The GSBGM Working Paper Series

WORKING PAPER 5/96

Optimal Policies for Solid Waste Disposal: Taxes, Subsidies and Standards

Karen Palmer and Margaret Walls

ISSN 1173-4523
ISBN 0-475-11503-1

The GSBGM Working Paper Series 5/96 May 1996.
Karen Palmer ** and Margaret Walls* 'Optimal Policies for Solid Waste Disposal: Taxes, Subsidies and Standards'

Please address inquiries concerning this paper direct to the authors*
General enquiries concerning GSBGM publications to:
Monica Cartner
Research Co-ordinator
The Graduate School of Business and Government Management
The Victoria University of Wellington
PO Box 600
Wellington
New Zealand

Telephone: 64-4-495 5085
Facsimile: 64-4-496 5435
E-mail: Monica.Cartner@vuw.ac.nz

* Margaret Walls
Economics Group
Victoria University of Wellington
PO Box 600
Wellington

** Karen Palmer
Resources for the Future
1616 P Street
Washington DC 20036
U.S.A.

Printed by The Victoria University of Wellington Printers.

Optimal Policies for Solid Waste Disposal: Taxes, Subsidies, and Standards

Karen Palmer
Resources for the Future

Margaret Walls
Economics Group, Victoria University of Wellington
and Resources for the Future

Abstract: Pricing trash collection and disposal services can be politically unpopular and may lead to increased illegal disposal of trash. Several studies have shown that deposit-refund systems can act like disposal charges without the illegal disposal problem and thus can generate an optimal amount of solid waste disposal. We assess the efficiency implications of an alternative policy currently in use in some states and considered at the federal level, recycled content standards. These are requirements that a certain fraction of total input use be comprised of secondary materials. We find that such standards by themselves cannot generate the optimal amount of disposal but must be combined with additional taxes on both the final product and other inputs to production. Moreover, the information requirements for setting the optimal standards and accompanying taxes are high. The deposit-refund approach would be preferred in most cases.

Key Words: Solid Waste, Recycling, Deposit-Refund, Recycled Content Standards

JEL Classification Codes: H21, Q28

Optimal Policies for Solid Waste Disposal: Taxes, Subsidies, and Standards

Karen Palmer and Margaret Walls*

I. Introduction

Many communities in the United States provide public trash collection and disposal services to all households within their boundaries. In most cases the costs of providing these services are covered by local property or other tax revenues and, therefore, each household's contribution to these revenues is largely independent of the volume of trash that it generates. Under such a funding mechanism, households face a zero price for each additional container of trash that they set out. Since the marginal cost of waste collection and disposal is greater than zero, an inefficiently large quantity of trash is generated.

A potential solution to this problem which has been adopted in some communities is to charge households for each bag or container of trash, a practice often referred to as "unit-pricing." If the per-unit charge on disposal reflects the sum of the marginal private cost of waste collection and disposal and any associated externalities, then the resulting level of solid waste disposal will be efficient in the absence of illegal dumping of waste (Jenkins, 1993). However, if consumers respond to the unit disposal charges by dumping, then the additional costs associated with dumping -- either the external costs or the costs associated with additional monitoring, enforcement, and collection of illegally disposed waste -- may outweigh the

* This research was supported by the U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, through a cooperative agreement with Resources for the Future (#R821821-01). We have benefited from discussions with and suggestions from Andrew Brod, Don Fullerton, George Garland, Tom Kinnaman, Clare Lindsay, Debbie Nestor, Hilary Sigman, Brett Van Akkeren, several of our colleagues at RFF, and two anonymous referees. We also appreciate the excellent research assistance of David Edelstein and Richard Akresh.

efficiency gains from the reduction in legal waste disposal. Fullerton and Kinnaman (forthcoming) offer some evidence that charging for disposal may lead to increased illegal disposal. Porter (1978) estimates substantial costs associated with such illegal disposal. Even if dumping is not likely to be a problem, communities may still be unable to adopt unit pricing of trash due to political opposition to what is perceived as a new tax.

