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GARBAGE, RECYCLING, AND ILLICIT BURNING OR DUMPING

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ABSTRACT

Additional solid waste disposal imposes resource and environmental costs, but most residents still pay no additional fee per marginal unit of garbage collection. In a simple model with garbage and recycling as the only two disposal options, we show that the optimizing fee for garbage collection equals the resource cost plus environmental cost.

When illicit burning or dumping is a third disposal option, however, the optimizing fee for garbage collection can change sign. Burning or dumping is not a market activity and cannot be taxed directly, but it can be discouraged indirectly by a system with a tax on all output plus a rebate on proper disposal either through recycling or garbage collection. This optimizing fee structure is essentially a deposit-refund system. The output tax helps achieve the first-best allocation even though it may affect the choice between consumption and untaxed leisure, because consumption leads to disposal problems while leisure does not.

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1. Introduction

Solid waste disposal has become more expensive recently due to rising land prices, strict environmental regulations, and host fees paid to localities to accept new landfills. Tipping fees in the northeastern U.S. approach $125 per ton. Most towns still pay for garbage collection using general revenues, however, with no price per bag. Thus the resident views it as free.

As an alternative, more towns in the U.S. are beginning to sell special bags or stickers necessary for curbside collection of each bag or can of garbage (U.S. EPA, 1990). These per-unit charges can help defray the cost of collection, and they help discourage waste. Two major recent studies describe the advantages of such charges. Project 88--Round II (1991), sponsored by Senators Timothy Wirth of Colorado and John Heinz of Pennsylvania, says that unit pricing "creates strong incentives for households to reduce the quantities of waste they generate, whether through changes in their purchasing patterns, reuse of products and containers, or composting of yard wastes" (pp. 49-50). The World Resources Institute (WRI, Repetto et al, 1992) further extols the virtues of "pay-by-the-bag," and it goes on to measure welfare gains from such a policy. For a densely-populated eastern seaboard state like New York or New Jersey, the WRI study estimates that each 32-gallon bag of garbage costs $1.12 in market payments to waste haulers and landfill operators, and $1.83 including non-market external costs on others near the landfill who may suffer from noise, odor, litter, and extra traffic. With this charge per bag, even with no curbside recycling, the WRI report finds that:

> the annual volume of wastes landfilled would fall by approximately 20 percent; where costs are moderate, the drop would be 11 percent. If adopted across these regions, the annual net economic savings, including both savings in waste handling and disposal and avoided environmental damages, would total almost $650 million on annual revenues from charges of $7.25 billion (p.25).

The purpose of this paper is to sound a note of caution. In response to unit charges, households may not only recycle, compost, and adjust purchasing habits, but they may also burn paper in fireplaces and carry household trash to commercial dumpsters, parking lots, back woods, and vacant lots. If New York City were to sell stickers for $1.83 each, and pick up only those bags with stickers, we believe that revenue would be small and piles of unidentified garbage would be large. Welfare gains would be negative.

We build a simple theoretical model of household choice between consumption and leisure, and among three disposal options: garbage, recycling, and illicit burning or dumping. A single consumption good is produced using a single primary factor, recycled input, and virgin materials such as timber or minerals. The model also includes three externalities. First, municipal garbage collection may impose aesthetic and health costs on those who live near the landfill or incinerator. Second, improper burning and dumping may impose even higher costs on others. Third, the extraction of virgin materials involves clear-cutting or strip-mining that may adversely affect not only the landowner who sells timber or mineral rights, but others who enjoy wilderness and wildlife.

Using this model, we make three main points. First, if garbage and recycling are the only two disposal choices, then the WRI study is correct that the optimal garbage collection fee includes not only the direct resource cost ($1.12 per bag) but also the external cost (for a total of $1.83 per bag in their study). With all three disposal options, however, the unit fee encourages more recycling <u>and</u> more illicit dumping. Garbage collection is no longer taxed but now must be subsidized, under reasonable conditions. The reason is that the dumping externality is worse than the landfill externality.[1] If the subsidy approximately offsets the direct resource cost ($1.12), then free collection of garbage is justified.

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[1]Other studies such as Dobbs (1991) and <u>Project 88 -- Round II</u> (1991) have discussed the problem of litter as a reason for deposits and refunds on particular commodities. In contrast to those studies, we consider a tax on all output and a subsidy for all proper disposal, in a general equilibrium model, when proper disposal might include either landfill or recycling.

