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The Pigouvian Principle with Consumption Taxes

Geir H. M. Bjertnæs

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Abstract

In the European Union and many other jurisdictions, environmental taxes form part of the base of the general consumption tax. This paper shows that, when the damage falls on households, a statutory environmental tax set equal to marginal damage, estimated as willingness to pay, fails to implement the Pigouvian allocation. Implementing the Pigouvian allocation requires the environmental tax difference, measured relative to the consumer price of clean consumption, to equal marginal damage in units of clean consumption, a condition invariant to the normalization of the tax system. The efficient statutory rate is therefore willingness to pay to avoid damage divided by one plus the consumption tax rate when the environmental tax is inside the consumption tax base, and willingness to pay when it is outside. Damage borne by firms is measured at producer prices and therefore adjusts in the opposite way: unchanged inside the base and multiplied by one plus the consumption tax rate outside.

Keywords: Pigouvian taxation; consumption taxes; value added tax; willingness to pay; normalization.

JEL classification: H21, H23, Q58.

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Address: P.O. BOX 2633, St. Hanshaugen, Oslo 0131, Norway, Statistics Norway, Research Department. E-mail: ghb@ssb.no

Sammendrag

Studien analyserer hvordan Pigou-prinsippet implementeres i økonomier med generelle konsumskatter. Pigou-prinsippet sier at miljøavgifter skal settes lik marginal miljøskade. I moderne miljøøkonomi uttrykkes dette ofte som at avgiftsforskjellen mellom forurensende og rene alternativer skal være lik marginal miljøskade målt i penger. Samtidig bestemmes ressursallokeringen av relative priser. Dette reiser spørsmålet om hvordan Pigou-prinsippet skal forstås og implementeres når konsum beskattes.

Ved hjelp av en enkel teoretisk modell viser artikkelen at Pigou-allokeringen ikke karakteriseres av en miljøavgift eller avgiftsforskjell målt i penger. Implementeringsbetingelsen krever at avgiftsforskjellen mellom forurensende og rene alternativer, målt relativt til konsumentprisen på rene goder, skal være lik marginal miljøskade målt i enheter av rene goder. Denne betingelsen er invariant med hensyn til normaliseringen av skattesystemet og gir dermed en eksplisitt relativprisformulering av Pigou-prinsippet.

Artikkelen analyserer deretter hvilke formelle miljøavgifter som implementerer denne allokeringen, og knytter resultatene til empiriske beregninger av marginal miljøskade. Når skaden måles ved betalingsvillighet, verdsettes den ved de prisene som møter dem som bærer skaden. Betalingsvillighet og den nødvendige avgiftsforskjellen skaleres derfor på samme måte med konsumentprisen på rene goder når skaden rammer husholdninger. En avgiftsforskjell lik betalingsvilligheten implementerer dermed Pigou-allokeringen under enhver normalisering av skattesystemet.

Videre analyseres implementeringen når det eksisterer en uniform konsumsskatt, slik som merverdiavgiften. Resultatene viser at den nødvendige lovfestede miljøavgiften avhenger av om miljøavgiften inngår i konsumskattegrunnlaget eller ikke. Dersom miljøavgiften ligger utenfor skattegrunnlaget og skaden rammer husholdninger, skal den settes lik betalingsvilligheten. Dersom den inngår i skattegrunnlaget, skal den settes lik betalingsvilligheten dividert med én pluss konsumskattesatsen. Artikkelen analyserer også miljøskader som kommer til uttrykk som reduserte produksjonsmuligheter. Slike skader verdsettes naturlig ved produsentpriser. Når miljøavgiften inngår i konsumskattegrunnlaget, implementeres Pigou-allokeringen av en avgift lik marginal skade målt ved produsentpriser. Dersom avgiften ligger utenfor konsumskattegrunnlaget, må den oppjusteres med konsumskatten.

Artikkelen bidrar dermed på to områder. For det første gir den en eksplisitt velferdsteoretisk karakterisering av avgiftsforskjellen som tidligere litteratur har identifisert som det relevante virkemiddelet i miljøpolitikken. For det andre etablerer den en direkte kobling mellom betalingsvillighetsbaserte anslag for marginal miljøskade og de formelle miljøavgiftene som implementerer Pigou-allokeringen i skattesystemer med konsumskatter. Resultatene viser at sammenligninger mellom miljøskader målt ved betalingsvillighet og observerte miljøavgifter krever kunnskap både om prisgrunnlaget som skaden er verdsatt i og om hvordan miljøavgiftene behandles i konsumskattesystemet.

