Litter and waste management: disposal taxes versus user charges

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Abstract. Littering and rubbish collection involve a divergence between private and social costs. This note suggests there is a need to consider these two problems jointly: viewed in isolation, a user charge for rubbish collection has often been suggested as a means of internalizing the waste management externality; however, viewed as part of the wider problem, it turns out that this charge should be negative; that is, there should be a refund or user subsidy associated with the proper disposal of rubbish.

La gestion des rebuts et des déchets: taxe sur la disposition versus frais pour usage du service de collecte. La collecte des rebuts éparpillés ça et là et des déchets pose un problème de divergence entre coûts privés et sociaux. Cette note suggère qu'il faut considérer ces deux problèmes conjointement: pris isolément, des frais pour l'usage du service de collecte des déchets ont souvent été proposés comme moyen d'intérioriser les effets externes dans la gestion des déchets, cependant, quand le problème est situé dans un cadre plus vaste, il s'avère clair que ces frais devraient être négatifs, c'est-à-dire qu'il devrait y avoir une subvention pour ceux qui disposent de leurs déchets d'une manière appropriée.

I. INTRODUCTION

It is now part of the conventional wisdom that, theoretically at least, externalities, whether deplettable or undepletable, can be corrected for by the use of Pigouvian taxes (e.g., Baumol and Oates 1988, 23). Both litter and waste management are instances of externality or market failure, so it seems reasonable to consider whether Pigouvian tax/price solutions will work in these cases. There are two different social costs involved; one associated with litter (collection, disposal, eyesore, damage, pollution etc.) and one with ‘proper’ disposal through the waste management system. Ideally, a Pigouvian tax/price should be applied directly to each. Unfortunately, it is impractical to apply a tax to litter per se, so the focus has usually

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been on setting a commodity tax, commonly termed a disposal tax, which reflects the social costs to which the product gives rise (see, e.g., Bingham 1971) or a user charge to cover the costs associated with normal (non-litter) waste collection and disposal (e.g., Butlin 1981, 148). The former is a blunt instrument in that it necessarily fails to distinguish between litter and non-litter social costs; the latter, on the other hand, suffers from the significant drawback that, when set at the level of marginal direct costs of collection and disposal as is usually recommended, it provides an incentive to littering and dumping and hence to additional social costs. The point of course is that user charges make volumes of litter and non-litter wastes interdependent.

Taking account of litter/non-litter waste interdependency, this note shows that using either of the above instruments is welfare inferior to using the two in combination and that the combination may be used to obtain a welfare optimum. This optimal solution involves setting a disposal tax at the marginal social cost associated with littering, with a subsidy (negative user charge) for the ‘proper’ (non-littering) disposal of wastes set at the difference in social marginal costs as between littering and non-littering. In fact, once the interdependency is recognized, the optimal user charge is quite likely to be negative (i.e., a user subsidy) even in the absence of the disposal tax.

Refundable deposits for beverage containers have been around for many years with varying degrees of popularity; the refundable deposit in this context is simply a special case of the disposal tax plus user subsidy in which the tax equals the subsidy. It follows that wherever a refundable deposit is feasible, the disposal tax plus user subsidy (equivalent to a refundable deposit with only a partial refund) is also feasible. Since the latter combination welfare-dominates the former, we do not discuss the simple refundable deposit. In principle the idea of a combined disposal tax plus refund may be extended to almost any form of waste or recyclable material. The refund has the merit of making the would-be litterer face a price for littering; the marginal individual who is just induced to choose to take litter home thus incurs private subjective costs (time plus effort) equal to the level of the deposit. The drawback of using a subsidy alone is that disposal through appropriate waste management channels also imposes social costs; with the user subsidy alone, returners are not made to face this cost.

II. THE MARKET MODEL

There is a consumption good for which total demand is \( q \); this total demand can be subdivided between the demand associated with those who choose to litter, \( q_1 \), and the demand associated with those who do not, \( q_2 \). For simplicity, it is assumed that the demand functions are linear and that the consumption good is produced competitively at constant marginal cost \( c \) (cf. Massell and Parish’s (1968) analysis of the empty bottle market!)

1 This is the only paper to my knowledge that looks explicitly at the economics of setting a (profit
\begin{align}
q_1 &= \alpha_1 - \beta_1 (c + \tau) - \gamma r \\
q_2 &= \alpha_2 - \beta_2 (c + \tau - r) + \gamma r,
\end{align}

where \(\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma\) are positive constants. Here \(r\) denotes the disposal tax and \(\tau\), the user subsidy (or negative user charge). The full price paid by individuals who choose to litter is \((c + \tau)\), while it is \((c + \tau - r)\) for those who choose not to. Thus, varying \(\tau\) and \(r\) varies the long-run equilibrium prices individuals face. The subsidy affects demand by litterers through the own-price effect but also encourages such individuals to switch to the non-litter market; the effect of \(r\) on shifting demand between the two markets is captured by the term \(-\gamma r\) in (1) and \(+\gamma r\) in (2).

