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Free-Riding on Environmental Taxation

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Abstract

We examine how tax avoidance affects the optimal design of a linear tax on polluting emissions in a monopoly setting. The firm is owned by shareholder who differ in their cost of tax dodging. Following Buchanan (1969), the optimal tax should correct for two negative externalities due to pollution and the monopolist's behavior. The analysis highlights two conflicting effects of tax avoidance on the environmental policy design: a *free-riding effect* and a *tax base erosion effect*. With heterogeneous tax avoidance, the regulator must also internalize the externality imposed by the free-riding of tax avoiders on the rest of the society. This free-riding makes the regulator either impotent or unfair, depending on the severity of the environmental damage and the firm's efficiency. We also show that a two-part tax schedule can achieve the first-best outcome.

Keywords: Envirnomental Taxation, Monopoly, Tax Avoidance.

JEL Code: D43, D82, H23, L12, Q28

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1 Introduction

Economists have long advocated for high Pigouvian taxes that would directly place prices on the most harmful of greenhouse gases to achieve significant reductions of these gases. For instance, the optimal Pigouvian tax on carbon dioxide should be set in the range of $75 to $175 per ton according to the best estimates of marginal damages of emissions (see Stavins, 2011). Although environmental taxation has great conceptual appeal, economists also recognize the challenge of inducing tax payers to comply with taxes at such high rates. Surprisingly enough, the concern formerly expressed by Adam Smith is rarely invoked in this respect:

"High taxes, sometimes by diminishing the consumption of the taxed commodities, and sometimes by encouraging smuggling, frequently afford a smaller revenue to government than what might be drawn from more moderate taxes" (Smith, 1776, Book V, Chapter II).

Long after publication of *The Wealth of Nations*, Laffer (1977) drew his famous curve illustrating the possibility of an inverse relationship between tax rates and government revenue. Understood in a broad metaphoric sense, the term "smuggling" used by Adam Smith may refer to a variety of tax dodging in today's economies, ranging from the relocation of a corporation's legal domicile to a lower-tax nation, usually known as tax inversion, to the substitution between labor and leisure discussed in general equilibrium models (see Fullerton, 1982, for instance). The type of "smuggling" we examine here is *tax avoidance*, referring to all the transactions that take advantage of legal loopholes to reduce total tax liabilities[1]. We shed light on adverse effects from the free-riding of tax avoiders on the efficiency of environmental regulation. In a partial equilibrium setting where a regulator levies an environmental tax to correct for the polluting behavior of a monopolistic firm, we characterize optimal taxation, assuming that firms' shareholders can choose between paying and avoiding the tax. That is, we consider the second-best problem of choosing the welfare-maximizing tax for which the regulator endogenizes the free-riding behaviors of tax avoiders.

[1] More precisely, throughout the article, we will use the term "tax avoidance" in the sense of "abusive tax avoidance transactions" (see GAO, 2011), that is, all the practices that don't contradict the law but diverge from its spirit. For instance, a company that uses artificial non-productive transactions through offshore entities with complex but legal profit-shifting techniques is involved in abusive avoidance, as it uses loopholes in law to optimize tax obligations in the ways not intended by the legislation. Slemrod (2007) distinguishes tax avoidance from illegal tax evasion, although this author highlights the difficulty of distinguishing illegal from legal intent on the part of a taxpayer.

In a recent work based on the "World Induced Technical Change Hybrid" model, Carraro et al. (2012) predict that carbon taxes might sometimes generate fiscal revenues which first increase, then achieve the highest levels of revenue, and finally decrease, thereby forming a "carbon Laffer" curve (p. 25). Their analysis questions the political and economic feasibility of large taxation schemes. We raise similar concerns regarding a polluting monopolist, following the tradition of Buchanan (1969). As has been thoroughly formalized by Lee (1975) and Barnett (1980), the regulator must scale down the environmental tax below the Pigouvian level to correct for the monopolist's tendency to underproduce. Therefore, compared to markets with perfect competition, the emissions control of imperfectly competitive firms requires a less stringent taxation. We take a fresh look at this second-best policy and examine how the environmental regulator copes with the possibility that the firm's shareholders bypass taxation. Clearly, this is an issue of theoretical importance. If the purpose of environmental taxation is to force individuals to consider the full set of consequences from polluting emissions, the optimal tax should also internalize the negative externality caused by the free-riding of tax avoiders.