As an alternative to unit pricing, environmental policy makers and legislators in the U.S. are considering a number of policy measures designed to increase recycling and thereby reduce the quantity of trash ultimately disposed of by households. These policies include subsidies for recycling, taxes on virgin inputs to production, deposit-refund systems for beverage containers, lead-acid batteries and other products, minimum recycled content standards for newsprint and other products, and investment tax credits for the purchase of recycling equipment. In recent years, recycled content standards -- requirements that products be manufactured with a certain minimum amount of secondary materials as a share of overall virgin plus secondary materials -- have garnered a great deal of attention. In the United States, thirteen states plus the District of Columbia have adopted recycled content standards for newsprint ranging from 23 to 50 percent. Several bills have also been introduced in the U.S. Congress that would establish recycled content standards for a number of different products. The Recycling Advisory Council, an organization whose members include representatives from American industry, environmental groups and government, has developed a list of federal government policy options for promoting the development of markets for recyclables; this list includes recycled content standards among the preferred options (RAC, 1993). In addition, many states and the U.S. federal government mandate that products purchased by government agencies be made with a certain minimum recycled content.

While several studies have examined the efficiency of tax and subsidy schemes for reducing waste disposal, there are no similar studies focusing on recycled content standards. In this paper, we develop a theoretical, partial equilibrium model of the market for a generic consumer good produced with virgin and secondary inputs that is ultimately disposed of in a landfill. The model encompasses both the consumption and disposal decisions of consumers and the production and input use decisions of firms. After characterizing the socially efficient outcome with the model, we analyze both a deposit-refund and a recycled content standard as means for achieving this outcome.

Several studies have shown the efficiency of the deposit-refund (Dinan, 1993; Fullerton and Kinnaman, 1995; Sigman, 1995). Since consumers end up paying a tax only on those units of the consumption good that are not recycled, the deposit-refund is equivalent to taxing disposal but without the attendant illegal disposal problems.

Dinan (1993) and Fullerton and Kinnaman (1995) also obtain the general result that policies focusing only on input use, such as recycling subsidies and virgin materials taxes, cannot generate the optimal amount of disposal unless coupled with a tax or subsidy on consumption. Fullerton and Kinnaman (1995) also show that, in the virgin materials tax case, other inputs to production must also be taxed to generate the optimum.[1]

We obtain similar results here for the recycled content standard. The standard alone cannot generate the optimal amount of output and waste disposal. It must be combined with

[1] In our working paper (Palmer and Walls, 1994), we also show that a virgin materials tax needs to be coupled with both an output tax and a tax on other inputs to production, such as labor, to generate the optimum. We find that the optimal set of taxes in this case depends on the form of the production function. Since policymakers usually do not have access to such information, this policy would be difficult to implement. We also analyze a recycling investment tax credit (ITC), a popular policy in many states. Like recycling subsidies, recycling ITCs must be coupled with a tax on output to generate the optimum but no additional taxes on other inputs are necessary.

taxes on other inputs to production and either a tax or a subsidy, depending on the form of the production function, on the final product. Setting the optimal taxes and standard could be very difficult for policymakers because of the firm-specific information required. In fact, often no *one* set of taxes and standard will achieve the optimum. We conclude that the recycled content standard is far inferior to the deposit-refund as a means of generating optimal amounts of solid waste disposal and recycling.

II. The Model and the Social Optimum

The model combines both producer and consumer behavior. All markets are assumed to be perfectly competitive and in long-run equilibrium. On the production side, we assume that there are n identical firms in the consumer product industry, each of which uses virgin materials, v, and recyclables, r, to produce output, q; each also uses an additional, nonmaterial input which we will call labor, l. The firm's production function is given by $q = f(v, r, l)$.[2]

We assume that there is a residual associated with the production process that is a function of the amount of inputs used and it is denoted $z = z(v, r, l)$. Explicitly incorporating a residual from production allows us to use a more general and more realistic production function where all of the material inputs are not necessarily converted into final product as assumed by Sigman (1995) and Miedema (1983).[3] This production residual could take a number of different forms ranging from particles emitted into the air at aluminum smelters to sludge that is generated by paper manufacturing.[4] We assume that the firm pays a price, p_Z, to dispose of the production residual and this price reflects the full marginal social costs of the residual. The firm

[2]In our working paper (Palmer and Walls, 1994), we include recycling capital equipment in the model because we wish to analyze the effects of a recycling investment tax credit. None of our results here are affected by exclusion of this additional factor.

[3] The production function in these studies is $q=v+r$. Dinan (1993) uses the more general form as we do but does not include any costs associated with disposal of the production residual.

[4] In the case of newspapers, deinking and repulping operations generate a large amount of sludge as a result of the breakdown of fibers from repeated recycling.

takes all prices -- the price of output, P_q, the price of the virgin material, p_v, the price of recyclables, p_r, the price of labor, p_l, and the charge for disposing of its own residual, p_z, as given.