1. Introduction

The Pigouvian principle states that a tax on a polluting activity should equal marginal external damage (Pigou, 1920). The principle holds under specific conditions within second-best optimal tax systems (Jacobs and de Mooij, 2015; Jacobs and van der Ploeg, 2019). Since the level of an environmental tax depends on the normalization of the tax system, the principle concerns the tax difference between polluting and clean goods rather than the level of the environmental tax (Fullerton, 1997; Schöb, 1997). With only linear distortionary taxes, this difference may fall short of marginal damage (Bovenberg and de Mooij, 1994; Fullerton, 1997). However, the literature does not establish whether the principle applies directly in economies with a uniform consumption tax that lowers the real value of a given tax difference, or specify which statutory rate implements the Pigouvian allocation under such taxation. Nor is it obvious how the principle relates to empirical estimates of marginal damage, which are obtained as willingness to pay and therefore scale with the prices faced by those who bear the damage.

This paper answers these questions. The Pigouvian allocation is implemented if and only if the environmental tax wedge, the tax difference measured relative to the consumer price of clean consumption, equals marginal damage measured in units of clean consumption, a condition invariant to the normalization of the tax system. The paper then derives the statutory taxes that generate this wedge. The rate equals households willingness to pay when the environmental tax is levied outside the consumption tax base, and willingness to pay divided by one plus the consumption tax rate when it is levied inside. The inside-base rate also applies when the tax is levied on producers, since with fixed producer prices the legal incidence is irrelevant and a tax on producers enters the consumption tax base. Damage borne by firms is a loss of output measured at producer prices and converts the other way, so it enters unchanged inside the base and is multiplied by one plus the consumption tax rate outside.

In the European Union and many other jurisdictions, the environmental tax is collected inside the base of a general consumption tax. A statutory rate set equal to marginal damage, as the Pigouvian principle prescribes in its usual form, then exceeds the efficient rate by a factor of one plus the consumption tax rate when the damage falls on households. With standard value added tax rates in the European Union between 17 and 27 percent, the overstatement is of the same order. Cost–benefit analysis converts between consumer and producer prices to value benefits and costs in a common unit of account (Drèze and Stern, 1987). The statutory environmental tax requires a different correction, which depends not on the unit of account but on the tax base and on who bears the damage. Official appraisal guidance recognizes that an adjustment is needed but leaves it unspecified (Department for Energy Security and Net Zero, 2023).

The analysis is carried out in a model framework with two households, two goods and a fixed supply of labor. The externality may harm a household, the production of the clean good, or both, and efficient Pigouvian taxation must handle each case. Section 2 presents the model and characterizes Pigouvian taxation. Section 3 derives the statutory environmental tax under a uniform consumption tax, and Section 4 applies the result to taxes levied on producers, summarizes the statutory rates and compares them with practice. Section 5 discusses caveats, and Section 6 concludes.

2. The model

Whether the Pigouvian principle survives in tax systems that also raise revenue has been debated at length (Bovenberg and de Mooij, 1994; Goulder, 1995). The principle holds under specific conditions within second-best optimal tax systems (Jacobs and de Mooij, 2015; Jacobs and van der Ploeg, 2019), and the tax difference is identified as the relevant object (see also Orosel and Schöb, 1996; Schöb, 1997). In Jacobs and de Mooij (2015), as in much of the literature, the clean good is an untaxed numeraire, so that consumer and producer prices coincide and the Pigouvian tax rate equals the tax difference.

The model set out below is a simple one, and what it retains from that debate is what matters for implementation in economies with consumption taxes, as Section 2.6 explains. Labor supply is inelastic; Section 5 discusses an elastic supply. Polluting and clean goods are taxed separately, and taxes are set to implement the Pigouvian allocation of goods.

2.1. Households and technology

The economy has two households, $h = 1,2$, and two consumption goods. Household 1 consumes a clean good, x_1, and a polluting good, y. Household 2 consumes the clean good only, x_2, and is harmed by household 1's consumption of the polluting good. Utility functions are

$$U_1(x_1, y), \qquad U_2(x_2, y), \tag{1}$$

which are twice continuously differentiable and strictly quasi-concave in the household's own consumption. Partial derivatives are denoted by $U_{1x} = \partial U_1/\partial x_1$, $U_{1y} = \partial U_1/\partial y$, and so on, with $U_{1x} > 0$, $U_{1y} > 0$, $U_{2x} > 0$ and $U_{2y} < 0$. Household 1 does not take into account the effect of its consumption on household 2, so the externality is not internalized.

