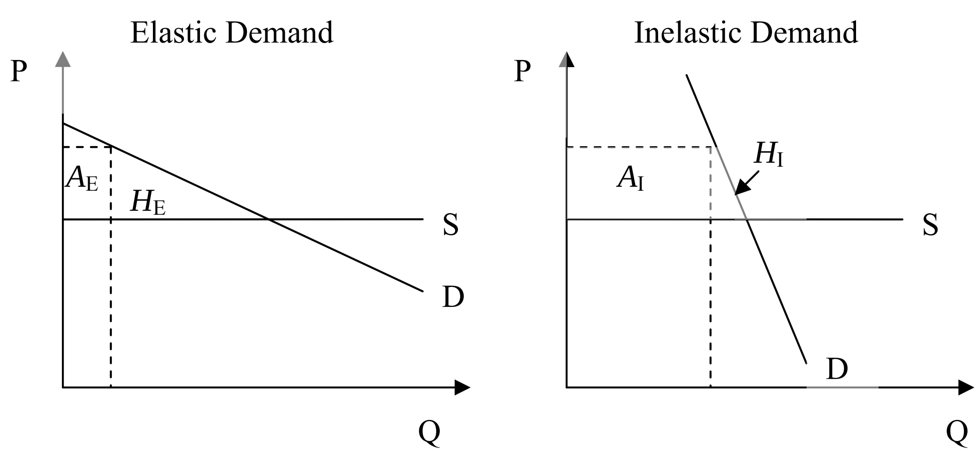


The $.80 tax is added to the original price, which is assumed to be $0 for simplicity.[5] When the tax is implemented a wedge is driven between the consumer price and the producer price. The equilibrium quantity of waste collection, measured in 32 gallon containers, falls from Q* to Q^t. Due to perfectly elastic supply, the producer price stays at Po, the original price, while the consumer price increases to $P_{consumer}$. Consumers are made worse off as the price they face increases by the full amount of the tax. This reduction in well being can be represented by a loss in consumer surplus.

[5] In reality, the price of garbage collection was not $0. Charlotteville's city government provided garbage collection and financed it with property tax revenue (Kinnaman and Fullerton, 1996). Even though the residents paid for their garbage collection, they faced no marginal cost of creating additional garbage. Thus, this incidence analysis is equally as meaningful in this situation.

To measure loss of consumer surplus, one must first note whether consumers in the model are price responsive. Kinnaman and Fullerton's data set provides the volume of garbage before and after the tax; the consumer's exact response is documented. Because consumers can respond to the price increase, the change in consumer surplus is simply represented by area *A*+ *H*. *A* is the government revenue, and *H* is the dead weight loss.[6]

To calculate area *A*+*H*, one must determine the price elasticity of demand, the slope of the demand curve. The elastic and inelastic situations are presented below. If consumers can easily reduce their demand for garbage as the price increases, they have relatively elastic demand curves and can greatly reduce their total tax paid. Thus, A_E is less than A_I. On the other hand, the more a consumer shifts their behavior away from the equilibrium, the greater the dead weight loss. Therefore, H_E is greater than H_I.



To compare burdens under this tax, I use the four income groups that are distinguished in Kinnaman and Fullerton (1996). Using survey results, households were categorized based on yearly income: less than $20,000, from $20,000 to $40,000, from $40,000 to $80,000, and greater than $80,000. These income groups are indicated by a 1, 3, 6, and 9 respectively. The average income used for each income group is the group's

[6] The dead weight loss is often referred to as the Harberger Triangle. Hence, the triangle is labeled "H".

indicator number multiplied by $10,000. This gives an average income equal to the median value for each group with the exception of the highest income group whose average is merely $10,000 greater than the lower bound. This method may not provide the actual average income for the group, but it is the best method considering the limited data on income. First, I simply calculate and compare the average garbage tax paid as a percentage of average income for the four groups.

