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Taxation of Reusable Goods

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Taxation of reusable goods

1. Introduction¹

The characteristic of a reusable good is that when a consumer does not want to use it any more it can be transferred to someone else for continued use so long as the commodity is not worn out. There seems to be a growing opinion that more extensive reuse is desirable, lending support to policies that would stimulate reuse of goods. The aim should be a circular economy. The notion is that reuse will diminish the need for producing the goods in question. In several cases the argument is that the production of many goods cause externalities in terms of environmental problems. For alleviating such problems, economists would typically recommend imposing Pigouvian taxes as the most direct and efficient instrument. Another argument is that reuse should be encouraged to economise on resources. The economists' view would typically be that in a proper market the role of prices is indeed to reflect scarcity and provide incentives for economising on resources. Only if there is some kind of market failure would policy intervention be warranted.

In a tax context it is frequently argued that transactions facilitating reuse should be leniently taxed, if at all². This view may be related to the arguments outlined above but is often presented as essentially a tax argument, for instance along the line that a good should only be taxed once and not a second time in a second-hand market. For instance, no VAT should be levied on sales in second-hand markets. Below we address the topic as an optimum commodity tax problem. We do not discuss conceivable market failures and focus entirely on effects of taxes, including possible tax distortions.

2. The basic model

We assume that there are three goods, the quantities of which are denoted by c , x , and z . The c -good is referred to as general consumption. The x -good is a reusable good. The z -good denotes the x -good when reused, for instance being available in a second-hand market. We assume that after one period part of the amount of the reusable good is worn out and cannot be used any more. Only a fraction a of the acquired units of the x -good is reusable. The agent may then sell the remaining units to a reuse operator or simply dispose of it, say at some landfill. For simplicity we shall assume that reuse takes place within a single period. At the end of that period the good is worn out. We assume that the agent can both sell units to and buy units from the reuse operator. The underlying assumption may be that after a period the units to be reused need some mending that must be carried out by the reuse operator, or one might like to acquire second hand units that differ a bit from those that one has already used (e.g. clothes with a different colour or style). A third option might be to assume that the agent could keep some units for his

¹ I thank Åsa Hansson for reading a first draft of the paper. Most helpful comments by Fred Schroyen on another previous version are gratefully acknowledged.

² A few examples can be mentioned. MPs in the UK Parliament have been calling for lower VAT on recycled products (UK Parliament 2014). This was also the proposal of the Czech delegation at the Environment Council meeting of 20 June 2023. Moreover, a Swedish report on circular economy SOU 217:22 advocated reduced tax rates to stimulate recycling. A Norwegian report (Klima- og miljødepartementet (2025), by contrast, discussed but did not recommend adopting a reduced VAT rate.

own continued use besides selling other units to the reuse operator. We choose to neglect this slightly complicating extension as it would not add significant substance.

It seems plausible that part of the goods is not being reused. We assume that delivering units of the reusable good to a reuse operator involves some activity which affects utility. The consumer may incur some inconvenience above the trouble experienced when disposing of the good without making it available for reuse. The inconvenience may for instance include efforts to ascertain that the goods fulfil the requirements for reuse, e.g. not being in a too bad state. Alternately, the consumer may derive utility from delivering the good for reuse.

To address the issue outlined above, suppose that each agent is active at three points in time. At any time, there is an agent who is in his first period and consumes c_1, x_1, z_1 . Moreover, there is an agent who is in his second period and consumes c_2, x_2, z_2 . We assume that $ax_1 - y_2$ units of the x -good acquired in the preceding period are handed over to the reuse operator, where y_2 units are disposed of some other way. Finally, there is an agent in his third period who consumes c_3 and disposes of y_3 units of the reusable x -good acquired in the preceding period without making it available for reuse. We note that the subscript indicates the point in time when the variable is chosen. We consider a steady state where different generations have identical consumption vectors over time.

Displaying the variables in a more compact way, at any point in time we can present the variables of the three generations in the following column:

$$\begin{aligned} & (c_1, x_1, z_1) \\ & (c_2, x_2, z_2, y_2) \\ & (c_3, y_3) \end{aligned}$$