Second, we address a debate in the literature about whether optimal fees would be imposed "upstream" at the point of production, or "downstream" at the point of disposal.[2] Our general equilibrium model accounts for circular flows: households send labor resources and recycling to producers who add some virgin materials and send output back to households. We assume that tax or subsidy rates can be applied to consumption, garbage, virgin materials, and recycling, but not directly to illicit burning or dumping. We find a positive tax on consumption, at a rate that reflects not the good's disposal cost but its possible externality from illicit burning or dumping. This tax is then returned as a subsidy on all recycling, and on all proper disposal of garbage, leaving a tax only on burning or dumping. The result is a deposit-refund system for all consumption goods, not just bottles or lead-acid batteries. A virgin materials tax is not necessary except to offset its own negative externality.

Third, existing public finance literature generally finds that a consumption tax distorts the choice between taxed consumption and untaxed leisure. Here, however, we find a positive consumption tax even though leisure is still untaxed. The reason is simply that consumption leads to disposal problems while leisure does not.

The next section characterizes the WRI report and other existing literature by describing a model with garbage and recycling as the only two disposal choices. It solves for the optimal tax on garbage collection. The following section adds the third choice, illicit burning or dumping, and finds that the optimal tax on garbage changes sign. It also considers virgin

[2]Wertz (1976) finds that a per-unit garbage fee raises the effective price of goods with high disposal content. Porter (1978) analyzes a deposit-refund system for bottles. Menell (1990) suggests retail disposal-content charges that reflect the subsequent disposal cost of each item. Sigman (1991) finds that a tax on virgin lead is equivalent to a deposit-refund system, when virgin lead and recycled lead are perfect substitutes in production. An empirical study by Jenkins (1991) finds that garbage collection has an income elasticity of .41 and a price elasticity of -.12. The pros and cons of alternative policies are nicely described in some of these papers, as well as in Miedema (1983) and Project 88–Round II (1991). These papers consider garbage and recycling. Copeland (1991) and Dobbs (1991) consider garbage and illegal dumping, but not recycling. Ours is the only model we can find with all three disposal options.

materials. The last section briefly describes extensions of the model to consider disaggregate consumption goods, population density, multiple levels of government, and administrative cost.

2. Just Garbage and Recycling

In order to characterize prior results, our initial model ignores illicit burning or dumping. Also, since none of the discussion above involves distributional issues, we consider a single jurisdiction with n identical individuals or households. Each buys a single composite consumption good c, and each generates waste in two forms. We use g for garbage collection, and r for recycling and subsequent reuse in production. These alternatives are substitutes in the "technology" of household consumption:[3]

$$c = c(g,r) \quad , \tag{1}$$

where $c(\cdot,\cdot)$ is continuous, quasi-concave, and has positive first derivatives c_g and c_r. This relationship captures the degree to which the household is able to shift between disposal methods. With a given amount of consumption, the household may be able to reduce g and increase r by recycling newspapers, composting food waste, purchasing bottles in glass instead of plastic, collecting aluminum, and buying goods with less packaging. For simplicity, we specify each form of disposal as a single continuous variable. As a special case of (1), we will later discuss a "mass balance" example where $c = g + r$ (and $c_g = c_r = 1$).

Utility depends not only on household consumption c, but also on home production h, and the total amount of garbage, $G=ng$:

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[3]Some readers may prefer to think of g and r as outputs of a function with input c, but equation (1) simply inverts that function. We think of g and r as amounts necessary to support c.

$$u = u[c(g,r),\ h,\ G] \tag{2}$$

where first derivatives are $u_c > 0$, $u_h > 0$, and $u_G \leq 0$. For practical purposes, think of h as leisure use of time and resources. We use lower case letters to denote values per household and upper case letters for aggregates. Total garbage G may impose aesthetic and health costs, even if it is regulated in a "sanitary" landfill.[4]

On the production side of the model, output c may be produced using the constant returns to scale production function:

$$c = f(k_c,\ r) \tag{3}$$

with input of resources k_c and recycled materials r. Just as we ignore transactions costs in the sale of c or k, we also ignore the cost of collecting and trading r.