We now develop an expression for economic welfare as measured by willingness to pay minus private and social costs. The prices individuals face for littering and non-littering are, respectively,

\begin{align}
p_1 &= c + \tau, \\
p_2 &= c + \tau - r.
\end{align}

Using these, (1) and (2) may be re-expressed as

\begin{align}
q_1 &= \alpha_1 - (\beta_1 + \gamma)p_1 + \gamma p_2 \\
q_2 &= \alpha_2 - (\beta_2 + \gamma)p_2 + \gamma p_1.
\end{align}

Consumers' surplus (CS) is given by the line integral

\begin{equation}
CS = \int_{\tilde{p}_1}^{\tilde{p}_2} \sum_{i=1}^{2} q_i(p)dp_i,
\end{equation}

where \(\tilde{p}_1, \tilde{p}_2\) denote choke prices. Note that \(\partial q_1 / \partial p_2 = \partial q_2 / \partial p_1\). This equality of cross-price derivatives guarantees that the line integral is path independent, so consumers' surplus is well defined (see, e.g., Mohring 1971). Overall social benefit (\(W\)) is given by

\begin{align}
W &= CS + (p_1 - c - s_1)q_1 + (p_2 - c - s_2)q_2 \\
&= CS - (\tau - s_1)q_1 - (\tau - r - s_2)q_2.
\end{align}

maximizing) refundable deposit (in their case, for empty bottles). There are several papers that discuss the costs and benefits of refundable deposits without entering into the analysis of the setting of the level for such deposits (Porter 1978 is one of the most comprehensive.).
where $s_1$, $s_2$ denote the marginal social costs associated with littering and non-littering, respectively, and $c$ denotes the marginal cost of production of the consumption good. $c_s$ may be regarded as a function of $\tau$ and $r$ in view of (3) and (4). Noting that $\partial c_s/\partial p_i = -q_i$ (see, e.g., Brown and Sibley 1986), we have
\[
\frac{\partial W}{\partial \tau} = (\partial c_s/\partial p_1)\partial p_1/\partial \tau + (\partial c_s/\partial p_2)\partial p_2/\partial \tau + q_1 + (\tau - s_1)\partial q_1/\partial \tau \\
+ q_2 + (\tau - r - s_2)\partial q_2/\partial \tau \\
= -\tau(\beta_1 + \beta_2) + \beta_2 r + \beta_1 s_1 + \beta_2 s_2. \tag{9}
\]
Similarly,
\[
\frac{\partial W}{\partial r} = -\gamma(\tau - s_1) + (\tau - r - s_2)(\gamma + \beta_2). \tag{10}
\]
The welfare function is strictly concave since the Hessian matrix
\[
\begin{bmatrix}
W_{\tau\tau} & W_{\tau r} \\
W_{r\tau} & W_{rr}
\end{bmatrix}
= \begin{bmatrix}
-(\beta_1 + \beta_2) & -\beta_1 \\
-\beta_1 & -(\beta_2 + \gamma)
\end{bmatrix}
\]
is negative definite.

Equations (9) and (10) provide the basis for determining (i) the optimal level for a disposal tax alone, (ii) the optimal level for a user subsidy alone, and (iii) the optimal combination of user subsidy and disposal tax.

1. The optimal level for a disposal tax (alone)
Setting $r = 0$ and solving the equation $\partial B/\partial \tau = 0$ yields the solution denoted $\tau_a$, given by
\[
(r = 0) \quad \tau_a = (\beta_1 s_1 + \beta_2 s_2)/(\beta_1 + \beta_2). \tag{11}
\]
That is, the optimal disposal tax is a weighted average of the marginal social costs associated with littering and non-littering, the weights being the respective own price response coefficients. Thus $\tau_a$ lies between $s_1$ and $s_2$. Note that $\tau_a$ is not in general the same as the weighted average social cost ($s_wa$) defined by
\[
s_wa = (s_1 q_1 + s_2 q_2)/(q_1 + q_2). \tag{12}
\]
For comparison purposes, it is useful to calculate welfare associated with imposing the disposal tax alone. With $r = 0$, welfare is a function simply of $\tau$ and the increase in welfare relative to the no-tax situation, denoted by $\Delta W_a$, is given by
\[
\Delta W_a = \int_{\tau = 0}^{\tau = \tau_a} |\partial W/\partial \tau| d\tau = -\tau_a^2(\beta_1 + \beta_2)/2 + (\beta_1 s_1 + \beta_2 s_2)\tau_a \\
= (\beta_1 s_1 + \beta_2 s_2)^2/2(\beta_1 + \beta_2). \tag{13}
\]
2. The optimal level for a user subsidy (alone)
Setting \( r = 0 \) and solving the equation \( \partial W / \partial r = 0 \) yields the solution denoted \( r_b \) given by

\[
(r = 0) \quad r_b = \left[ 1 / (\gamma + \beta_2) \right] s_1 - s_2. \tag{14}
\]