The consumer side of the market is represented by the (inverse) market demand function, $P_q(nq)$. Consumers also make decisions about recycling and disposal of used products. We assume that each consumer has increasing marginal costs of recycling and that this leads to a market supply curve for recyclables represented by $c_r(nr)$. Consumers take the price of solid waste disposal, p_d, as given. This price is assumed to reflect the full marginal social cost of disposal of municipal solid waste, including all environmental costs.[5]

We assume that a materials balance condition must hold -- i.e., that the sum of all new material inputs used in the production process across all firms must equal the sum of all residuals from consumption and production or $nv = D + nz$, where D is the total quantity of solid waste disposed of in a landfill. Total solid waste disposal equals total production minus total recycling or $D = n(q-r)$.[6] Substituting this expression into the materials balance condition yields $nv+nr = nq+nz$, or $v+r = q+z$.

The socially optimal levels of v, r, l, and D are determined by maximizing net social surplus subject to the mass balance condition. Substituting in for z from the mass balance condition yields the following objective function:

$$(1) NSS = \int_0^{nf(v,r,l)} P_q(s)\,ds - \int_0^{nr} c_r(x)dx - np_v v - np_l l - np_z(v+r-f(v,r,l)) - np_d(f(v,r,l)-r)$$

[5] A real world alternative to domestic disposal and reusing r in production of q is exporting r. Including this alternative, however, only adds another dimension to the model without changing our general conclusions about the policy options. Essentially, when exporting r is a possibility, an export subsidy is always necessary with any of the policy options considered. (In the Dinan (1993) model, r can be used to produce a second product from which domestic consumers receive benefits but for which there are no social costs of disposal. It is not clear to us what products fit this characterization, so we choose to leave this feature out of our model as well.)

[6] To avoid issues of discounting and price changes over time, we assume that products last only one period or that the market is in a long-run steady state.

Maximizing *NSS* with respect to *v*, *r*, and *l* under the assumption that the market for the secondary material is in equilibrium, and therefore $p_r^* = c_r$, yields the following first-order conditions:

$$(2)\left(P_q^* + p_z - p_d\right)\left(\frac{\partial f}{\partial v}\right) = p_v + p_z$$

$$(3)\left(P_q^* + p_z - p_d\right)\left(\frac{\partial f}{\partial r}\right) = p_r^* + p_z - p_d$$

$$(4)\left(P_q^* + p_z - p_d\right)\left(\frac{\partial f}{\partial l}\right) = p_l$$

where P_q^* is the market-clearing price of output.

According to these three first-order conditions, each input will be employed until the point where the value of its marginal product, given by the expression on the left-hand side of each equation, is equal to its net price. The net price of the virgin input equals the sum of the market price of virgin materials and the marginal social cost of the additional manufacturing residual associated with additional virgin material use. The net price of the secondary material equals its market price less the marginal disposal cost avoided plus the marginal social cost of the additional manufacturing residual associated with additional secondary material use.

The socially optimal outcome described by equations (2), (3), and (4) will result, in the absence of illegal disposal, when consumers are required to pay a disposal price equal to the full marginal social cost of product disposal. However, either due to the incentives for illegal dumping created by charging for legal disposal or to the political opposition to imposing such a fee, we assume that it is impossible to charge consumers the full social cost for solid waste disposal. We show in the next section that a deposit-refund can achieve the same outcome. We then analyze the feasibility of using recycled content standards to obtain the optimum. In these policy exercises we assume that there is a zero charge for waste disposal.

III. Deposit-refund System

As stated in the introduction, several studies have shown that a deposit-refund system -- i.e., a combination of a tax on the final product and a subsidy to recycling -- can achieve the socially optimal amount of waste disposal. In the context of our model, firms would choose inputs *v, r,* and *l* so as to maximize profits:

$$(5)\Pi = (P_q - t_q)f(v,r,l,) - (p_r - s_r)r - p_v v - p_l l - p_z(v + r - f(v,r,l))$$

where t_q is the tax on output -- i.e., the deposit -- and s_r the subsidy to recycling -- i.e., the refund. The first-order conditions are:

$$(6)(P_q - t_q + p_z)\left(\frac{\partial f}{\partial v}\right) = p_v + p_z$$

$$(7)(P_q - t_q + p_z)\left(\frac{\partial f}{\partial r}\right) = p_r - s_r + p_z$$

$$(8)(P_q - t_q + p_z)\left(\frac{\partial f}{\partial l}\right) = p_l$$

Assuming $P_q = P_q^*$ and $p_r = p_r^*$ (conditions that must hold to achieve the optimum) and comparing equations (6), (7), and (8) to the socially optimal first-order conditions (2), (3), and

(4), we note that the expressions are identical as long as $t_q = s_r = p_d$ -- i.e., the deposit must equal the refund and both must be set equal to the marginal social cost of disposal. No taxes or subsidies on the other inputs to production are necessary. Notice that subsidizing recycling alone will not generate the optimum. It will lead to the optimal *combination* of inputs for a given level of output, but it will lead to too much output and solid waste.[7]

IV. Recycled Content Standards

Recycled content standards require that products be manufactured with a certain minimum amount of secondary materials as a fraction of total virgin plus secondary inputs. As we state in the introduction, several states in the U.S. have such requirements for newspapers and the idea has met with some support at the federal level. The federal government and several state governments also have requirements that their own purchases consist of products that meet certain minimum recycled content standards.