Provision of garbage collection services requires use of resources k_g in a simple linear production function, and home production uses resources k_h:

$$g = \gamma k_g, \qquad h = k_h \tag{4}$$

Finally, the model is closed by the resource constraint:

$$k = k_c + k_g + k_h \tag{5}$$

where k denotes a fixed total resource such as capital, labor, or land.

In this model, the social planner's problem is to maximize utility of the representative household subject to the resource constraint, production constraints, and $c(g,r) = f(k_c,r)$. The resource and production constraints can be substituted directly, to maximize:

[4]In this static model of annual flows, G is total garbage per year. See Vernon Smith (1972) for a dynamic treatment of waste flows into a landfill with a stock externality.

$$\mathcal{L} = u[c(\gamma k_g, r), k_h, n\gamma k_g] + \delta[f(k-k_g-k_h, r)-c(\gamma k_g, r)] \tag{6}$$

with respect to k_g, r, and k_h. This optimization recognizes that every individual imposes cost on others through their use of garbage collection services.[5] The first-order conditions are:

$$u_c c_g + u_G n = \delta(c_g + f_k/\gamma) \tag{7a}$$

$$u_c c_r = \delta(c_r - f_r) \tag{7b}$$

$$u_h = \delta f_k \tag{7c}$$

These equations will be employed shortly. They just indicate that the marginal utility made possible through additional g, r, or h must equal the marginal social cost.

For the case of private markets, individuals maximize utility in equation (2) subject to a budget constraint that may be affected by a tax or subsidy on each good:[6]

$$p_k k = (1 + t_c)c + (p_g + t_g)g + (p_r + t_r)r + p_k k_h \tag{8}$$

where p_k is the price earned on resources, the price of consumption equals one since c is numeraire, t_c is the tax per unit of consumption, p_g is the price paid for garbage collection, t_g is the tax per unit garbage, p_r is the price paid by the consumer for recycling (which may be positive or negative), and t_r is the tax per unit recycling. Note that consumers pay prices gross of tax, but producers receive prices net of tax. Here, however, households ignore the effect of their own activities on the total externality. Tax and subsidy rates can simply be set to zero for the case of private markets with no government interference.

[5] We assume second-order conditions hold, solutions are internal, and a unique solution exists (see Baumol and Oates, 1988, pp.37-38).

[6] We ignore the government revenue requirement, assuming implicitly that lump-sum taxes are available to finance spending and to pay for necessary subsidies.

Producers of c maximize profits $(c + p_r r - p_k k_c)$ under perfect competition with constant returns to scale. Thus $f_k = p_k$ and $f_r = -p_r$. Producers of garbage collection services similarly maximize $(p_g g - p_k k_g)$, so $p_g = p_k/\gamma$. In this decentralized economy, the consumer chooses g, r, and h such that:

$$u_c c_g = \lambda[(1+t_c)c_g + f_k/\gamma + t_g)] \tag{9a}$$

$$u_c c_r = \lambda[(1+t_c)c_r - f_r + t_r] \tag{9b}$$

$$u_h = \lambda f_k \tag{9c}$$

where λ is the marginal utility of income. These first-order conditions indicate that private marginal utility matches the individual's cost of each activity. With tax rates of zero, it is easy to see that the outcome is not optimal. The right-hand sides of (7a) and (9a) would be similar, but only the left side of (7a) would account for the external cost of garbage, u_G.

With Pigouvian tax rates, however, private behavior in (9) can be induced to match the unique social optimum in (7). In this case, (7c) and (9c) indicate that $\delta = \lambda$. Since both problems maximize utility subject to a resource constraint, and both attain the same optimum, the social marginal utility equals the private marginal utility of the resource.

Next compare (7b) and (9b). By inspection, and using $\delta = \lambda$, these two equations will both hold when $t_c = t_r = 0$. In this model, no tax or subsidy is required for private behavior to yield this first-order condition of the social optimum.[7]

Finally, we compare (7a) and (9a). When $t_c = 0$, these equations both hold so long as $t_g = -nu_G/\lambda$. Since $u_G \leq 0$, this tax may be zero or positive. This model provides no justification for free collection of garbage. Additional garbage collection is not a pure public

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[7]Actually, this condition allows for any tax on consumption t_c, as long as it is returned as a subsidy to both garbage and recycling such that the net tax is still zero.

good but uses scarce resources of labor, capital, and landfill. Consumers would pay $(p_g + t_g)$, equal to $1.83 per bag in the WRI study, enough to cover both the resource cost and the negative externality from garbage.