Technology is linear. Labor is available in fixed supply L, one unit of the clean good requires a_x units of labor and one unit of the polluting good a_y units, and L_g units of labor are employed in the public sector. Household 1's consumption of the polluting good also destroys d units of clean output per unit consumed, and the loss falls on each firm in the clean sector in proportion to its output. Output of the clean good net of this loss equals consumption, $X = L_x/a_x - dy$ with $X = x_1 + x_2$, while output of the polluting good is $y = L_y/a_y$. Labor market clearing, $L_x + L_y + L_g = L$, then implies

$$a_x(x_1 + x_2) + (a_y + a_x d)y + L_g = L. \tag{2}$$

Each unit of the polluting good therefore absorbs a_y units of labor directly and a further $a_x d$ through the clean output it destroys. The same constraint arises when it is the production of the polluting good

rather than its consumption that harms the clean sector, since all output of the polluting good is consumed by household 1.

2.2. The Pigouvian allocation

A social planner chooses x_1, x_2 and y to maximize

$$W = U_1(x_1, y) + \lambda U_2(x_2, y) \tag{3}$$

subject to the resource constraint (2), where $\lambda > 0$ is the welfare weight on household 2. Assuming an interior solution and that the second-order conditions hold, the first-order conditions are

$$U_{1x} = \mu a_x, \qquad \lambda U_{2x} = \mu a_x, \qquad U_{1y} + \lambda U_{2y} = \mu(a_y + a_x d), \tag{4}$$

where μ is the shadow value of labor. The first two conditions imply $U_{1x} = \lambda U_{2x}$: the planner equalizes the social marginal utility of clean consumption across households. Define marginal environmental damage to household 2, measured in units of the clean good, as

$$b \equiv -\frac{U_{2y}}{U_{2x}} > 0, \tag{5}$$

evaluated at the optimum. The value of b is the quantity of the clean good that household 2 is willing to give up to avoid a marginal increase in y. The damage borne by the clean sector is already measured in those units, since d is itself a quantity of the clean good. Combining the conditions in (4) and using $U_{1x} = \lambda U_{2x}$ gives

$$\frac{U_{1y}}{U_{1x}} = \frac{a_y + a_x d}{a_x} + b = \frac{a_y}{a_x} + b + d. \tag{6}$$

Thus, the social marginal cost of an additional unit of the polluting good, measured in units of the clean good, is $a_y/a_x + b + d$: the labor cost of production, the marginal damage to household 2 and the marginal damage to the clean sector, either of which may be zero. At the social optimum this equals the marginal rate of substitution between the two goods.

2.3. Household behavior and taxation

Let the government levy unit taxes t_x and t_y on the two goods and a proportional tax t_w on labor income, so that consumer prices are $P_x = p_x + t_x$ and $P_y = p_y + t_y$. The households supply L_1 and L_2 units of labor inelastically, with $L_1 + L_2 = L$, and face the budget constraints

$$P_x x_1 + P_y y = (1 - t_w) w L_1, \qquad P_x x_2 = (1 - t_w) w L_2,$$

where w is the wage rate. Because labor supply is fixed, the income tax is non-distortionary, and it is the rate that adjusts once the commodity taxes are set; Section 5 returns to what changes when labor supply responds. With no lump-sum redistribution the division of clean consumption between the

households is determined by their labor endowments. The welfare weight λ in (3) is taken to be the one at which the planner's division of clean consumption coincides with this division. The Pigouvian allocation is consequently defined relative to the existing distribution of labor, and the commodity taxes have the single task of correcting the externality, see Jacobs and de Mooij (2015). Household 1 chooses consumption such that its marginal rate of substitution equals the relative consumer price:

$$\frac{U_{1y}}{U_{1x}} = \frac{P_y}{P_x}. \tag{7}$$

Household 2's marginal willingness to pay in money to avoid a marginal increase in pollution, WTP, is the monetary value of marginal environmental damage. Since b measures this damage in units of the clean good and P_x is the consumer price of that good,

$$\text{WTP} \equiv bP_x. \tag{8}$$

This is the quantity that valuation studies seek to estimate, whether by revealed preference (e.g., travel cost, hedonic pricing) or stated preference methods (Freeman et al., 2014), and it is therefore measured in consumer prices.

2.4. Firms and the government budget

Firms are competitive, produce under constant returns and earn no pure profit. Because the loss caused by the externality falls on each firm in proportion to its output, marginal and average cost coincide. Suppose that the damaged firms are compensated for the output they lose, at the producer price of that output, so that the clean sector receives $S = p_x dy$. Zero profit, $\pi_x = p_x X - wL_x + S = 0$ with $L_x = a_x(X + dy)$, then gives $p_x = a_x w$, and the same argument in the other sector gives $p_y = a_y w$. Producer prices are therefore proportional to unit labor requirements and fixed once the wage is, so that taxes are fully passed on to consumer prices. Write $D \equiv p_x d$ for the monetary damage reported by firms. This damage is valued at the producer price of the output that is damaged.