In terms of our model, the requirement that a certain fraction, β, of total material input use consist of recyclables means that $r = \beta(r+v)$, or $v = r\left(\frac{1-\beta}{\beta}\right)$. We would then like to know what value of β, if any, will yield the optimal amounts of *r, v, l,* and *q* (and thus *D*).

We note first that there is a *v/r* implicitly defined by the ratio of equations (2) and (3) -- i.e., there is a $\frac{v^*(p_v, p_r, p_l, p_z, p_d, q)}{r^*(p_v, p_r, p_l, p_z, p_d, q)}$ chosen so that $\frac{\partial f/\partial v}{\partial f/\partial r} = \frac{p_v + p_z}{p_r + p_z - p_d}$. Thus, we can define a recycled content standard that will yield the optimal *combination* of the two material inputs for a given level of output. Figure 1 shows how the recycled content standard works. The slope of a ray going through point A is defined by the ratio of equations (2) and (3) given above and this slope defines the recycled content standard that will achieve the optimal combination of inputs

[7] In practice, there could be significant administrative costs associated with refunding deposits which could reduce the efficiency of this approach. See Palmer, Sigman, and Walls (1995) for a discussion of this issue and numerical estimates of the effects of administrative costs on the overall efficiency of deposit-refunds relative to product taxes and recycling subsidies.

for a given output level. However, like a recycling subsidy, the standard by itself, in general, will not yield the optimal amount of output and solid waste. Notice that there are many potential points along the ray where the tangency condition could hold; points B and C in the figure are two examples. In fact, if the production function is homothetic, there are an infinite number of such points since the output expansion path for a homothetic function is a straight line out of the origin. Even in the case of a nonhomothetic function, there may be more than one tangency along the ray. And finally, even with a nonhomothetic function and one tangency, there is no guarantee that the firm will locate exactly at point A.

Since β by itself cannot achieve the optimum, we ask what combination of β and an output tax and/or labor tax would generate the optimum. To do this, we must select a particular functional form for the production function. We use a Cobb-Douglas production function: $q = f(v, r, l) = v^{1-\alpha-\gamma} r^{\alpha} l^{\gamma}$. In this case, the first order conditions for the social optimum -- analogous to equations (2), (3), and (4) -- are:

$$(9)\left(P_q^* - p_d + p_z\right)(1-\alpha-\gamma)v^{-(\alpha+\gamma)} r^{\alpha} l^{\gamma} = p_v + p_z$$

$$(10)\left(P_q^* - p_d + p_z\right)\alpha v^{1-\alpha-\gamma} r^{\alpha-1} l^{\gamma} = p_r^* + p_z - p_d$$

$$(11)\left(P_q^* - p_d + p_z\right)\gamma v^{1-\alpha-\gamma} r^{\alpha} l^{\gamma-1} = p_l$$

Combining (9) and (10) and rearranging terms yields the ratio of the optimal quantity of v to r, or the expression for $\dfrac{1-\beta}{\beta}$ at the optimum:

$$(12)\left(\frac{1-\beta^*}{\beta^*}\right) = \frac{v^*}{r^*} = \left(\frac{1-\alpha-\gamma}{\alpha}\right)\left(\frac{p_r^* + p_z - p_d}{p_v + p_z}\right)$$

We now set up the firm's profit-maximization problem with $p_d=0$ and a recycled content standard given by equation (12) and solve for the taxes on output and labor that generate the overall social optimum. The requirement with the recycled content standard is that $v=\left(\frac{1-\beta^*}{\beta^*}\right)r$. Incorporating this condition and potential taxes on labor, t_l, and output, t_q, into the firm's profit expression yields:

$$(13)\Pi=(P_q^{rcs}-t_q)\left(\frac{1-\beta^*}{\beta^*}\right)^{1-\alpha-\gamma}r^{1-\gamma}l^{\gamma}-p_v\left(\frac{1-\beta^*}{\beta^*}\right)r-p_r^{rcs}r-(p_l+t_l)l$$
$$-p_z\left(\left(\frac{1-\beta^*}{\beta^*}\right)r+r-\left(\frac{1-\beta^*}{\beta^*}\right)^{1-\alpha-\gamma}r^{1-\gamma}l^{\gamma}\right)$$

