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ABSTRACT

This paper suggests two generalizations of the deposit-refund idea. In the first, we apply the idea not just to solid waste materials, but to *any* waste from production or consumption – including wastes that may be solid, gaseous, or liquid. Using a simple general equilibrium model, we derive the optimal combination of a tax on a purchased commodity and subsidy to a "clean" activity (such as emission abatement, recycling, or disposal in a sanitary landfill). This "two-part instrument" is equivalent to a Pigovian tax on the "dirty" activity (such as emissions, dumping, or litter). In the second generalization, we consider the case where government must use distorting taxes on labor and capital incomes. To help meet the revenue requirement, would the optimal deposit be raised and the refund reduced? We derive the second-best revenue-raising DRS or two-part instrument to answer that question.

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For most pollutants, the standard response of economists since Arthur Pigou (1920) is to tax the offending activity. A direct tax is not easy to impose on dumping or litter, however, so a useful alternative is the deposit refund system (DRS). The tax paid upon purchase is refunded on items *not* dumped, so the result can be equivalent to a tax on dumping. Around the world, DRS systems have applied to beverage containers, used motor oil, batteries, and car hulks.

In this note, we suggest two important generalizations of the deposit-refund idea. In the first generalization, we apply the idea not just to solid waste materials such as those listed above, but to *any* waste from production or consumption -- including wastes that may be solid, gaseous, or liquid. Using a simple general equilibrium model, we derive the optimal combination of a tax on a purchased commodity and subsidy to a "clean" activity (such as emission abatement, recycling, or disposal in a sanitary landfill).[1] This "two-part instrument" is equivalent to a Pigovian tax on the "dirty" activity (such as emissions, dumping, or litter). Moreover, the tax and subsidy do not need to apply to the same commodity; they do not need to apply at the same rate; and they are not necessarily paid and received on the same side of the market.

In the second generalization, we consider the case where government must use distorting taxes on labor and capital incomes. To help meet the revenue requirement, would the optimal deposit be raised and the refund reduced? We derive the second-best revenue-raising DRS or two-part instrument to answer that question.

I. The Two-Part Instrument

Consider n identical consumers with utility $u(c, d, h, G, D)$ defined over per-capita consumption of a clean good c, dirty good d, home-produced good h, the total amount of a government-provided public good G, and total waste D (where $D{=}nd$).[2] Each individual has one unit of resources r (such as labor, capital, and land) that can be used at home to produce one unit of h or sold in the market to buy one unit of c or d. All prices are one. If t_r is defined as the tax on market sale of resources, then the individual budget constraint is $(1\text{-}h)(1\text{-}t_r) = c(1+t_c) + d(1+t_d)$.

In order to describe three interpretations of our results below, we rewrite the utility function as $u(q(c, d), h, G, D)$. Obviously, then, one interpretation is that q is a subutility function, where c and d are separable in utility. This separability does not affect the nature of our results below, but it makes them easier to express and interpret. In this first case, d is a consumer good with fixed pollution per unit (either from production or from consumption of it).

A second interpretation is that q is a single consumption good, where the technology of disposal can be represented by $q(c, d)$. In this case, c represents the amount of clean disposal such as recycling or sanitary landfill, while d is dirty disposal such as dumping or litter. The function $q(c, d)$ shows the combinations of c and d that are consistent with any particular level of consumption q. Individuals do not get utility from either type of disposal *per se*, but $q(c, d)$ can be substituted into utility to get u as a function of c and d as above. In this case, a tax t_q can be collected per unit of q (but note that t_q on all consumption makes t_r redundant).

A third interpretation is that $q = q(c, d)$ is a constant-returns-to-scale production function. Competitive agents produce per-capita output q using two inputs. The clean input c includes labor, capital, or other resources. The dirty input is emissions (which may be solid, gaseous, or liquid). Emissions are needed to produce, but successive units are less crucial, so emissions have positive and declining marginal product q_d ($\equiv \partial q/\partial d$). A unit of emissions is the amount with *private* cost of a dollar, but note that social costs exceed this private cost. The resource constraint is still $1=c+d+h$. Taxes might apply to inputs or to output.

All of these interpretations follow from the same model. By comparing the social planner's first order conditions to the market's first order conditions, the method described in

William Baumol and Wallace Oates (1988) can easily be used to show that the first-best optimal solution of Pigou (1920) is a tax per unit of the dirty good:

$$t_q = 0 \qquad t_c = 0 \qquad t_d = -nu_D/\lambda \tag{1}$$

where $u_D \equiv \partial u/\partial D$, and λ is the marginal utility of income. The tax t_d is "marginal external damages" (MED), the sum of all n individual losses (u_D), converted into dollars when divided by λ. Since u_D is negative, the tax is positive.

Already the three interpretations are useful, to point out that this solution requires a tax specifically on the dirty activity. If d is a consumption good, and pollution is fixed per unit, then the Pigovian tax can easily be collected upon purchase, like an ordinary excise tax. Examples might include cigarettes or gasoline, where consumption of the commodity creates negative externalities. In the second interpretation, however, d is not purchased on the market. The tax is not on all disposal, but on dirty disposal such as dumping. The Pigovian tax may not be feasible. In the third interpretation, clean inputs such as labor and other resources are purchased in observable market transactions, with invoices that the authorities can use to help enforce any tax. But "emissions" are not purchased on the market. They are necessary for production, but may be difficult to observe.