Although there may be occasional exceptions (remote habitations, etc.), it will usually be the case that \( s_1 > s_2 \); that is, the social costs associated with litter are significantly greater than those of non-litter wastes. If so, then \( r_b \) may be positive or negative (negative or positive user charge). Clearly, from (14), \(-s_2 < r_b < s_1 - s_2\). Ceteris paribus, the user subsidy (i) encourages non-littering (marginal benefit \( s_1 - s_2 \)), but (ii) encourages more sales of the product (marginal social cost \( s_2 \)). Thus as \( \gamma \to \infty \), \( r_b \to s_1 - s_2 \) (positive subsidy) while if \( \gamma \to 0 \), \( r_b \to -s_2 \) (positive user charge). This is intuitive, since \( \gamma \) large/small corresponds to the principal effect of the subsidy being (i)/(ii), respectively.

The increase in welfare relative to the no tax situation in this case is given by

\[
\Delta W_b = \int_{r=0}^{r=r_b} [\partial W / \partial r] dr = [\gamma s_1 - (\gamma + \beta_2) s_2] r_b - (\gamma + \beta_2) r_b^2 / 2
\]

\[
= \left[ \gamma s_1 - (\gamma + \beta_2) s_2 \right] ^2 / [2(\beta_2 + \gamma)]. \tag{15}
\]

3. Optimal levels for disposal tax and user subsidy
The solution in this case is obtained by solving the equations \( \partial W / \partial r = 0 \) and \( \partial W / \partial \tau = 0 \). The optimal levels are denoted \( r^* \) and \( \tau^* \) and from (9) and (10) are given by

\[
r^* = s_1 - s_2 \tag{15}
\]

\[
\tau^* = s_1, \tag{17}
\]

which in turn imply that consumers face prices \( s_1 \) and \( s_2 \) for littering and non-littering, respectively. Thus the solution involves simply making individuals face the full social costs they impose on society. This is a global welfare maximum solution, since the benefit function is strictly concave. In general, \( s_1 > s_2 \), so the solution involves a positive user subsidy.

4. Welfare comparisons
Using the optimal combination of instruments gives maximum welfare; strict concavity implies that using either instrument alone is welfare inferior. Whether using a disposal tax alone is better or worse than a user subsidy alone is generally ambiguous, depending as it does on \( \beta_1, \beta_2, s_1, s_2, \) and \( \gamma \). However, it is clear from (13) and (15) that, assuming \( s_1 > s_2 \), then as \( \gamma \to 0 \), \( \Delta W_\tau > \Delta W_b \), while as \( \gamma \to \infty \), \( \Delta W_\tau < \Delta W_b \) so, ceteris paribus, the larger \( \gamma \) is, the more likely that the
user subsidy is preferable. This is as one would expect, since the larger the value for $\gamma$, the more effective the subsidy is for reforming otherwise would-be litterers.

Relative to applying either instrument on its own, it is straightforward to show that the optimal user subsidy $r^*$ is greater than the subsidy $r_b$ alone and that the optimal disposal tax $\tau^*$ is also greater than the tax alone $\tau_d$; thus,

\[-s_2 < r_b < r^* = s_1 - s_2 \]
\[s_2 < \tau_d < \tau^* = s_1. \tag{20} \]
\[s_2 < \tau_d < \tau^* = s_1. \tag{21} \]

Intuitively, this makes sense, since in combination each cures the other of its defects; the tax alone is unable to distinguish between litter and non-litter social costs, while the user subsidy alone provides no incentive to curb wastes in general.

III. CONCLUDING COMMENTS

So far, the use of refundable deposits seems to be fairly limited (and is mainly to do with bottles\(^2\)), yet in principle the idea could be extended to a variety of applications including non-glass containers (plastic bottles, tins, and cans) and dealing with packaging and paper wastes. Obviously, the benefits from any such scheme would need to be weighed against the implementation costs. However, if the environment is, as it is often claimed to be, becoming an increasingly scarce resource, then it would seem that disposal taxes and user subsidies may well have a role to play at some stage in its protection; if marginal social costs are increasing over time, then the benefits to be derived from such schemes are also increasing relative to the costs of implementing them.

REFERENCES


\(^2\) Oregon's bottle bill is discussed in Baumol and Oates (1981); a similar exercise for Michigan is discussed in Porter (1978, 1983).