Maximizing this expression with respect to the two independent inputs, r and l, yields two first order conditions:

$$(14)\left(P_q^{rcs}-t_q+p_z\right)\left(\frac{1-\beta^*}{\beta^*}\right)^{1-\alpha-\gamma}(1-\gamma)r^{-\gamma}l^{\gamma}=\left(p_v+p_z\right)\left(\frac{1-\beta^*}{\beta^*}\right)+p_r^{rcs}+p_z$$
$$(15)\left(P_q^{rcs}-t_q+p_z\right)\left(\frac{1-\beta^*}{\beta^*}\right)^{1-\alpha-\gamma}\gamma r^{1-\gamma}l^{\gamma-1}=p_l+t_l$$

Substituting v/r for $\frac{1-\beta^*}{\beta^*}$ on the left-hand side of these two equations and $\left(\frac{1-\alpha-\gamma}{\alpha}\right)\left(\frac{p_r^*+p_z-p_d}{p_v+p_z}\right)$ for $\frac{1-\beta^*}{\beta^*}$ on the right-hand side (from equation (12)) yields:[8]

[8] We assume $p_r^{rcs}=p_r^*$ and $P_q^{rcs}=P_q^*$, conditions that must hold at the optimum.

$$(16)\left(P_q^* - t_q + p_z\right)(1-\gamma)\left(\frac{v}{r}\right)^{1-\alpha-\gamma}\left(\frac{l}{r}\right)^{\gamma} = \left(\frac{1-\gamma}{\alpha}\right)\left(p_r^* + p_z\right) - \left(\frac{1-\alpha-\gamma}{\alpha}\right)p_d$$

$$(17)\left(P_q^* - t_q + p_z\right)\gamma\left(\frac{v}{r}\right)^{1-\alpha-\gamma}\left(\frac{l}{r}\right)^{\gamma-1} = p_l + t_l$$

Jointly solving (16) and (17) for t_l and t_q gives:[9]

$$(18)\, t_l = \left(\frac{\alpha}{1-\gamma}\right)\left(\frac{\gamma r}{\alpha l}\right)p_d$$

$$(19)\, t_q = p_d\left[1 - \left(\frac{1}{1-\gamma}\right)\left(\frac{r}{v}\right)^{1-\alpha}\left(\frac{v}{l}\right)^{\gamma}\right]$$

The tax on labor is positive and increasing in p_d, thus the greater the social costs associated with waste disposal, the greater the tax on labor that is necessary to reduce labor, output, and ultimately waste. The tax on labor is also increasing in the term in the second parentheses in equation (18). This term is the ratio of the marginal product of labor to the marginal product of recyclables -- i.e., the marginal rate of technical substitution (MRTS) between labor and recyclables. A greater MRTS indicates that the marginal unit of labor input leads to a larger increase in output than does the marginal unit of recyclables. To overcome this difference in marginal productivities and get to the social optimum, one needs a larger tax on labor.

---

[9] One can solve for t_l and t_q by taking ratios of equations (16) and (17), substituting from the ratio of first-order conditions for the social optimum (equations (10) and (11)), and solving for t_l, then substituting the solution for t_l, in equation (17) and using (11) to solve for t_q.

The tax on output is also increasing in p_d, the marginal social cost of disposal, but the tax could be positive, negative, or zero. To see this, notice that the last two terms in parentheses in equation (19) are related to the marginal product of recyclables. We rewrite (19) as the following:

$$(20)\, t_q = p_d\left[1-\frac{\alpha}{(1-\gamma)}\cdot\frac{1}{MP_r}\right]$$

If $MP_r > \frac{\alpha}{1-\gamma}$ then the tax on output is positive; if $MP_r < \frac{\alpha}{1-\gamma}$ then the tax on output is negative (i.e., we need to subsidize output); and if $MP_r = \frac{\alpha}{1-\gamma}$ then no output policy is needed -- the labor tax and the recycled content standard together achieve the social optimum.