Second, I run a regression similar to that of Kinnaman and Fullerton (1996) which estimates the percent change in volume of garbage created while controlling for demographic variables. The estimation takes the following general form:

$$P\Delta VOLUME = \beta_1 + \beta_2 INC3 + \beta_3 INC6 + B_4 INC9 + \beta_5 NEWS$$
$$+ \beta_6 CHILD + \beta_7 EDUC + \beta_8 MARRY + \beta_9 RACE + \varepsilon$$

The dependent variable is the percent change in volume of garbage created after imposing the tax. *INCi* are dummy variables for each of the four income groups (1, 3, 6, and 9). One income group, *INC1*, is omitted from the regression. Therefore, the coefficient for *INC1* is represented by the constant $\beta_{1.}$ *NEWS* is the number of newspapers delivered daily. *CHILD* is the fraction of household members less than three years of age. *EDUC* is a dummy equal to one if at least one member of the household has some post-secondary education. *MARRY* is a dummy variable equal to one if the household includes a married couple. *RACE* is dummy variable equal to one if the household is white. I incorporate these control variables in order to closely mimic the regression of Kinnaman and Fullerton (1996). Although they collected data on several additional variables, they only incorporated *NEWS*, *CHILD*, *EDUC*, *MARRY,* and *RACE* to minimize standard errors and conserve degrees of freedom. Exclusion of the other variables had “virtually no effect on the coefficient estimates of remaining variables” (Kinnaman and Fullerton, 1996,

p. 977).

While Kinnaman and Fullerton do not provide an explanation for the expected effects of the variables, one can easily intuit why some of these controls may have an effect on waste creation. The more newspapers a household receives, the more newspapers they are expected to discard. Infants in the household may be expected to increase waste creation with diapers and food containers. College educated individuals may be more likely to understand the impacts of waste creation and may be more aware of recycling options. Married couples may create more waste by opting to cook at home more frequently. However, they may also experience a degree of economies of scale by sharing waste creating products. Expectations for their waste creation are ambiguous. I am at a loss, however, for reasoning behind including race as a control variable. Kinnaman and Fullerton may have included it simply because it is a common demographic control.

The four income group coefficients represent the percentage change in volume of garbage following tax implementation. The four price elasticities of demand are then calculated as follows:[7]

$$\frac{\%\Delta \text{ in volume}}{\%\Delta \text{ in price}}$$

With the price elasticity of demand, I predict the average income group-specific volume of garbage created after the tax. The new volume is multiplied by the tax to find the government revenue. The dead weight loss triangle is then computed assuming that demand is linear.[8] The sum of these two areas gives the full consumer surplus loss for each income group. A final comparison of consumer surplus loss as a fraction of income across income quartiles indicates the distributional effect of the quantity based tax.

[7] The percentage change in price is calculated with the midpoint formula: (P2-P1)/((P2+P10/2)= (.80-0)/.4=50%.

[8] The area of the dead weight loss triangle is calculated with the following formula: $(.8(Q^t\text{-}Q^*))/2$.

4. Data and Summary Statistics

As mentioned before, this paper completes a partial-equilibrium analysis of a unit-based garbage tax. Such analysis requires significantly less data than the ideal general-equilibrium analysis that considers the tax's effects on the entire economy. Though less data is required, very specific, hard-to-get data is still needed.

Ideally, household level data would be employed, as they are the unit that is taxed. Furthermore, a random sample of households representing different climates and geographic locations would be used to control for seasonal and locational effects (Kinnaman and Fullerton, 1996). Exact incomes for each household would be available, thus allowing for small comparison groups, such as income deciles. All additional demographic information possibly affecting the households' waste creation would be incorporated to control for all effects outside of the price change.

The most challenging data to acquire is that which measures garbage creation and its response to price changes. A measurement of the volume of garbage created, both before and after a price change occurs, is needed. As garbage creation can fluctuate highly from week to week, an average volume over several weeks before and after would be ideal.

Obviously, acquiring this ideal data relies on the occurrence of simultaneous implementations of unit-based garbage taxes in a wide variety of locations across the U.S., not to mention, requiring the collection of personal data from households in each location. Even though such a natural experiment of this magnitude is unlikely, a smaller scale scenario did occur in Charlottesville, VA in 1992.

Kinnaman and Fullerton took advantage of this occurrence and collected data very close to the ideal needed for a distributional analysis. They requested participation from a random sample of 400 households in the town, 75 of which were willing to have their garbage measured and to provide personal information. The volume of these households' garbage creation was measured on four occasions before the tax implementation and four after. To control for expectational effects, Kinnaman and Fullerton did not measure the garbage during the three weeks leading up to the tax implementation. They also skipped the two months after implementation to allow for a brief adjustment period. Average volumes from each are provided in the data set.

The households also filled out questionnaires providing a number of various demographic characteristics.[9] They were not asked to specify their exact income, but just to place themselves into one of four income groups. Therefore, my analysis is limited to a comparison across income quartiles. Summary statistics of this data is presented in Table I.