3. Virgin Materials, and Illicit Burning or Dumping

This section makes two modifications to the model. First, we allow for a third disposal alternative:

$$c = c(g,r,b) \quad , \tag{1'}$$

where b stands for burning and other improper disposal such as dumping by the side of the road. Again b is a single continuous variable, and $c_b > 0$. The household may reduce g and raise b by burning cardboard boxes in the fireplace, carrying trash to commercial dumpsters, or leaving it out in the woods. Total $B = nb$ may reduce the utility of others $(u_B \leq 0)$. In the "mass balance" example, $c = g + r + b$.

Second, we consider virgin materials, $V = nv$, which also may reduce the utility of others $(u_V \leq 0)$. Implicitly, this cost may represent the shadow price of over-using scarce minerals in a more complicated dynamic model.[8] More explicitly, in our model, total V may reduce the public enjoyment of natural areas through clear-cutting or strip-mining. The new utility function is:

$$u = u[c(g,r,b),\ h,\ G,\ B,\ V] \quad . \tag{2'}$$

In addition, $u_B \leq u_G$. That is, improper burning and dumping is presumed to impose negative externalities that exceed those of proper garbage disposal.

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[8]Neher (1990, chapter 13) shows conditions under which (1) economies systematically underprice environmental resources (p. 238), and (2) the static optimizing solution is the steady state solution of a corresponding dynamic problem (p. 243).

Production of c is modified to use virgin materials, which themselves are produced or extracted using a simple linear function:

$$c = f(k_c, r, v) \ , \tag{3'}$$

$$v = \alpha k_v \ . \tag{4'}$$

Each of these goods can be provided for a market price, but improper burning and dumping cannot. Yet illegal burning does involve time, psychic costs, and risk of getting caught. We assume burning uses private resources $k_b = \beta(b)$, with marginal costs that are positive ($\beta_b > 0$) and rising ($\beta_{bb} > 0$). We also assume that any direct tax or penalty on burning or dumping would be difficult to enforce.[9] Finally, the resource constraint becomes:

$$k = k_c + k_g + k_h + k_v + k_b \ . \tag{5'}$$

With these modifications, the social planner maximizes consumer utility with respect to k_g, r, k_h, b, and k_v. First-order conditions (7a, b, c) are unchanged, and:

$$u_c c_b + u_B n = \delta(c_b + f_k \beta_b) \tag{7d}$$

$$u_V n = \delta(f_k/\alpha - f_v) \tag{7e}$$

With private markets, competitive firms set the marginal product f_v equal to their cost $p_v + t_v$. Other firms produce v and maximize profits $[p_v(\alpha k_v) - p_k k_v]$, so $p_v = p_k/\alpha$.

The consumer's budget constraint in (8) must now include the cost of burning, $p_k \beta(b)$, which is not taxed for reasons cited above. First-order conditions (9a, b, c) are unchanged, and:

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[9]See Lee (1984) for a full treatment of enforcement costs and taxpayer avoidance costs. A simple enforcement model might suggest arbitrarily high penalties, in order to save real police resources. Our model avoids this problem in two ways. First, an internal solution for the social optimum implies that a certain amount of burning may be less socially costly than more landfill or recycling. The optimal tax on b is finite. Second, in our model, no direct tax on b is required. As long as the government can enforce taxes or pay subsidies on market transactions (of c, g, r, and v), we will show that the first-best allocation is attainable.

$$u_c c_b = \lambda[(1+t_c)c_b + f_k\beta_b] \qquad \textbf{(9d)}$$

$$f_k = (f_v - t_v)\alpha \qquad \textbf{(9e)}$$

Again we solve for the Pigouvian tax rates that induce private behavior in equations (9) to match the social optimum in (7). Again (7c) and (9c) imply that $\delta = \lambda$. This time, however, (7d) and (9d) can be solved for a particular value of t_c that is not zero. Then (7b) and (9b) require $t_r = -t_c c_r$. The full set of optimizing tax rates are:

$$t_c^* = -nu_B/\lambda c_b \qquad \text{(10a)}$$

$$t_r^* = nu_B c_r/\lambda c_b \qquad \text{(10b)}$$

$$t_g^* = n[u_B c_g - u_G c_b]/\lambda c_b \qquad \text{(10c)}$$

$$t_v^* = -nu_v/\lambda \qquad \text{(10d)}$$

If illicit burning or dumping has no external effect ($u_B = 0$), then this model reduces to the previous model, with $t_c = t_r = 0$ and $t_g = -nu_G/\lambda$. With $u_B < 0$, however, consumption must be taxed at $t_c^* > 0$ to attain the first-best conditions, even if leisure is still untaxed. This tax is returned on goods that are properly disposed, as garbage or recycling. The net effect is a tax on illicit burning or dumping, circumventing the problem that b could not be taxed directly.