These results make sense. Again, the greater the marginal social costs of disposal, the more we need to tax output to reduce it and reduce disposal. The second condition is less obvious but also intuitive. First, recall from Figure 1 that the recycled content standard encourages the use of recyclables and discourages the use of virgin materials but it may tend to increase or decrease output depending on the form of the production function. If the marginal product of recyclables is relatively high -- greater than $\frac{\alpha}{1-\gamma}$ to be specific -- the standard tends to increase output (and thus solid waste) so equation (20) indicates that we need to tax output; if the marginal product of recyclables is relatively low, the standard tends to reduce output below the optimum so we need to subsidize output.

Although the set of policies given by equations (12), (18), and (20) can generate the socially optimal amount of disposal, there are several reasons why this approach is less preferred than the deposit-refund. First, an additional tax is necessary. Under the deposit-refund approach, labor could be left alone; with the recycled content standard policy, a tax on labor is needed to get the overall optimum. Second, the optimal recycled content standard and associated taxes are complicated and depend on the form of the production function. By contrast, the optimal deposit and refund depend only on the marginal social cost of disposal -- not a trivial information requirement, but certainly less demanding than knowing the form of the production function. Third, setting one standard and set of taxes for a given product may be impossible in cases where multiple recyclables are used to produce a single product. For example, when old newspaper is used to produce newsprint, it is almost always combined with between 20 and 50 percent coated old magazine stock to help with deinking and to provide strength. Setting the optimal recycled content standard and associated labor and output taxes would require knowledge of the aggregate marginal product of an optimal mix of the two recycled inputs. Finally, we are assuming that all firms are identical. If firms in an industry have different production functions, then there is no single standard that all firms could meet that would generate the social optimum. Even setting an industry-wide standard and allowing trading across firms in the industry would still leave the government with the dilemma of how to tax labor and output. With differentiated firms, optimal labor and output tax rates would need to be firm-specific and setting such tax rates would pose a seemingly insurmountable problem for government.[10]

[10] Many of these same issues arise with virgin materials taxes. See Palmer and Walls (1994).

V. Conclusions

Many of the solid waste policies which have been proposed by the U.S. government or adopted by some states in the U.S. including virgin materials taxes, investment tax credits for recycling equipment and recycled content standards actually focus on the inputs to production instead of on disposal itself. Earlier studies have shown that virgin materials taxes used in isolation can either lead to inefficient reductions in production of valuable consumer products or actual increases in municipal solid waste disposal (Dinan, 1993). Such taxes must be combined with taxes on output and other inputs to production in order to generate the optimal amount of solid waste disposal (Fullerton and Kinnaman, 1995; Palmer and Walls, 1994).

In this paper, we show that the recycled content standard has problems similar to the virgin materials tax. By itself, the standard can lead to either too much or too little output or solid waste, depending on the form of the production function; it also leads to an inefficient use of other factors of production such as labor. In order to avoid these unintended effects, additional taxes or subsidies are necessary. In this paper, we derive an expression for the optimal product tax and tax on other inputs to production that must be used in combination with a recycled-content standard when the firm has a Cobb-Douglas production function. However, actually implementing this combination of policies requires information that is generally beyond the reach of policy-makers. Moreover, in the case where firms are heterogeneous, setting the optimal policies may be impossible.

An alternative policy that overcomes many of the pitfalls of recycled-content standards and other input-directed policies is the deposit-refund. As demonstrated above, the optimal deposit-refund consists of a tax on production combined with a subsidy of recycled products both of which are equal to the marginal social cost of disposal. The combined deposit-refund is relatively easy to set, particularly when compared to the recycled content standard, and does not depend on the specific form of the firm's production function. Moreover, this policy does not require any additional taxes or subsidies in order to achieve optimal input use.

References

Dinan, Terry M. 1993. "Economic Efficiency Effects of Alternative Policies for Reducing Waste Disposal" *Journal of Environmental Economics and Management* 25, 242-256 (December).

Fullerton, Don and Tom Kinnaman. 1995. "Garbage, Recycling and Illicit Burning or Dumping." *Journal of Environmental Economics and Management* 29, 78-91 (July).

Fullerton, Don and Thomas Kinnaman. forthcoming. "Household Demand for Garbage and Recycling Collection with the Start of a Price Per Bag," *American Economic Review.*

Jenkins, Robin. 1993. *The Economics of Solid Waste Reduction: The Impact of User Fees* (Brookfield, VT: Edward Elgar Press).

Miedema, Allen K. 1983. "Fundamental Economic Comparisons of Solid Waste Policy Options," *Resources and Energy* 5, 21 - 43 (March).

Palmer, Karen, Hilary Sigman, and Margaret Walls. 1995. "The Costs of Reducing Municipal Solid Waste," draft manuscript (September).