Table I: Summary Statistics (standard deviations in parentheses)

Variable	**Calculated from available data set**	**Reported in Kinnaman and Fullerton (1996)**	**Description**
NEWS	0.47 (0.42)	0.47 (0.42)	Number of newspapers delivered daily per person
INFANT	0.02 (0.10)	0.03 (0.10)	Fraction of people in household less than 3 years old
COLLEGE	0.75 (0.43)	0.75 (0.44)	Dummy variable equal to 1 if at least one member of household has some college
INC	4.58 (2.63)	4.63 (2.66)	Annual household income level 1-less than $20000 3-from $20,000 to $40,000 6-from $40,000 to $80,000 9-greater than $80,000
INC1	0.18 (0.39)		
INC3	0.32 (0.47)		
INC6	0.33 (0.48)		
INC9	0.16 (0.36)		
LINC	0.40 (0.86)	0.41 (0.86)	Natural log of per capita income
MARRY	0.66 (0.50)	0.65 (0.51)	Dummy variable equal to 1 if married couple lives in household
WHITE	0.94 (0.25)	0.95 (0.28)	Dummy variable equal to 1 if head of household is white
ΔVOLUME	-0.64 (0.76)	[10]	Difference between average volume before and after the tax
PΔVOLUME	-0.30 (0.37)		Percent change in average volume following tax
# observations	77	75	

[9] A discussion of all survey questions can be found at http://www.eco.utexas.edu/~dfullert/TK-data/CvilleDescrip.pdf.

[10] Kinnaman and Fullerton did not report the mean and standard deviation of their dependent variable, ΔVOLUME, thus I cannot incorporate it in the table.

A few comments need to be made regarding the data set provided by Kinnaman and Fullerton. First of all, they claim to have had 75 participating households with complete demographic data. However, the data set has 77 households that appear to have complete information. I am unable to determine which two Kinnaman and Fullerton deemed "incomplete". Therefore, I use 77 households in my analysis. Second, one of the entries in the *WHITE* variable was a 2. Seeing as this variable is a dummy that is equal to only 0 or 1 depending on whether the head of the household is white, I changed this variable to a 1 assuming a simple typographical error.

For the purposes of this paper, I attempt to replicate their results to confirm the understanding of their data. Next, as discussed in section 3, I replace the *LINC* variable with the four income group dummies (*INC1, INC3, INC6,* and *INC9*) and use the percent change in volume (as opposed to change in volume) as my dependent variable.

Their regression results, my attempt at replication, and my alternative regression results are presented in Table II, where t-statistics are in parentheses.

Table II: Regression Results

Independent Variables	**Results from Kinnaman and Fullerton (1996)**	**Regression 1: Replication from available data set**	**Regression 2: Dependent variable is the % change in volume**
Constant	-0.52 (-3.40)	-0.87 (-2.25)	-0.39 (-2.17)
NEWS	0.17 (1.37)	0.33 (1.44)	0.19 (1.89)
INFANT	0.75 (1.59)	1.44 (0.91)	0.73 (1.73)
COLLEGE	0.13 (1.11)	-0.02 (-0.10)	0.08 (0.76)
LINC	-0.11 (-1.75)	0.05 (0.44)	
INC3			-0.02 (-0.16)
INC6			-0.27 (-1.98)
INC9			-0.08 (-0.45)
MARRY	0.17 (1.76)	0.08 (0.45)	0.13 (1.39)
WHITE	0.06 (0.37)	-0.02 (-0.05)	-0.05 (-0.33)
R^2	0.117	0.071	0.186
F-stat	F(6,68)= 1.505	F(6,70)= 0.88	F(8,68)= 1.94
Number of observations	75	77	77

From these results, it is obvious that I was unable to exactly duplicate the results of Kinnaman and Fullerton (1996). These differences may be a result of the number of observations (75 vs. 77), the error in their data set, and any unreported regression techniques. Additionally, only two of the income groups' coefficients in my altered regression are statistically significant, *INC1* and *INC6*. This implies that the price elasticities of demand are not statistically significantly different from each other. This lack of significance is not a surprise as Kinnaman and Fullerton also found that "the null hypothesis that all slope coefficients are zero cannot be rejected for three of [their] four regressions" (1996, p. 977).

Despite these differences and lack of statistical significance, I complete the analysis discussed in section 3 with the results from regression 2. The coefficients for the income group dummies (*INC1* being the omitted variable) are used to calculate the group-specific price elasticities of demand.