Instead considering a horizontal timeline with three points in time, we can order the variables of a given generation across the three periods in the following way:

$$(c_1, x_1, z_1)(c_2, x_2, z_2, y_2)(c_3, y_3)$$

For simplicity we neglect discounting. The consumption pattern across generations observed at a point in time is then equivalent to the consumption pattern of an agent over time. To focus on social efficiency, leaving aside any distributional issue, we assume that agents of the same age are identical. We assume that in his first period the agent derives utility

$$u(c_1, x_1, z_1).$$

In the second period, he derives utility

$$u(c_2, x_2, z_2) - k(ax_1 - y_2)$$

where $k(ax_1 - y_2)$ denotes the disutility incurred by delivering $(ax_1 - y_2)$ units for reuse rather than opting for some other and more convenient way of disposal. $k'(ax_1 - y_2)$ denotes the marginal effect. After reuse the good will have to be disposed of. In case free disposal is not available, we may interpret the utility derived from the reuse (the effect of the z -argument in the utility function) as utility net of the cost of disposal.³

Finally, we assume that in the third period of an agent no reusable good is acquired and the agent enjoys the utility

³ If one is concerned with details, one may interpret the utility derived from the x -good according to the utility function as utility net of the disutility incurred by having to dispose of the $1-a$ units that are worn out.

$$u(c_3) - k(ax_2 - y_3)$$

where $k(ax_2 - y_3)$ denotes disutility or utility if negative.

We assume that reuse of the x-good requires that it is somehow processed by a reuse operator, and the processing (mending, administration, etc.) requires a resource amount $h(z)$, where $h'(z) > 0$.

We assume that in each period the available resource amount is r . We assume that one unit of the c-good requires one resource unit and likewise one unit of the x-good requires one resource unit. We also denote by g the resource use in the public sector. Then we have the resource constraint

$$r = c_1 + x_1 + c_2 + h(z) + x_2 + c_3 + g \quad (1)$$

where $h(z) = h(z_1 + z_2)$.

3. The first best allocation.

The first best allocation maximises total utility

$$u(c_1, x_1, z_1) + u(c_2, x_2, z_2) - k(ax_1 - y_2) + u(c_3) - k(ax_2 - y_3) \quad (2)$$

subject to the resource constraint. Another constraint is

$$ax_1 - y_2 - z_1 + ax_2 - y_3 - z_2 = 0. \quad (3)$$

The quantity of second-hand goods is equal to the amount of the x-good delivered for reuse. The first order conditions are derived in appendix A. Slightly reformulating the first order conditions, we get the following conditions.

$$\frac{u_{c_2}}{u_{c_1}} = 1 \quad (4)$$

$$\frac{u_{c_3}}{u_{c_1}} = 1 \quad (5)$$

$$\frac{u_{x_1}}{u_{c_1}} = 1 \quad (6)$$

$$\frac{u_{x_2}}{u_{c_2}} = 1 \quad (7)$$

In all the cases above the marginal valuation of the good being considered is equal to the marginal cost.

$$k'(ax_1 - y_2) = k'(ax_2 - y_3) \quad (8)$$

$$\frac{k'(ax_1 - y_2)a}{u_{c_1}} = a \left(\frac{u_{z_1}}{u_{c_1}} - h'(z) \right) \quad (9)$$

$$\frac{k'(ax_2 - y_3)a}{u_{c_2}} = a \left(\frac{u_{z_2}}{u_{c_2}} - h'(z) \right) \quad (10)$$

The inconvenience of delivering a marginal unit of the reusable good to the reuse operator must be equal to the benefit of an extra unit of a reused good net of the cost of preparing the good for reuse.

Finally, adding the two constraints (1) and (3) to the conditions (4) – (10) we have nine equations to determine $c_1, x_1, z_1, c_2, x_2, z_2, c_3, y_2$, and y_3 .

4. The market allocation

We shall consider two types of market allocation where the goods are being taxed to finance public resource use. We let t denote the tax rate on general consumption, m denotes the tax rate on the reusable x -good, and s denotes the *ad valorem* tax rate on the z -good available as a recycled good. In one regime there are commercial markets for all goods. In the first regime the reuse operator pays a price p for the used good and charges a pre-tax price q when selling it after the necessary processing. The pre-tax prices on the c -good and the x -good are equal to one, that is, the unit cost. In the other regime, there is no commercial market for used goods made available for the reuse operator, while commercial markets exist for all other goods. Instead, there are charities or similar entities that receive used goods without any charge. We shall address this regime in Sections 5 and 6 below.

In a large number of countries, commodity taxes are value added taxes which may be differentiated by applying different rates, exemptions or zero-rating. We apply a very simple model where no deduction of input VAT takes place. For most goods there is a single production stage. Primary resources are acquired, and goods are produced and sold at a tax-inclusive price. Then there is no difference between a value added tax and a sales tax on final use. This is also how we treat the production and sales of new reusable goods. When reusable goods are actually being reused there is of course a second stage where the goods are handled, and resales are organised. However, the agents connecting the two stages are consumers who are not liable to pay VAT on sales to the reuse agents. They pay a tax-inclusive price when buying goods in the second-hand market but remit no tax when selling or otherwise transferring used goods to the resale agents. The question is what tax, if any, that should be levied in the second-hand market regardless of which type of commodity tax regime that is being deployed.