Garbage receives the rebate of t_c^*, but it also receives a tax that depends on its own externality. In section 2 above, the tax was positive. Here, the net tax t_g^* is likely to be negative. In the "mass-balance" case where $c_g = c_b = 1$, garbage receives a net subsidy because u_B is more negative than u_G. In general, the tax depends on the relative ease of burning versus garbage collection (c_b versus c_g). If the optimal price $p_g + t_g^*$ is <u>near</u> zero, then the city or county can save administrative and billing costs by providing free garbage collection.

Finally, the tax on virgin materials is not part of any deposit-refund system. It is not used to encourage recycled input or discourage generation of garbage. Instead, the tax on virgin materials would only correct negative externalities from the use of virgin materials.

4. Limitations, Extensions, and Discussion

Using broad brush strokes, this paper characterizes the optimal taxation of garbage, recycling, and general consumption. These broad strokes may miss some important detail, however. First, we can further modify the model to include m different consumption goods c_i, for $i=1,...,m$. These goods may have different technologies $c_i(g_i,r_i,b_i)$ and production functions $f_i(k_i,r_i,v_i)$. Subscripts also are required for u_G, u_B, δ, p, t_c, t_g, and t_r. Results look exactly the same, except for subscripts. In particular, the sales tax on each good is:

$$t_{ci} = -nu_{Bi}/\lambda c_{bi} \quad . \tag{11}$$

In other words, each tax rate must reflect the social cost of burning or dumping that particular item. Similarly, to get the detail exactly right, the first-best policy would have to rebate that same amount upon proper disposal of each item. Differences may arise because some items are more toxic, more unsightly, or more easily burned. Any policy that tried to account for all such differences would be too difficult to administer. Perhaps only some items could be targeted. In general, however, external costs arise when any item is improperly discarded anywhere. Therefore policy might still employ a general consumption tax and a general subsidy to all proper garbage collection and recycling.

A second extension would consider how these optimizing fees are related to population density. We hypothesize that fees would work best in suburban areas or small towns where the charges can be enforced. In densely-populated urban areas, any price for garbage collection may be greeted by huge piles of unidentified garbage on the streets or vacant lots. In very rural areas, similarly, dumps may appear on back roads. Thus, these results may help explain differences in actual municipal pricing mechanisms.[10]

A third problem arises with different levels of government. States traditionally set sales tax rates, but municipal governments subsidize garbage collection. Perhaps some revenue could be transferred from one to the other. Goods may be purchased in one state, however, and then traded or carried across state lines before disposal. Various spillover effects might justify a national-level tax and rebate system, but spillovers may still cross national boundaries. This issue deserves further scrutiny (as in Copeland, 1991).

Finally, our model ignores some compliance costs and market imperfections. With regard to recycling, Nestor (1993) points out that subsidies to households may generate supply of recycled goods without yet the industrial capacity to make use of them. With regard to a per-unit garbage fee, the town would have to sell special bags or stickers. This administrative cost might induce towns to provide free garbage collection.

None of these considerations alter our three main points, however. First, existing studies find that a negative externality from garbage can be offset by a tax on garbage. When we add illicit dumping as a third disposal option, however, the tax on garbage may turn negative. Garbage collection may be subsidized if it helps prevent the worse environmental costs of improper disposal. Second, existing literature suggests that a tax on virgin materials may help encourage recycling. In our model, a tax on virgin materials can only offset ill effects of using virgin materials. Third, in existing public finance literature, a consumption tax distorts the choice between labor and leisure. This paper finds a positive tax on consumption, however, even when leisure is untaxed. No tax on leisure is required, because leisure does not cause disposal problems.

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[10]The U.S. EPA (1990) lists sixteen towns that have unit fees for garbage collection, and we have extended that list for empirical work. All are small or moderate in size, with the exception of Seattle.

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