The government employs L_g units of labor and pays the compensation, so that its budget constraint is

$$t_x(x_1 + x_2) + t_y y + t_w wL = wL_g + S.$$

This is not an additional restriction on the tax system. Adding the two household budget constraints, substituting the zero-profit conditions and using (2) delivers it exactly, as Walras's law requires.

Two degrees of freedom remain. The first is the numéraire: zero profit determines producer prices only up to the wage, and fixing the wage fixes their scale. The second is the normalization of the tax system: given producer prices, the tax on clean consumption can be chosen freely, the condition derived below then determines the tax on the polluting good, and the budget constraint determines

the income tax. The revenue requirement therefore imposes no restriction on the normalization, since it is met at every point of the family derived in Section 2.6. Following Schöb (1997), the term normalization refers to this second choice throughout.

2.5. Damage to households, to firms, or to both

The specification covers three scenarios: damage inflicted on households alone, such as motorists imposing costs on other motorists ($d = 0$), damage inflicted on the clean sector alone ($b = 0$), and damage inflicted on both. Efficient Pigouvian taxation must handle each of them, and condition (6) does so, since the two components enter additively and either may be zero.

The scenarios with damage to firms rest on the assumption that the damaged sector is compensated for the output it loses, which keeps producer prices proportional to unit labor requirements. Without compensation, zero profit in the clean sector requires $p_x = a_x w(1 + dy/X)$: the loss is fixed by y but shared out in proportion to each firm's output, so the producer price carries part of the damage. If the polluting sector itself lost d_y units of output per unit consumed, zero profit would give $p_y = a_y(1 + d_y)w$, which is its social marginal cost, so that the price would internalize the loss and only household damage would remain to be taxed. The compensation is designed so that relative producer prices are unaltered, i.e. so that p*(y)*/*p*(x) = a*(y)*/*a*(x). This also holds without compensation if the damage reduces productivity in both sectors in the same proportion: both producer prices then rise by the same factor, which is a change in the price level that the choice of numéraire absorbs. The compensation can therefore be read literally, as a transfer that prevents damage concentrated in one sector from changing relative producer prices, or as a convenient representation of any setting in which the damage leaves relative producer prices unchanged.

The compensation is not a Coasean side payment (Coase, 1960). It is financed from the budget rather than paid by the polluter, and the correction of the polluter's margin comes from the tax alone. Nor does it conflict with Baumol (1972), who shows that victims should not be compensated at the margin. His argument is that compensation weakens the victims' incentive to avoid the damage, for example by relocating or taking protective measures.

2.6. Pigouvian taxation

The purpose of a Pigouvian tax is to induce agents to internalize the external cost, thereby ensuring that the decentralized equilibrium reproduces the first-best allocation. Accordingly, Pigouvian taxation is defined as a system of consumption taxes that implements the Pigouvian allocation characterized by (6). Combining the household's optimality condition in (7) with the social optimum condition in (6), the Pigouvian allocation is implemented if and only if

$$\frac{p_y + t_y}{p_x + t_x} = \frac{a_y}{a_x} + b + d. \tag{9}$$

Producer prices equal unit labor costs, so that $a_y/a_x = p_y/p_x$ and the condition can be written in producer prices.

Define the environmental tax difference as $\omega \equiv t_y - \frac{p_y}{p_x} t_x$, the tax on the polluting good in excess of the tax that would leave relative consumer prices unchanged. Rearranging (9) then gives

$$\omega/P_x = b + d. \tag{10}$$

Thus, implementation requires the consumption tax system to satisfy equation (10). The condition becomes particularly transparent when quantity units are chosen so that producer prices are equal, i.e. where $p_x = p_y = p$. Equation (10) reduces to

$$\frac{t_y - t_x}{P_x} = b + d. \tag{11}$$

Hence, the tax difference measured in units of the clean good must equal total marginal environmental damage measured in the same units. An application of the condition to greenhouse gas emissions that harm aid-receiving poor countries appears in Bjertnæs (2024). Using (8) to express the condition in money gives

$$t_y - t_x = \mathrm{WTP} + dP_x. \tag{12}$$

The two components enter in different units. Willingness to pay is already the monetary value of b at consumer prices and enters as it stands. The damage to the clean sector is estimated as a loss of output at producer prices, $D = dp_x$, and has to be rescaled by P_x/p_x to the consumer prices of (12) before the two components are added. A tax difference set equal to measured marginal damage, $\mathrm{WTP} + D$, therefore does not implement the Pigouvian allocation in (6) when part of the damage falls on firms. With damage to households alone the condition reduces to $t_y - t_x = \mathrm{WTP}$, the familiar monetary form of the Pigouvian rule.