Whether commodity taxes should be uniform or differentiated is an old question addressed in several papers. A pioneering paper was Corlett and Hague (1953). A common point of departure is an economy where labour supply is distorted due to taxation of labour income either directly or through indirect taxation. The key question in the Corlett and Hague tradition is whether differentiating commodity taxes may alleviate the pre-existing labour supply distortion. This is not a topic addressed in the current paper. To make the analysis as simple and focussed as possible endogenous labour supply is excluded from the analysis to concentrate fully on conceivable tax arguments related to the reuse of goods.

The reuse operator buys a number of x -units that have been used and sells the same units after carrying out the necessary processing. We denote this number by e , which thus measures both the input and the output of the operator, who then earns a profit $\pi = qe - pe - h(e)$. Maximising profits yields

$$q - p - h'(e) = 0 \quad (11)$$

The price charged in the second-hand market is equal to the marginal cost, which consists of the acquisition price plus the marginal processing cost. Assuming that agents are identical, we can let the population be represented by a single agent who owns the resource endowment, receives profits, and earns income by selling quantities of the used good as a price taker.

The budget constraint of the consumer is $r = (1 + t)c_1 + (1 + m)x_1 + (1 + t)c_2 + (1 + s)qz_1 + (1 + m)x_2 + (1 + s)qz_2 + (1 + t)c_3 - p(ax_1 - y_2) - p(ax_2 - y_3) - \pi$

The budget available for buying the various goods at tax-inclusive prices is the initial resource endowment plus the income from selling units of the used x -good to the reuse operator and the profit received in addition to the resource endowment. The first order conditions of the consumer optimisation are derived in appendix A. Slightly reformulating the first order conditions we get the following conditions.

$$\frac{u_{c_2}}{u_{c_1}} = 1 \quad (12)$$

$$\frac{u_{c_3}}{u_{c_1}} = 1 \quad (13)$$

$$\frac{u_{x_1}}{u_{c_1}} = \frac{1+m}{1+t} \quad (14)$$

$$\frac{u_{x_2}}{u_{c_2}} = \frac{1+m}{1+t} \quad (15)$$

$$\frac{u_{z_1}}{u_{c_1}} = \frac{1+s}{1+t} q \quad (16)$$

$$\frac{u_{z_2}}{u_{c_2}} = \frac{1+s}{1+t} q \quad (17)$$

$$\frac{k'(ax_1 - y_2)}{u_{c_1}} = \frac{p}{1+t} \quad (18)$$

$$\frac{k'(ax_2 - y_3)}{u_{c_2}} = \frac{p}{1+t} \quad (19)$$

Market clearing implies that the amount of input demanded by the reuse operator is equated to the amount of used goods supplied by the consumers.

$$e = ax_1 - y_2 + ax_2 - y_3, \quad (20)$$

and supply equals demand in the second-hand market,

$$e = z_1 + z_2.$$

Considering equation (11), the ten equations (12) through (21) and also including the budget constraint, we have twelve equations to determine the variables $c_1, x_1, z_1, c_2, x_2, z_2, c_3, y_2, y_3, e, p, q$.

Let us now compare the market allocation to the first best allocation.

Consider the case where there is uniform taxation of the c -good and the x -good, i.e. $m=t$, then the conditions (12) through (15) coincide with the first-best conditions (4) – (7). The allocation between these goods is undistorted. Moreover, we note that $k'(ax_1 - y_2) = k'(ax_2 - y_3)$, which also coincides with first-best conditions [cf. equations (18) and (19)]. To achieve the first best allocation, condition (9) requires that.

$$\frac{u_{z_1}}{u_{c_1}} - \frac{k'(ax_1 - y_2)}{u_{c_1}} - h'(z) = 0$$

According to condition (11) profit maximisation requires that

$$q - p - h'(e) = 0.$$

Invoking eq. (16) and eq. (18), we can rewrite this condition as

$$\frac{1+t}{1+s} \frac{u_{z_1}}{u_{c_1}} - (1+t) \frac{k'(ax_1 - y_2)}{u_{c_1}} - h'(z) = 0$$

which is equivalent to

$$\frac{u_{z_1}}{u_{c_1}} - \frac{k'(ax_1 - y_2)}{u_{c_1}} - h'(z) + \frac{t-s}{1+s} \frac{u_{z_1}}{u_{c_1}} - t \frac{k'(ax_1 - y_2)}{u_{c_1}} = 0$$