The Pigovian tax may still be feasible for sulfur dioxide emissions of large electric power plants that are required to use expensive continuous emissions monitoring (CEM) equipment. Also, carbon emissions might be estimated accurately by the carbon content of fossil fuels purchased in market transactions. But many other kinds of emissions are hard to monitor. For any operation other than large power plants, CEM equipment might be too expensive. A tax on hazardous chemical wastes can be evaded by midnight dumping, and it cannot be approximated accurately by taxes on purchased chemical inputs (since those taxes would not provide incentive to reduce the waste by-product per unit of chemical input). For households, a tax collected on all non-recycled waste would provide a powerful incentive to recycle as much waste as possible, but also to burn or dump the rest of it (Fullerton and Thomas Kinnaman, 1995).

Fortunately, the same model can be used, as in Fullerton and Wolverton (1999), to show that the exact same optimal outcome can be achieved without a tax on emissions or dumping:

$$t_q = (-nu_D/\lambda)(1/q_d) \qquad t_c = (nu_D/\lambda)(q_c/q_d) \qquad t_d = 0 \tag{2}$$

When q is a purchased commodity, it is taxed at a rate equal to the MED per unit of *output*, calculated as the marginal damage per unit of dirty input ($-nu_D/\lambda$) times the extra dirty input per unit of output ($1/q_d$). This "deposit" is returned only to the extent that output is produced using the *clean* input ($t_c < 0$, since $u_D < 0$). This subsidy is the *reduction* in damages from using the clean input, calculated as the damage per unit of the dirty input times the change in the dirty input for a change in the clean input (q_c/q_d, holding output constant along the isoquant).

We call this solution a "two-part instrument." It achieves the exact same equilibrium as the Pigovian tax in equation (1), but it does not require measurement of emissions or dumping. Taxes apply only to market sale of output or purchase of inputs such as labor or capital. In the first interpretation, t_q can be replaced by an income tax t_r (returned only on clean purchases).

Further intuition is provided by considering two effects of the Pigovian tax, t_d. First, it raises the price of d relative to c and reduces pollution per unit of output through a "substitution effect." Second, it also raises the cost of production and thus the equilibrium output price, which reduces demand through an "output effect." Both effects reduce pollution. The same two effects are achieved by the two-part instrument. The subsidy to c induces a substitution effect that reduces d per unit of output. That subsidy alone would tend to reduce the equilibrium output price and increase demand, but the tax on output reverses that effect and reduces output to the optimal degree.

Note that the deposit and the refund are not at exactly the same rate, as they do not apply to the same commodity. The tax is a normal excise tax on output, which may be paid by the seller *or* by the consumer. The subsidy may apply to recycling or sanitary landfill, so it could be paid either to the household or to the waste-processing firm. To minimize administrative costs, the subsidy could be paid per ton of waste at the sanitary landfill, or per ton of recycled material such as aluminum or glass. In competitive equilibrium, this subsidy would be passed through market prices to consumers. In other words, for the recycling firm to receive more subsidy, it would be willing to offer inducements to consumers such as free collection of recyclable waste. Individuals have no need to stand in line for the 10¢ refund.

Most importantly, this DRS applies not just to solid waste but to all industrial emissions. The model here is abstract, but the general idea is that government can subsidize pollution abatement -- just as the lobbying efforts of firms would suggest. That subsidy would tend to reduce output price and induce more consumption of the polluting good, however, so the subsidy must be accompanied by a tax on output. The revenue from the output tax can be used to subsidize purchases of low-sulfur coal, scrubbers, and other pollution control equipment.[3] In fact, since the two-part instrument is equivalent to the Pigovian tax, the output tax revenue must exceed the abatement subsidy by exactly the amount of revenue that would have been collected by the Pigovian tax.

II. The Revenue-Raising Two-Part Instrument

The economics literature has analyzed deposit-refund systems,[4] but not how the rate of deposit or refund would optimally be modified to raise revenue when lump sum taxes are not available and government uses distorting taxes on labor and capital. We just showed that our two-part instrument is equivalent to a tax on pollution, however, and the economics literature certainly has analyzed how the Pigovian tax would be modified with a prior distorting labor tax.[5] A. Lans Bovenberg and Frederick van der Ploeg (1994) have shown that the second-best pollution tax is marginal environmental damages (MED) divided by the marginal cost of funds (MCF). Distorting taxes mean than the MCF is more than one, so the second-best pollution tax is *reduced* from MED to MED/MCF. Fullerton (1997) and Ronnie Sch`b (1997) show how this result depends on the normalization. Specifically, Sch`b (1997) derives the second-best tax on the dirty good with prior distorting taxes on labor or on the clean good.