Proposition 1. *With producer prices proportional to unit labor requirements, Pigouvian taxation is characterized by an environmental tax wedge, the environmental tax difference measured relative to the consumer price of clean consumption, equal to total marginal environmental damage measured in units of clean consumption:*

$$\omega/P_x = b + d.$$

When quantity units are chosen so that $p_x = p_y$, this is the monetary form (12):

$$t_y - t_x = \mathrm{WTP} + dP_x.$$

Proof. Equate the household's condition (7) with the social optimum condition (6) and multiply by P_x. The second display then follows when $p_x = p_y$, using (8). ■

Proposition 1 provides a relative-price characterization of Pigouvian taxation. The relevant policy variable is the environmental tax wedge rather than the tax on the polluting good in isolation. The required environmental tax wedge may be implemented through a tax on polluting consumption, a subsidy to clean consumption, or a combination of both. Many countries have introduced fee-bate systems, in which polluting goods are taxed while cleaner alternatives are subsidized. Such systems implement the required environmental tax wedge through a combination of taxes and subsidies. The Pigouvian allocation is attained when the resulting tax wedge satisfies Proposition 1.

Condition (10) can be solved for the tax on the polluting good. For given producer prices, and with b evaluated at the Pigouvian allocation,

$$t_y = (b + d)p_x + \frac{p_y + (b + d)p_x}{p_x} t_x, \tag{13}$$

for any $t_x > -p_x$. The tax systems that implement the Pigouvian allocation therefore form a one-parameter family, and the free parameter is the tax on clean consumption, that is, the normalization. Along this family both consumer prices move in proportion, since $P_y = (p_y + (b + d)p_x)P_x/p_x$, so that a change in t_x scales the consumer price level and leaves the relative price of the two goods unchanged. Setting $t_x = 0$ gives the conventional Pigouvian tax, $t_y = (b + d)p_x$. The uniform consumption tax is presented in Section 3. With a negative tax on clean consumption, the family includes a member at which the polluting good is untaxed and clean consumption is subsidized.

Corollary 1. *(Normalization invariance)*

Consider a move along the family in (13), in which the tax on clean consumption changes, the tax on the polluting good adjusts so that (10) continues to hold, and the labor income tax adjusts so that the net wage moves in proportion to consumer prices. Real incomes and the allocation are then unchanged, and the government budget continues to hold by Walras's law. By the preceding paragraph this is a common proportional scaling of consumer prices. Then:

(a) The statutory taxes change, and the tax difference measured in money and households' willingness to pay scale in the same proportion as the consumer price of clean consumption. None of them is invariant.

(b) The environmental tax wedge, ω/P_x, and total marginal environmental damage, $b + d$, are invariant. The condition in Proposition 1 therefore characterizes the same family under every normalization.

(c) When the damage falls on households, willingness to pay scales in the same proportion as the required tax difference. The monetary condition that the tax difference equals willingness to pay then selects the same set of tax systems under every normalization, even though neither side of it is invariant.

(d) Damage borne by firms, measured as a loss of output at producer prices, $D = dp_x$, does not scale with the normalization. A tax difference equal to $\mathrm{WTP} + D$ *implements the Pigouvian allocation only at the normalization at which clean consumption is untaxed, $t_x = 0$.*

Corollary 1 sharpens the connection to the normalization literature. Fullerton (1997) and Schöb (1997) establish that the level of the environmental tax has no meaning independent of the normalization, and that the relevant object is the tax difference between polluting and clean consumption. Fullerton (1997) measures both the tax difference and marginal damage in money, converting damage by dividing by the marginal utility of income, so that it is valued at consumer prices. Part (a) shows why this matters: money is not a real unit here. Because the normalization fixes the consumer price level, any tax difference or damage measured in money is itself normalization dependent. Dividing by the consumer price of clean consumption expresses it in the units in which marginal damage is defined, which is part (b). Part (c) is not a restatement of part (b): willingness to pay scales exactly as the required difference does, so their equality survives every normalization although neither side does. Part (d) gives a precise sense in which the familiar rule is formulated for an economy in which clean consumption is untaxed: with damage to firms measured in producer prices, the rule is right at that normalization where clean goods are untaxed and at no other. That this monetary measure moves with the normalization is not stated in this literature, although Fullerton (1997, fn. 3) notes that the value of marginal damage depends on the point at which it is evaluated. The question is also distinct from the classical comparison of specific and ad valorem taxation, which concerns how a given tax burden is best levied (Keen, 1998).