Table III presents these comparisons across income groups with a group-specific price elasticity of demand and an average price elasticity of demand.

Table III: Income Group Comparisons

Income group by annual income	**Income group-specific price elasticity of demand**	**Avg. tax as fraction of income**	**Consumer surplus loss as a fraction of income**	**Avg. price elasticity of demand**	**Avg. tax as a fraction of income (from avg. elasticity)**	**Consumer surplus loss as a fraction of income (from avg. elasticity)**
1(avg. = $10,000)	-0.39	.00635	.00704	-0.48	0.00607	0.00690
3(avg. = $30,000)	-0.41	.00196	.00207	-0.48	0.00179	0.00204
6(avg. = $60,000)	-0.66	.00088	.00106	-0.48	0.00097	0.00110
9(avg. = $90,000)	-0.47	.00064	.00073	-0.48	0.00064	0.00072

These calculations show that income group-specific price elasticity of demand increases through the first three income groups and then decreases for the highest. Both average tax and consumer surplus loss, as fractions of income, decrease as income increases for both specific and average elasticity calculations. A more detailed discussion of the distributional implications appears in section 5.

5. Results

Columns 2-4 of table III show that average tax paid and consumer surplus loss as fractions of income, when calculated using the income group-specific price elasticity of demand, both decrease as income increases. This suggests that a unit-based garbage tax is indeed regressive. The lowest income group spends an average of .64% of their income each year on waste management services, whereas the highest income group only spends .06%. Because the tax induces a change in behavior, the consumers bear more burden than is indicated by the tax paid measure. Spending time recycling or searching for goods that will produce less waste may create additional burden on households. Thus, a consumer surplus measure of burden gives a more meaningful description of the actual welfare loss associated with the tax. According to this measure, the tax induces a loss equal to .70% of income for the lowest income group and .07% for the highest.

Use of the sample mean elasticity (in columns 5-7) to predict the response to the tax gives a slightly less regressive picture. The lowest income group only alots .60% of their income to the tax. Their consumer surplus loss is only equivalent to .69% of their income. This suggests that poorer households are slightly less responsive to the tax; they can not or do not alter their garbage creation to the same extent as wealthier households. The level of responsiveness can also be interpreted from the income group specific price elasticities of demand. The lowest income group is the least elastic at -.39. Elasticity peaks in income group 6 at -.66. The lowest two income groups are less elastic than the average garbage consumer. Thus calculating incidence using an average price elasticity of demand overstates their ability to alter behavior in response to the tax and understates the regressivity of the tax.

6. Conclusion

This analysis supports the hypothesis that unit-based garbage taxation is regressive. Furthermore, the aforementioned results suggest that it is crucial to allow the responsiveness of income groups to vary when completing a distributional analysis of a garbage tax. Income groups do indeed respond differently. If responsiveness is ignored, the regressiveness of the tax is understated.

There are many reasons why this tax may be regressive. Poorer households may not have the time to recycle or the ability to shop around for goods that will create less waste. They may also not be able to take part in activities that inherently create less waste, such as dining out. This implies that a unit-based garbage tax may also need to incorporate special considerations for lower income households. For example, the unit-based fee could kick in after one complimentary 32 gallon container of trash.

While the results presented here are important, it must be noted that this is not the ideal measure of incidence. Ideally, incidence analysis should be completed from a larger number of observations and across a larger variety of income groups, such as deciles, to provide a more detailed look at the tax burden. Furthermore, a partial equilibrium analysis does not consider the far-reaching effects of the tax. A general equilibrium analysis would provide a more complete analysis as it would additionally consider the burden borne by owners of waste management businesses and those who are employed in the industry. A long run analysis would also be beneficial, as it would allow for greater price responsiveness. Households need time to efficiently incorporate recycling, composting, and reusing into their daily routines. Lastly, these results may also suffer from survey bias. The participants may have been more accepting of the tax in the first place. They also may have responded to the tax more extremely knowing that their behavior was being analyzed. These considerations all provide future areas for research on garbage taxation.

While this analysis is not ideal, it is a step in the right direction. It fills a void in the literature by addressing the distributional effects of a unit-based tax. This analysis also shows that one cannot just accept the "inherent fairness" that would seem to result with each household paying for exactly what they throw away.[11] Evidence suggests that, in reality, unit-based garbage taxation is truly regressive.

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[11] Pay As You Throw, Introduction, Retrieved 03/2006 from http://www.epa.gov/epaoswer/non-hw/payt/intro.htm

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