Palmer, Karen and Margaret Walls. 1994. "Materials Use and Solid Waste Disposal: An Evaluation of Policies," Resources for the Future Discussion Paper 95-02 (Washington, DC: RFF, October).

Porter, Richard C. 1978. "A Social Benefit-Cost Analysis of Mandatory Deposits on Beverage Containers," *Journal of Environmental Economics and Management* 5, 351-375 (December).

Recycling Advisory Council (RAC). 1993. *RAC Market Development Committee: Market Structure Policy Options Briefing Book*, Washington, DC (April).

Sigman, Hilary. 1995. "A Comparison of Public Policies for Lead Recycling," *Rand Journal of Economics.*

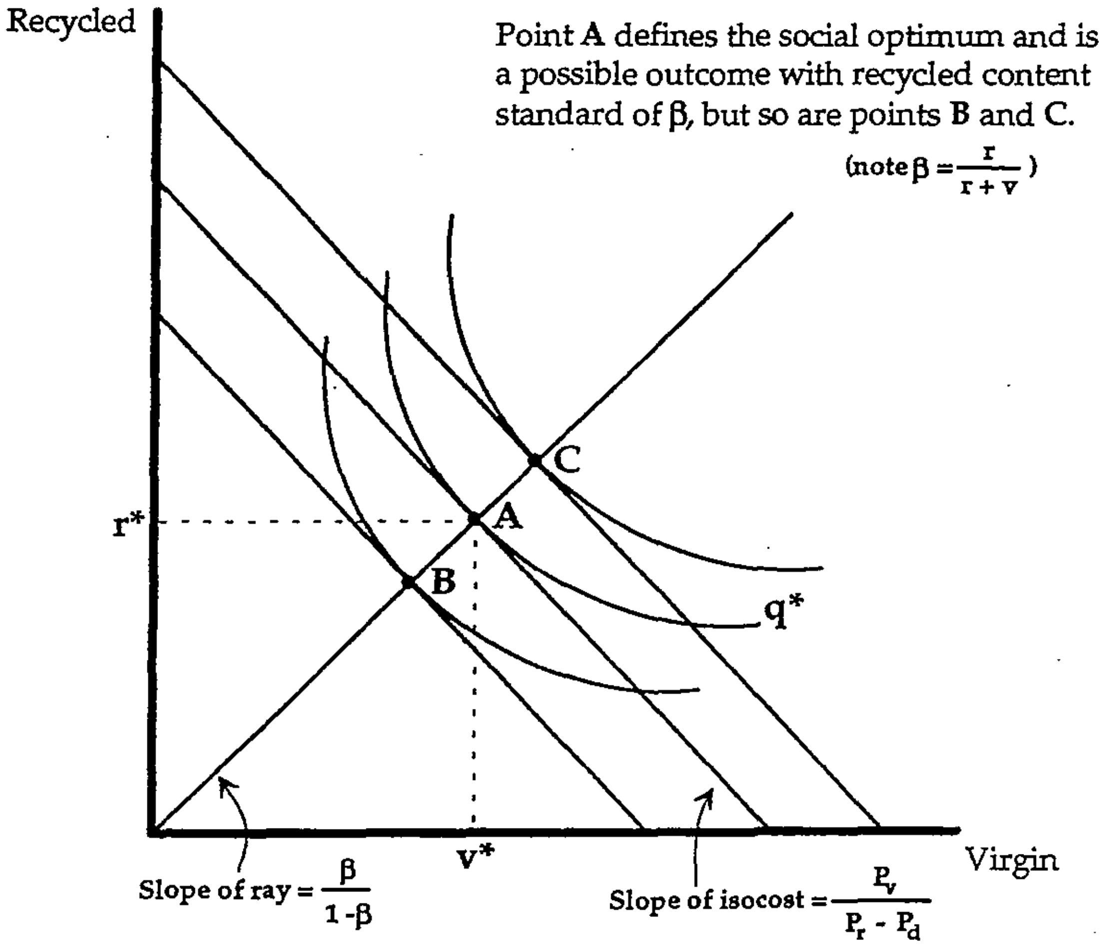

Figure.1. Recycled Content Standard

THE GSBGM WORKING PAPER SERIES

The main purpose of this series is to reach a wide audience quickly for feedback on recently completed or in progress research. All papers are reviewed before publication.

A full catalogue with abstracts and details of other publications is available, for enquires and to be included in our distribution list, write to:

Monica Cartner
Research Programmes Co-ordinator,
GSBGM, Victoria University of Wellington,
PO Box 600, Wellington, New Zealand
Tel: (04) 495 5085; Fax: (04) 712 200

Code in bold denotes order number, eg: WP 1/91

--- Group denotes the author's academic discipline Group (note this does not necessarily define the subject matter, as staff's interests may not be confined to the subjects they teach).