Two members of the family correspond to the familiar normalizations, which set one of the tax rates to zero; with producer prices given, this is equivalent to fixing one consumer price (Schöb, 1997). At $t_x = 0$ clean consumption is untaxed and revenue comes from the labor income tax and the environmental tax, Schöb's labor tax system; where the income tax is zero, revenue comes from commodity taxes alone, his commodity tax system. Moving between them shifts revenue between the income tax and a uniform component of the commodity taxes, which are equivalent because both acts only through the net wage measured in consumer prices (Fullerton, 1997). With an endogenous labor supply the equivalence still holds, provided the income tax reaches all income, and labor supply is then also invariant to the normalization. The normalization does, however, change statutory tax rates, including the environmental tax, as well as the monetary measure of marginal environmental

damage, and this is precisely the degree of freedom that matters for the question addressed in this paper.

Tax systems that differ only by normalization implement the same allocation with different statutory rates; a higher consumption tax offset by a lower labor income tax is such a change. A higher consumption tax that finances additional public employment is not: it reduces private consumption and changes the allocation, and with it marginal damage and willingness to pay.

3. Uniform consumption tax

Consider now a uniform ad valorem consumption tax at rate m on both goods, such as a retail sales tax or a value added tax, combined with a unit environmental tax t on the polluting good. Proposition 1 can then be used to determine the environmental tax required to implement the Pigouvian allocation. Two tax regimes are considered. In regime O, the environmental tax is outside the consumption tax base. In regime I, the environmental tax is included in the tax base, so that the consumption tax is levied on the producer price inclusive of the environmental tax.

Consumer prices are

$$\text{Regime O:} \qquad P_x = (1+m)p_x, \qquad P_y = (1+m)p_y + t, \tag{14}$$

and

$$\text{Regime I:} \qquad P_x = (1+m)p_x, \qquad P_y = (1+m)(p_y + t). \tag{15}$$

In both regimes, the consumer price of clean consumption is $P_x = (1+m)p_x$. In regime O, the environmental tax increases the consumer price of the polluting good by t, implying an environmental tax difference of $\omega = t$. In regime I, the environmental tax itself is subject to the consumption tax and therefore increases the consumer price by $(1+m)t$, so that $\omega = (1+m)t$.

By Proposition 1, the environmental tax wedge must equal total marginal environmental damage measured in units of clean consumption, so that the required tax difference is $(b+d)P_x$ in both regimes. The statutory environmental tax that generates it, however, differs between the two tax systems.

Proposition 2. *Under the conditions of Proposition 1, and with a uniform consumption tax at rate m, the Pigouvian allocation is implemented if and only if the statutory environmental tax, with willingness to pay evaluated at that allocation, is*

$$\text{(a) Regime O:} \qquad t_O = \text{WTP} + (1+m)D = (1+m)(b+d)p_x, \tag{16}$$

$$\text{(b) Regime I:} \qquad t_I = \frac{\text{WTP}}{1+m} + D = (b+d)p_x. \tag{17}$$

Proof. Insert the tax differences $\omega = t$ and $\omega = (1+m)t$, together with $P_x = (1+m)p_x$, into (10). ■

Proposition 2 separates the tax difference required for efficiency from the statutory tax that generates it. Inside the consumption tax base, the statutory rate equals total marginal damage at producer prices, whatever the consumption tax rate; outside the base it is $1+m$ times as large, because the tax must then supply the difference on its own. Whether a rate set equal to measured damage is efficient depends on who bears the damage. Damage to households is measured as willingness to pay at consumer prices; as a statutory rate it is correct in regime O but exceeds the efficient rate by the factor

$1 + m$ in regime I. Damage to firms is measured as lost output at producer prices; it is correct in regime I but falls short by the same factor in regime O. When the damage falls on both, the measured total is correct in neither regime. Which regime applies is an institutional matter, and regime I is the normal case (Section 4.2). Without consumption taxation the two regimes coincide, and the conventional Pigouvian rule is recovered.

4. The tax base and statutory rates

4.1. Taxes levied on producers

Environmental taxes are often levied on producers rather than on consumers. Suppose that emissions arise from the production of the polluting good, so that each unit produced causes the same marginal damage as in Section 2, and that the environmental tax is levied on the producer. Since all output of the polluting good is consumed by household 1, the planner's problem is unchanged, and the Pigouvian allocation is still characterized by (6). What changes is only the point at which the tax is collected.