For eq. (9) to hold we must have

$$\frac{t-s}{1+s} \frac{u_{z_1}}{u_{c_1}} - t \frac{k'(ax_1 - y_2)}{u_{c_1}} = 0 \quad (21)$$

Once again invoking eq. (16) and eq. (18), we get the condition

$$\frac{1+s}{1+t} \frac{t-s}{1+s} q - t \frac{p}{1+t} = \frac{t-s}{1+t} q - t \frac{p}{1+t} = 0$$

being equivalent to

$$\frac{s}{t} = 1 - \frac{p}{q} = 1 - \frac{p}{p+h'} = 1 - \frac{1}{1+\frac{h'}{p}} > 0, \quad (22)$$

which gives us an optimum tax rule. We observe that $0 < s < 1$. The key to comprehend why the z-good should not be left untaxed is the recognition that there is a trade-off between expending resources on recycling goods and producing other goods. Not taxing this resource use would favour recycling and distort the allocation. Only if the good could be transferred costlessly to a new consumer, i.e. $h' = 0$, would s be set equal to zero. This insight also explains that *cet. par.* a larger marginal resource cost, h' , leads to a larger tax rate, s , relative to t . Where h' is the dominant input cost a tax regime approaching uniform taxation may be desirable.

To elaborate on our findings, we can consider the chain of transactions where a used unit is delivered by a consumer to the reuse operator who processes the good and then supplies it in the second-hand market. At the first stage, the price compensating the consumer for his marginal cost is $\frac{p}{1+t}$ while the operator's willingness to pay is $p > \frac{p}{1+t}$. There is a tax wedge $\frac{t}{1+t}p$, in itself causing a downward distortion of recycling. We can refer to this as an input price distortion. Then there is a social gain from inducing further recycling through preferential treatment of the sale of the recycled good, i.e. by setting $s < t$.⁴ At this stage, the supplier of the recycled good charges a price q to be compensated for his marginal cost, while the buyer's marginal willingness to pay for the recycled good is $\frac{1+s}{1+t}q < q$. There is a tax wedge $-\frac{t-s}{1+t}q$. We can refer to this as an output price distortion, which can offset the input price distortion.

Proposition 1

Where a reuse centre buys used goods, which are sold in a second-hand market to maximise profits, social efficiency requires that sales of the second-hand goods be taxed at a positive but reduced rate, whereas other goods are taxed at a higher standard rate. The larger is the marginal processing cost (h') relative to the price paid for used goods (p) the closer one gets to uniform taxation. Equivalently, we see that a small marginal cost relative to the price is a case for significant differentiation.

5. Charitable donations

Now we consider the following case. To be reused, commodities have to be donated to a charity free of charge. The charity will mend the goods and sell them. It does not pay for the goods it receives. The supply is based on donations due to altruism. We suppose that consumers are willing to deliver used goods because they derive utility from doing so. There is a warm glow. The used commodities can either be donated to a charity or disposed of without being reused. We assume that an agent derives utility from delivering goods to the charity rather than disposing of it in some other simpler way. We let y_2 and y_3 denote the respective amounts disposed of in the latter way in period 2 and period 3. We assume that the amount disposed of in this way is not observed by the authorities. Even if kinds of observable disposal may exist, the consumers can find non-observable alternatives. An implication is that a potential tax on disposal is not an available instrument. Then the respective amounts delivered for reuse are $ax_1 - y_2$ and $ax_2 - y_3$. The utilities generated by this behaviour are respectively $b(ax_1 - y_2)$ and $b(ax_2 -$

⁴ There may be a number of further aspects (administration, enforcement, etc) to be considered before determining whether a reduced rate should actually be applied.

y_3). Despite altruistic behaviour, not all the used goods may be recycled. This may happen because at some level the *marginal* utility of delivering goods to the charity may turn negative. The sign of $b'()$ is positive for small values of the argument, declines as the amount of donations increases and, at some point, becomes negative. In other respects, the structure of the model is the same as in the model above.

The utility function is

$$u(c_1, x_1, z_1) + u(c_2, x_2, z_2) + b(ax_1 - y_2) + u(c_3) + b(ax_2 - y_3). \quad (23)$$

For reuse to be possible, used commodities must be delivered for reuse. In formal terms we have the constraint $z_1 + z_2 \leq ax_1 - y_2 + ax_2 - y_3$. The number of units being recycled cannot exceed the number of units handed in for reuse.