We now extend that analysis to the case with *no* tax on the dirty good or input: how is the deposit (t_r or t_q) and the refund (t_c) modified when the government needs more revenue than can be obtained through lump sum taxation? Would the deposit be raised and the refund reduced to save funds? Fullerton and Wolverton (1999) use an optimal tax model like that of Sch`b (1997) to find the second-best *ad valorem* tax rates (proportional to the consumer price):

$$t_c/(1+t_c) = -MED/MCF \tag{3a}$$

$$t_r/(1-t_r) = MED/MCF + R \tag{3b}$$

where R is a Ramsey term that depends on revenue needs.[6] In this normalization, an increase in government revenue requirements would directly raise R and thus t_r. The higher distorting income tax would raise the marginal cost of funds (MCF) and thus reduce the subsidy t_c. In other words, this answer to the question above is *yes*: increased revenue needs would imply both a higher tax t_r and lower subsidy t_c.

On the other hand, not all of the income tax is really a "deposit." Without the pollution problem, the MED would be zero and the income tax would be based solely on revenue needs (R). The introduction of a pollution problem introduces the need for a policy such as a pollution tax (at rate MED/MCF) or a deposit-refund system (which adds MED/MCF to the income tax and returns the same amount through a subsidy to the clean good). Thus we might say that the "deposit" is only the first term in equation (3b) for the income tax rate. Using this terminology, the answer to the question above is *no*: increased revenue needs would increase the income tax rate, which raises the marginal cost of funds (MCF), but that means a reduction in both the refund and the deposit (MED/MCF).

It may seem surprising that the need for extra revenue implies a *lower* deposit, but the reason is the same as the reason that the need for extra revenue implies a *lower* tax on pollution. As discussed Fullerton (1997), the higher income tax itself acts like a higher tax on *all* consumption (both c and d), which reduces the demand for both goods in favor of leisure. Thus the income tax itself helps reduce pollution, and optimality requires a smaller additional pollution tax (or deposit-refund system).

III. Final Remarks

In general, the effects of a pollution tax can be matched by a two-part instrument with a tax on output and a subsidy to all inputs other than emissions. We now discuss a few caveats. First of all, the subsidy to clean activities may have problems of implementation. Policymakers may find it difficult to identify and subsidize *all* such inputs. A partial response is that all such inputs earn a return that is subject to the income tax, and so this "subsidy" may really just amount to a lower rate of income tax. If so, it would not involve any special forms for administration. With multiple sectors, however, the lower rate of tax on clean inputs would only apply in the polluting sector (the output of which is subject to an extra excise tax).

Second, if the subsidy for recycling or proper disposal in the sanitary landfill is high enough, it might induce some individuals to steal waste from others in order to obtain the subsidy. Again we have only a partial response, as the two-part instrument may work only in particular favorable circumstances. It may work best where the subsidy is implicit, such as the free collection of curbside garbage and recycling. Remember, the point of the two-part instrument is to avoid midnight dumping, and the free collection of waste is enough to do that.

Third, a problem arises if a particular industry generates variable amounts of two or more pollutants with *different* marginal environmental damages. The only way to achieve all the right relative prices in this case would be to tax output at a rate based on damages of the worst pollutant. That deposit would then be fully returned on all clean inputs and partially returned on other pollutants (at a rate equal to the difference in damages). That solution means providing a subsidy to any emissions that are less damaging than the worst emissions.

Fourth, although we have inadequate space for discussion, another problem arises for an open economy. The deposit would have to be collected on imports, and the refund may not be received on exports. Other problems are worth further investigation, as well.

Finally, we note that this two-part instrument need not appear to be a unified deposit-refund system (DRS). The deposit may be hidden within the income tax, where individuals see only the total rate of tax (as in equation 3b). The only apparent pollution policy may be a subsidy for clean activities: sanitary landfill disposal, recycling, or pollution control equipment. If that subsidy is financed by a somewhat-higher income tax rate, then the result is an *implicit* DRS. For example, municipalities collect a sales tax and use some of the revenue to pay for free curbside garbage and recycling collection. The Federal government imposes an income tax and provides a tax credit or accelerated depreciation for pollution abatement equipment. The optimality of such schemes may depend primarily on the degree of targeting: if the pollution is generated only by one industry, then the deposit would optimally appear within that industry's output tax and not within the general income tax.

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[1] Similar ideas appear in Gunnar Eskeland and Shantayanan Devarajan (1996), Don Fullerton (1997), Margaret Walls and Karen Palmer (1997), and Fullerton and Ann Wolverton (1999).

[2] In the first-best model, government has a lump sum head tax to finance the public good.

[3] This subsidy is not a payment per unit of pollution reduced (which would *raise* the cost of pollution by the subsidy forgone and thus raise the cost of production). Instead, it is a subsidy to clean inputs, which would reduce the cost of production.

[4] See, for examples, Peter Bohm (1981) or Fullerton and Kinnaman (1995).

[5] For a review of this literature, see Lawrence Goulder (1995).

[6] Specifically, $R = (c/s_{cr})(1-P)/(1-t_r)$, where s_{cr} is the compensated cross-price effect on c from a change in the price of leisure (the net wage or return on resources, $1-t_r$), and where P is the net social marginal utility of household income (including the value of the extra private utility and the social value of the extra tax revenue collected).