Producers are competitive and produce the polluting good at the constant unit cost p_y. A unit environmental tax t is levied on each unit produced, so that the producer price of the polluting good becomes

$$q_y = p_y + t.$$

The consumption tax is levied on the producer price, which now includes the environmental tax. Consumer prices are therefore

$$P_x = (1+m)p_x, \qquad P_y = (1+m)q_y = (1+m)(p_y + t).$$

These are the consumer prices of regime I in (15). Proposition 2 gives the statutory environmental tax required to implement the Pigouvian allocation:

$$t = \frac{\text{WTP}}{1+m} + D = (b+d)p_x.$$

Taxing producers rather than consumers therefore does not alter the analysis. With fixed producer prices the tax is fully passed on, and the legal incidence of the environmental tax is irrelevant. What matters is that the consumption tax is levied on a producer price that includes the environmental tax, which places the economy in regime I. The same applies to the consumption tax itself: whether it is remitted by the seller or collected from the buyer, only its base matters. When the damage falls on households, setting the statutory rate equal to willingness to pay would make household 1 face a relative price corresponding to a marginal damage of $(1+m)b$ rather than b; damage borne by firms, measured as D, enters correctly as it stands.

4.2. Statutory rates and practice

Table 1 summarizes the statutory rates derived above. Two questions determine the rate, and they are independent. The first is whether the environmental tax forms part of the consumption tax base, which it does when it is levied on consumers and included in the base, and whenever it is levied on

producers. The second is who bears the damage, which fixes the unit in which it is estimated: willingness to pay at consumer prices for households, a loss of output at producer prices for firms. A tax levied on firms is always inside the base, so the last two rows have no counterpart outside it.

Table 1. Statutory environmental taxes that implement the Pigouvian allocation

Environmental tax levied on	Damage borne by	Statutory rate
Household consumption, outside the base	Households	WTP
Household consumption, inside the base	Households	$\mathrm{WTP}/(1+m)$
Household consumption, outside the base	Firms	$(1+m)D$
Household consumption, inside the base	Firms	D
Output of firms	Households	$\mathrm{WTP}/(1+m)$
Output of firms	Firms	D

In practice the environmental tax is generally inside the base. In the European Union the taxable amount for value added tax includes taxes, duties, levies and charges other than the tax itself (Council Directive 2006/112/EC, Article 78), which follows from the design of an invoice-credit value added tax: it is charged on the consideration for the supply, of which an upstream excise forms part. Rows 2 and 4 of Table 1 are therefore the normal cases for taxes on household consumption. The two regimes can nevertheless coexist. In Japan the gasoline tax enters the base of the consumption tax, whereas the delivery tax on light oil may be kept outside it (National Tax Agency, 2026), so that the same damage calls for statutory rates that differ by the factor $1+m$ between the two fuels.

Policy work sets statutory rates measured in producer prices against damage estimates that are largely measured in consumer prices. Statistics on effective carbon prices exclude value added tax (OECD, 2019), whereas valuation studies estimate willingness to pay at the prices faced by those who bear the damage. The damage functions behind estimates of the social cost of carbon express losses as shares of consumption or output; to the extent that such an estimate values losses of output at producer prices, it is a composite in the sense of Table 1, and a rate set equal to it overstates the efficient rate inside the base by a factor smaller than $1+m$. The guidance accompanying the United Kingdom's Green Book notes that firms and consumers face different rates of indirect taxation and that a correction may therefore be advisable, but leaves its details unspecified (Department for Energy Security and Net Zero, 2023). Table 1 supplies the corresponding correction for statutory rates.

5. Caveats

Many households and firms. With many affected households, b is the sum of their marginal rates of substitution, as in the Samuelson condition, and willingness to pay is the corresponding sum. If distributional weights are applied to the household components, as some approaches to second-best policy evaluation do, they change the measure of damage but not the conversion between consumer and producer prices. Output losses borne by firms are resource costs and are simply added.

Non-uniform consumption taxes. With reduced rates or exemptions, the conversion factor becomes a weighted average of one plus the tax rates applying to the clean goods consumed by the affected households.

Taxes on polluting inputs. The analysis concerns environmental taxes on final consumption and on the output of polluting goods. With full deduction under an invoice-credit value added tax, a levy on a polluting input is embodied in the producer price of the final good, as in regime I. The efficient statutory rate is then marginal damage at producer prices. Cascading taxes or exemptions from deduction may call for different rates, and the statutory rate in those cases is left for future research.

Distortionary taxation. The model assumes inelastic labor supply. With elastic labor supply, the same result holds when the income tax is optimal and preferences are weakly separable between goods and leisure (Kaplow, 2012; Jacobs and de Mooij, 2015). Otherwise environmental tax formulas contain additional revenue or labor-tax terms (Bovenberg and de Mooij, 1994), but these supplement rather than replace the Pigouvian component (Sandmo, 1975). The conversion between consumer and producer prices derived here therefore applies to that component irrespective of broader fiscal objectives.

Marginal willingness to pay. The results concern marginal willingness to pay evaluated at the optimal allocation. Empirical estimates are often obtained at the observed allocation and may refer to non-marginal changes. The analysis therefore determines how willingness-to-pay estimates should be converted into statutory tax rates, not how they should be extrapolated to the optimum.