Donations will take place until $b'(ax_1 - y_2) = 0$ and $b'(ax_2 - y_3) = 0$. In the current regime, these conditions are then constraints on the optimisation in addition to the resource constraints. In order to assess the effects of the various constraints at the respective margins, we write $z_1 + z_2 = ax_1 - y_2 + ax_2 - y_3 + n$ (assigned the shadow price θ), $b'(ax_1 - y_2) - v = 0$ and $b'(ax_2 - y_3) - w = 0$ where n , v and w can be used to consider tightening or softening of the respective constraints.

Taking these conditions into account, we can derive an allocation which is a restricted social optimum.⁵ It maximises the utility (23) subject to the resource constraint and the other constraints above. The first order conditions are derived in appendix B.

The first order conditions derived in the appendix can be reformulated as

$$\frac{u_{c_2}}{u_{c_1}} = 1 \quad (24)$$

$$\frac{u_{c_3}}{u_{c_1}} = 1 \quad (25)$$

$$\frac{u_{x_1}}{u_{c_1}} = 1 \quad (26)$$

$$\frac{u_{x_2}}{u_{c_2}} = 1 \quad (27)$$

$$b'(ax_1 - y_2) = 0 \quad (28)$$

$$b'(ax_2 - y_3) = 0 \quad (29)$$

$$\frac{u_{z_1}}{u_{c_1}} = h' + \theta/\mu \quad (30)$$

$$\frac{u_{z_2}}{u_{c_2}} = h' + \theta/\mu \quad (31)$$

where μ is the shadow price of the resource constraint.

These eight conditions plus the resource constraint and the constraint $z_1 + z_2 = ax_1 - y_2 + ax_2 - y_3$ determine the values of $z_1, c_1, c_2, x_1, x_2, z_2, c_3, y_2, y_3$, and θ/μ .

Two types of optima are possible. Where donations are so plentiful that the constraint $z_1 + z_2 \leq ax_1 - y_2 + ax_2 - y_3$ is not binding, the shadow price θ is zero. Then it follows that

⁵ The social optimum is restricted by the institutional setting and informational constraints that have been assumed.

$\frac{u_{z_1}}{u_{c_1}} = \frac{u_{z_2}}{u_{c_2}} = h'$. Used units of the x -good will be reused only up to the point where the marginal valuation of reuse equals the cost of preparing the good for reuse. The excess amount will be disposed of without being reused. However, this allocation raises an awkward question. Will the donors of the used x -good behave according to the assumed motivation when they realise that part of their donations is not being reused?⁶

A different outcome is that when giving is based solely on altruism the amount is inadequate for achieving the desired supply of recycled goods. The scarce supply of used x -goods implies that the charity is rationed in the input market and the constraint $z_1 + z_2 \leq ax_1 - y_2 + ax_2 - y_3$ is strictly binding. Where the supply of the z -good is constrained by the availability of the used x -good a relaxation of the constraint, formally increasing n , is beneficial and the shadow price θ is strictly positive. This constraint is closely related to the restriction on $b'(ax_1 - y_2)$. We denote by σ the shadow price of v , *i.e.* the value of forcing $b'(ax_1 - y_2)$ above zero where initially $v=0$. Analogously, ρ is the shadow price of w , *i.e.* the value of forcing $b'(ax_2 - y_3)$ slightly above zero where initially $w=0$.

From eq. (b9) and eq. (b10) in the appendix we know that $-\theta + \sigma b''(ax_1 - y_2) = 0$ and $-\theta + \rho b''(ax_2 - y_3) = 0$. We see that we have a combination of shadow prices where $\theta > 0$, $\sigma < 0$ and $\rho < 0$. To increase the availability of the used x -good, b' must be allowed to diminish since $b'' < 0$. Forcing b' to increase above zero, *i.e.*, increasing v and w above zero, is harmful. From eqs. (b2) – (b4) and eqs. (b7) and (b8) follows that

$$\frac{\theta}{\mu} = \frac{u_{z_1}}{u_{c_1}} - h' > 0$$

$$\frac{\theta}{\mu} = \frac{u_{z_2}}{u_{c_2}} - h' > 0$$

The marginal valuation of the z -good exceeds the marginal production cost due to the limited availability of the used x -good.

6. The constrained market allocation

The constraint is that used commodities that consumers want to be recycled, have to be delivered to a reuse operator without any payment being received.