1990 - 1993 titles available on request.

WP 1/95 **Management Group**
Gilbertson, D.K., Wright, H., Yska, G, Gilbertson, D.W. and 1994 Students of MGMT 306 'Kiwi entrepreneurs: A study.'

WP 2/95 **Management Group**
Cavana, R. 'Policy issues related to coastal and international shipping in New Zealand'

> Shipping policy issues. *Transportant: The Journal of the Chartered Institute of Transport in New Zealand* 1995, Vol 25, No 2, 17-19.

WP 3/95 **Information Systems Group**
Bonner, Marcus 'On seeing information systems as bridges'

WP 4/95 **Management Group**
Cavana, Bob, Rob Crozier, Barrie Davis and Perumal Pillai 'A survey of academic staff attitudes towards the system of academic titles used in New Zealand universities'

WP 5/95 **Econometrics Group**
Krawczyk, J.B. and G. Zaccour 'Pollution management through levies and subsidies'

WP 6/95 **Marketing Group**
Ashill, Nicholas and Malcolm Wright 'Marketing information systems - A review and reconceptulisation'

WP 7/95 **Information Systems Group**
Casey, Mary-Ellen 'An exploratory study into the use of information technology as an important enabler of organisational differentiation in the financial sector'

WP 8/95 **Economics Group**
Boles de Boer, David and Lewis Evans 'The economic efficiency of telecommunications in a deregulated market: the case of New Zealand'

WP 9/95 **Management Group**
Mabin, Victoria J. 'Using spreadsheet optimisation facilities as a decision aid within the theory of constraints framework'

WP 10/95 **Economics Group**
M. Khaled, M.D. Adams and M. Pickford 'Estimates of scale and scope economies in the New Zealand life insurance industry.'

WP 11/95 **Economics Group**
John A. Carlson and Robert A. Buckle 'Price duration with two-sided pricing rules'

WP 12/95 **Economics Group**
Ganesh Nana 'Developing a multi-sectoral CGE model of the New Zeland economy.'

WP 13/95 **Money and Finance Group and Economics Group**
Stephen Burnell, Lewis Evans and Shuntian Yao 'Network games: The optimal network contract and the efficiency of bypass in oligopolistic network industries under light regulation'

WP 14/95 **Economic History Group**
Gordon Boyce 'The Nickel Syndicate, 1901 - 1939'

WP 15/95 **Money and Finance Group**
Jan Whitwell 'Monetary disinflation with inflation inertia: Central bank autonomy in an open economy'

WP 16/95 **Economics Group**
Emery, H. Daniel V. Gordon and Doug McClintock 'On the efficacy of construction site safety inspections.'

WP 17/95 **Economics Group**
Ganesh Nana 'An inter-temporal CGE model with fiscal and sector balances'

WP 18/95 **Economics Group**
Jie Zhang 'Government debt, human capital, and endogenous growth'

WP 19/95 **Accountancy Group**
Zahirul Hoque and Manzurul Alam 'Quality management and accounting in a New Zealand service organisation: Towards an institutional perspective on management accounting'

WP 20/95 **Economics Group**
Paul Calcott 'Can we test for supplier-induced demand by comparing informed with uninformed consumers?'

WP 1/96 **Management Group**
M.W. Lee, J. Bennett, R.J. Taylor and R.Y. Cavana 'A dynamic simulation model for possum and gorse control on a farm woodlot.'

WP 2/96 **Economics Group**
Jie Zhang 'Optimal public investments in education, and endogenous growth'

WP 3/96 **Economics Group**
Paul Tompkinson 'The benefits of tariff reductions in the presence of psychological adjustments costs.'

WP 4/96 **Economics Group**
Shuntian Yao 'A note on the decision of a sales maximizer in response to the increase of per unit cost.'

WP5/96 **Economics Group**

Karen Palmer and Margaret Walls 'Optimal policies for solid waste disposal: taxes, subsidies and standards'

WP6/96 **Economics Group**

Margaret Walls and Jean Hanson 'Distributional impacts of an environmental tax shift: the case of motor vehicle emission taxes.'

WP7/96 **Economics Group**

Lloyd S Shapley and Shuntian Yao 'Dynamic properties of the Nash equilibrium.'

WP 8/96 **Accountancy Group**

Kamran Ahmed, Kazi Feroz Alam and Manzurul Alam 'An empirical study of factors affecting accounting students' career choice in New Zealand'