6. Concluding remarks

This paper has shown that a statutory rate set equal to marginal environmental damage on households, estimated as willingness to pay, taxes the polluting good above the Pigouvian level by a factor of one plus the consumption tax rate when the environmental tax is collected inside the base of a general consumption tax. That is the normal case in the European Union and many other jurisdictions. The familiar rule is formulated for an economy in which clean consumption is untaxed, so that its consumer and producer prices coincide. Once clean consumption is taxed they differ, and the monetary value of a given damage depends on the price at which it is measured. For damage to households, neither the tax difference in money nor willingness to pay is invariant to the normalization of the tax system, but their equality is, which gives welfare-theoretic content to the tax difference emphasized by Fullerton (1997).

The general rule is that the statutory rate equals marginal damage expressed in the prices of the base on which the tax is levied. Willingness to pay is measured at consumer prices and must be divided by one plus the consumption tax rate when the tax is levied inside the base, whether on consumers or on producers. Damage borne by firms is measured at producer prices; it enters unchanged inside the base but is multiplied by one plus the consumption tax rate outside it, which presumes that relative producer prices are undisturbed. A composite estimate must be converted component by component. A damage estimate can therefore be translated into a statutory rate only once two things are known: the prices at which the damage has been measured, and the tax base on which the tax is levied.

References

Baumol, W. J. (1972). On taxation and the control of externalities. *American Economic Review*, 62(3), 307–322.

Bjertnæs, G. H. M. (2024). Optimal carbon taxes and foreign aid. Discussion Papers No. 1012, Statistics Norway.

Bovenberg, A. L., & de Mooij, R. A. (1994). Environmental levies and distortionary taxation. *American Economic Review*, 84(4), 1085–1089.

Coase, R. H. (1960). The problem of social cost. *Journal of Law and Economics*, 3, 1–44.

Council Directive 2006/112/EC of 28 November 2006 on the common system of value added tax. *Official Journal of the European Union*, L 347, 11.12.2006, 1–118.

Department for Energy Security and Net Zero (2023). Valuation of energy use and greenhouse gas (GHG) emissions: Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government. London: Department for Energy Security and Net Zero, November 2023.

Drèze, J., & Stern, N. (1987). The theory of cost-benefit analysis. In A. J. Auerbach & M. Feldstein (Eds.), Handbook of Public Economics, Vol. 2 (pp. 909–989). Amsterdam: North-Holland.

Freeman, A. M., III, Herriges, J. A., & Kling, C. L. (2014). *The Measurement of Environmental and Resource Values: Theory and Methods* (3rd ed.). New York: RFF Press/Routledge.

Fullerton, D. (1997). Environmental levies and distortionary taxation: Comment. *American Economic Review*, 87(1), 245–251.

Goulder, L. H. (1995). Environmental taxation and the double dividend: A reader's guide. *International Tax and Public Finance*, 2(2), 157–183.

Jacobs, B., & de Mooij, R. A. (2015). Pigou meets Mirrlees: On the irrelevance of tax distortions for the second-best Pigouvian tax. *Journal of Environmental Economics and Management*, 71, 90–108. https://doi.org/10.1016/j.jeem.2015.01.003

Jacobs, B., & van der Ploeg, F. (2019). Redistribution and pollution taxes with non-linear Engel curves. Journal of Environmental Economics and Management, 95, 198–226.

Kaplow, L. (2012). Optimal control of externalities in the presence of income taxation. *International Economic Review*, 53(2), 487–509.

Keen, M. (1998). The balance between specific and ad valorem taxation. *Fiscal Studies*, 19(1), 1–37.

National Tax Agency (2026). *Tax Answer No. 6313: Treatment of individual excise taxes such as liquor tax and tobacco tax* (in Japanese), citing Consumption Tax Basic Circular 10-1-11. Tokyo: National Tax Agency. Consulted 6 October 2026.

OECD (2019). *Taxing Energy Use Database: Methodology*. Paris: OECD. https://www.oecd.org/en/data/datasets/carbon-pricing-and-energy-taxation-database.html. Consulted 6 October 2026.

Orosel, G. O., & Schöb, R. (1996). Internalizing externalities in second-best tax systems. *Public Finance / Finances Publiques*, 51(2), 242–257.

Pigou, A. C. (1920). *The Economics of Welfare*. London: Macmillan.

Sandmo, A. (1975). Optimal taxation in the presence of externalities. *Swedish Journal of Economics*, 77(1), 86–98.

Schöb, R. (1997). Environmental taxes and pre-existing distortions: The normalization trap. *International Tax and Public Finance*, 4(2), 167–176. https://doi.org/10.1023/A:1008690304507