Assuming that agents are identical, we can let the population be represented by a single agent who owns the resource endowment and receives profits. The budget constraint of the agent is

$$(1+t)c_1 + (1+m)x_1 + (1+t)c_2 + (1+m)x_2 + (1+t)c_3 + (1+s)qz_1 + (1+s)qz_2 - r - \pi = 0.$$

The agent maximises utility. Making use of the first order conditions derived in the appendix and dividing by u_{c_1} , we obtain the following conditions.

$$\frac{u_{c_2}}{u_{c_1}} = 1 \tag{32}$$

$$\frac{u_{c_3}}{u_{c_1}} = 1 \tag{33}$$

⁶ A consequence might be that the utility derived from donations is scaled down. However, it is not clear how to do a normative analysis with endogenous preferences.

$$\frac{u_{x_1}}{u_{c_1}} = \frac{1+m}{1+t} \quad (34)$$

$$\frac{u_{x_2}}{u_{c_2}} = \frac{1+m}{1+t} \quad (35)$$

$$\frac{u_{z_1}}{u_{c_1}} = \frac{1+s}{1+t} q \quad (36)$$

$$\frac{u_{z_2}}{u_{c_2}} = \frac{1+s}{1+t} q \quad (37)$$

$$b'(ax_1 - y_2) = 0 \quad (38)$$

$$b'(ax_2 - y_3) = 0 \quad (39)$$

Substituting for π in the consumer's budget constraint, we get

$$(1+t)c_1 + (1+m)x_1 + (1+t)c_2 + (1+m)x_2 + (1+t)c_3 + (1+s)qz_1 + (1+s)qz_2 = r + qz_1 + qz_2 - h(z)$$

Assuming that tax rates are set to equate tax revenue to public expenditure, $tc_1 + mx_1 + tc_2 + mx_2 + tc_3 + sqz_1 + sqz_2 = g$, it follows that $c_1 + x_1 + c_2 + x_2 + c_3 + h(z) + g = r$. The resource constraint is satisfied.

Combining (36) and (37), to get $\frac{u_{z_1}}{u_{c_1}} = \frac{u_{z_2}}{u_{c_2}}$, and taking into account (32) – (35), (38)-(39), and the resource constraint, we have eight conditions. Now there are two conceivable cases. One is the scarcity case where the reuse operator is rationed by the supply of inputs, i.e. the amount of the used x-good. Then a further condition is $z_1 + z_2 = ax_1 - y_2 + ax_2 - y_3$, and we have nine equations to determine $z_1, c_1, c_2, x_1, x_2, z_2, c_3, y_2, y_3$. Also setting $m=t$, i.e. equal taxes on the x -good and the c -good, we see that the conditions being considered coincide with the conditions determining the restricted social optimum.

Comparing the constrained market allocation to the restricted social optimum, we see that the conditions determining the allocations coincide where $m=t$, i.e. equal taxes on the z -good and the x -good. The constrained market equilibrium realises the restricted social optimum.

Moreover, we note that given the resulting consumption bundle, $\frac{1+s}{1+t} q$ is determined by $\frac{1+s}{1+t} q = \frac{u_{z_1}}{u_{c_1}}$.

We further note that we can set $s = m = t$, which is uniform commodity taxation, where t is set to satisfy the government's budget constraint and hence the resource constraint of the economy. Then the value of q is determined by $q = \frac{u_{z_1}}{u_{c_1}} = \frac{u_{z_2}}{u_{c_2}}$, which is the equilibrium price of the z -good. Then from equation (30) $q - h' = \frac{\theta}{\mu} > 0$. The implication is that the charity (the reuse operator) could enhance profits at the margin but is prevented from doing so by being rationed in the input market⁷.

Proposition 2

Where used goods are donated to a charity for free, and the charity as reuse operator is rationed by the donations of used goods, there is no case for deviating from uniform taxation.

⁷ We may note that the same allocation could be obtained even where s differs from t since q adjusts such that $\frac{1+s}{1+t} q = \frac{u_{z_1}}{u_{c_1}}$ and t is adjusted to satisfy the resource constraint.

Let us also consider the abundance case where the supply of used units of the x -good is plentiful, disregarding the conceivable problems with this case mentioned above. Then the amounts of z_1 and z_2 determined by profit maximisation require an amount of used goods below the quantity supplied by the consumers: $z_1 + z_2 < ax_1 - y_2 + ax_2 - y_3$, and, setting $s = t$, $q = \frac{u_{z_1}}{u_{c_1}}$, and profit maximisation implies that $h' = q = \frac{u_{z_1}}{u_{c_1}}$. Not all the available used units of the x -good are being processed because it would be too costly. Also, in this case the restricted social optimum can be realised as a constrained market equilibrium where commodity taxes are uniform.

7. Concluding remarks

We have considered an economy where the key ingredient is the existence of a reusable good, i.e. a good that after a period of use and some processing can be available for reuse. The consumer first using the good can at the end of the period hand it over to a reuse centre that will prepare the good for being supplied in a second-hand market or he can dispose of it in a simpler and less inconvenient way. Two regimes are considered. In the first case transactions take place in fully commercial markets. The reuse centre pays the first users of the good for delivering the used good to the centre and sells it in a second-hand market to make a profit. In the other case the reuse centre is a charity that receives used goods that consumers supply for free. The charity then sells the good to raise funds for the charitable purpose.

The purpose of the analysis is to examine what is the optimal commodity tax on the goods offered for reuse in the second-hand market where the sole focus is on how reuse may impact the optimum tax, abstracting from other circumstances that in general may be relevant for setting commodity taxes. We assume that there is a fixed resource endowment which means that we abstract from any preexisting distortion of labour supply. Moreover, we assume away any externality arguments for Pigouvian taxes. Also, distributional concerns are neglected to focus entirely on social efficiency. The implications of all these concerns are well known from the existing literature (see for example Christiansen and Smith (2021)). To focus entirely on commodity taxes, no other taxes are considered.

We conclude that in the commercial regime there is a case for partial differentiation of commodity taxes. There should be uniform taxation in first-hand markets, i.e. new reusable goods and non-reusable goods should be taxed at the same rate, while a positive but reduced rate should be applied to recycled goods. The intuition is that commodity taxes diminish the real value of the price received for used goods delivered to the reuse centre, which distorts the choice between delivering used goods for reuse and simply throwing it away. The effect of the tax favour is to alleviate this distortion.

Where a used good can only be made available for reuse by being delivered to a charity for free a conceivable case is that the supply of used goods falls short of the amount needed to satisfy the demand for reuse. In that sense, the charities are rationed in the input market. In this situation there is no case for deviating from uniform commodity taxation.

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Appendix A.

The first best allocation.

We formulate the Lagrange function

$$\begin{aligned}\Lambda = & u(c_1, x_1, z_1) + u(c_2, x_2, z_2) - k(ax_1 - y_2) + u(c_3) - k(ax_2 - y_3) \\ & - \mu(c_1 + x_1 + c_2 + h(z) + x_2 + c_3 + g - r) + \theta(ax_1 - y_2 - z_1 + ax_2 - y_3 - z_2)\end{aligned}$$

where μ and θ denote the Lagrange multipliers. We let subscripts denote partial derivatives. We find the first order conditions.

$$u_{c_1} = u_{c_2} = u_{c_3} = \mu \quad (a1)$$

$$u_{x_1} - k'(ax_1 - y_2)a + \theta a = \mu \quad (a2)$$

$$u_{x_2} - k'(ax_2 - y_3)a + \theta a = \mu \quad (a3)$$

$$u_{z_1} - \mu h'(z) - \theta = 0 \quad (a4)$$

$$u_{z_2} - \mu h'(z) - \theta = 0 \quad (a5)$$

$$k'(ax_1 - y_2) = \theta \quad (a6)$$

$$k'(ax_2 - y_3) = \theta \quad (a7)$$

$$k'(ax_1 - y_2) = u_{z_1} - \mu h'(z) \quad (a8)$$

$$k'(ax_2 - y_3) = u_{z_2} - \mu h'(z) \quad (a9)$$

Invoking (a6) and (a7), we can reduce (a2) and (a3) to

$$u_{x_1} = \mu \quad (a2')$$

$$u_{x_2} = \mu \quad (a3')$$

Making use of the first order conditions and dividing by μ ($=u_{c_1} = u_{c_2}$), we get the conditions (4) through (10) in the main text.

The consumer optimum.

To maximise utility subject to the budget constraint, we formulate the Lagrange function

$$\begin{aligned}L = & u(c_1, x_1, z_1) + u(c_2, x_2, z_2) - k(ax_1 - y_2) + u(c_3) - k(ax_2 - y_3) \\ & - \lambda((1+t)c_1 + (1+m)x_1 + (1+t)c_2 + (1+s)qz_1 + (1+m)x_2 + (1+s)qz_2 + (1+t)c_3 - \\ & p(ax_1 - y_2) - p(ax_2 - y_3) - r - \pi)\end{aligned}$$

where λ is the Lagrange multiplier associated with the budget constraint.

We get the first order conditions

$$u_{c_1} = u_{c_2} = u_{c_3} = \lambda(1 + t) \quad (a10)$$

$$u_{x_1} - k'(ax_1 - y_2)a - \lambda(1 + m) + \lambda pa = 0 \quad (a11)$$

$$u_{x_2} - k'(ax_2 - y_3)a - \lambda(1 + m) + \lambda pa = 0 \quad (a12)$$

$$u_{z_1} - \lambda(1 + s)q = 0 \quad (a13)$$

$$u_{z_2} - \lambda(1 + s)q = 0 \quad (a14)$$

$$k'(ax_1 - y_2) = \lambda p \quad (a15)$$

$$k'(ax_2 - y_3) = \lambda p \quad (a16)$$

Invoking (a15) and (a16), we can rewrite (a11) and (a12) as

$$u_{x_1} = \lambda(1 + m) \quad (a11')$$

$$u_{x_2} = \lambda(1 + m) \quad (a12')$$

Dividing by u_{c_1} ($= u_{c_2} = \lambda(1 + t)$), we get the conditions (12) – (19) in the main text.

Appendix B.

The restricted social optimum.

To derive an allocation which is a restricted social optimum, we formulate the Lagrange function

$$\begin{aligned} & u(c_1, x_1, z_1) + u(c_2, x_2, z_2) + b(ax_1 - y_2) + u(c_3) + b(ax_2 - y_3) \\ & - \mu(c_1 + x_1 + c_2 + h(z) + x_2 + c_3 + g - r) - \theta(z_1 + z_2 - ax_1 + y_2 - ax_2 + y_3 - n) - \sigma[b'(ax_1 - y_2) - v] - \rho[b'(ax_2 - y_3) - w] \end{aligned} \quad (b1)$$

where μ, θ, σ and ρ are Lagrange multipliers and initially $v = w = n = 0$.

Differentiating wrt the c -variables, the x -variables and the z -variables, respectively, we get the following first order conditions:

$$u_{c_1} = u_{c_2} = u_{c_3} = \mu \quad (b2)-(b4)$$

$$u_{x_1} - \mu + \theta a - a\sigma b''(ax_1 - y_2) = 0 \quad (b5)$$

$$u_{x_2} - \mu + \theta a - a\rho b''(ax_2 - y_3) = 0 \quad (b6)$$

$$u_{z_1} - \mu h' - \theta = 0 \quad (b7)$$

$$u_{z_2} - \mu h' - \theta = 0 \quad (b8)$$

Differentiating wrt to y_2 and y_3 , we get the further first order conditions:

$$-\theta + \sigma b''(ax_1 - y_2) = 0 \quad (b9)$$

$$-\theta + \rho b''(ax_2 - y_3) = 0 \quad (b10)$$

Invoking equation (b9) and equation (b10), we can simplify the conditions (b5) and (b6) to get

$$u_{x_1} - \mu = 0 \quad (\text{b5}')$$

$$u_{x_2} - \mu = 0 \quad (\text{b6}')$$

The nine equations (b2)-(b10) and the three constraints determine the values of the variables $c_1, x_1, z_1, c_2, x_2, z_2, c_3, y_2, y_3, \theta, \sigma$ and ρ .

Making use of the first order conditions and dividing by μ ($= u_{c_1} = u_{c_2} = u_{c_3}$) we get the conditions (24) –(31) in the main text.

The consumer optimum.

The agent maximises utility subject to the budget constraint. We formulate the Lagrange function

$$\begin{aligned} & u(c_1, x_1, z_1) + u(c_2, x_2, z_2) + u(c_3) + b(ax_1 - y_2) + b(ax_2 - y_3) \\ & - \lambda((1+t)c_1 + (1+m)x_1 + (1+t)c_2 + (1+m)x_2 + (1+t)c_3 + (1+s)qz_1 + (1+s)qz_2 - r - \pi) \end{aligned} \quad (\text{b11})$$

Maximisation yields the following first order conditions.

$$u_{c_1} = u_{c_2} = u_{c_3} = \lambda(1+t) \quad (\text{b12})$$

$$b'(ax_1 - y_2) = 0 \quad (\text{b13})$$

$$b'(ax_2 - y_3) = 0 \quad (\text{b14})$$

$$u_{x_1} = \lambda(1+m) \quad (\text{b15})$$

$$u_{x_2} = \lambda(1+m) \quad (\text{b16})$$

$$u_{z_1} = \lambda(1+s)q \quad (\text{b17})$$

$$u_{z_2} = \lambda(1+s)q \quad (\text{b18})$$

Dividing by u_{c_1} ($= u_{c_2} = \lambda(1+t)$), we get the conditions (32) –(39) in the main text.