Furthermore, tax avoidance has emerged as a systemic problem with the globalization of the economy. The deregulation of the financial system in industrialized countries, which took place in the 1980s, together with the technological progress, has made the mobility of capital far greater than that of labor. While labor mobility is largely limited to national jurisdiction, the capital can almost instantaneously move around the globe. As a result, almost every multinational firm is to some extent involved in avoidance activities (Christensen and Kapoor, 2004, p. 9). Indeed, many multinational companies such as Apple, Amazon and Microsoft (Young, 2013) or Starbuck, Total and Colgate (Harel, 2012) have drawn public attention for remarkably low taxes paid on profit. More importantly for our purposes, tax avoidance is closely related to companies operating in greenhouse gas producing sectors, including the extractive industries, aviation, shipping, pharmaceuticals, traded commodities and weapons industry (Christensen and Kapoor, 2004), p.3).

As pointed out by the optimal taxation literature, avoidance or sheltering is the behavioral response to taxation where an individual searches a legal opportunity to reduce his tax liability (see Cowell, 1990). Besides this issue, the mainstream literature on avoidance is concerned with optimal enforcement expenditure (Mayshar, 1991, and Slemrod, 1994). In the present paper, we ignore income effects and abstract from enforcement efforts to focus on the impact of tax avoidance on environmental regulation; only the effect of diminishing the tax base caused by tax sheltering is under consideration. To our knowledge, the concern of tax base erosion has not yet been addressed in the field of environmental economic. The only study of environmental tax evasion belongs to Liu (2013) who questions its impact on environmental taxation. He shows in a generalized equilibrium model with perfect competition that an environmental tax may enhance welfare provided that environmental tax is more difficult to evade than other 'regular' taxes.

In our framework, the firm's profit is distributed to shareholders who differ in their opportunity cost of avoiding taxation. They will gradually bypass taxation as the tax rate increases. Hence, the regulator's objective function excludes part of the monopoly profits attributable to tax avoidance. The environmental tax is designed so that the regulator optimally chooses the level of tax avoidance compatible with the dual task of internalizing the polluting externality and mitigating the monopolist's overpricing. The analysis highlights two conflicting effects of tax avoidance on the environmental policy design: a *free-riding effect* and a *tax base erosion effect*. On the one hand, tax avoiders free-ride on tax payers as well as consumers by passing on to them the burden of the tax. The regulator internalizes this externality by taxing the complying shareholders more heavily than it would do under full compliance. On the other hand, the regulator must take into consideration that the tax increase will induce more shareholders to avoid taxation. As shrinking the tax base reduces tax revenues, the regulator has an opposite incentive to soften taxation in order to compensate for the shareholders' mobility. As a result, depending on which effect of tax avoidance prevails, the second-best optimal taxation proves more or less severe relative to full compliance.

We find that the tax base erosion effect dominates when the monopolist is significantly clean and the polluting good is relatively cheap to produce, so that environment has a low rank in the agenda of economic priorities. The regulator gives up a positive tax that would otherwise internalize the monopolist's environmental externality under full tax compliance, for the sake of maintaining the tax base. Anticipating that positive taxation would induce some shareholders with low costs of avoidance to escape, the regulator refrains from taxation. This may somewhat explain the sluggishness in introducing carbon taxes when the focus on economic growth takes priority over the environmental concern. If, on the contrary, the monopolist is significantly dirty and/or moderately efficient, the environmental damage becomes the major concern and the free-riding effect of tax avoidance dominates. To cope with the dire need of internalizing the polluting externality, the regulator can no longer afford not to tax emissions. Instead, the regulator taxes pollution at the cost of losing shareholders. The revenue lost as a result of tax avoidance creates a further negative externality on those who bear the burden of environmental taxation. These are the shareholders who remain under the regulator's authority, as well as the consumers who pay the monopoly price inflated by the tax. To correct for the tax avoiders' free-riding, the regulator must raise the environmental tax above the level recommended by Buchanan (1969). Consequently, the remaining taxpayers must bear a greater tax than that under no tax avoidance.

We finally allow the regulator to use the combination of a unit tax on emissions and a lump-sum tax. We show that this two-part tax schedule successfully achieves the first-best outcome in our setting.

The present article is organized as follows. In Section 2, we set up the formal model. Section 3 characterizes the second-best optimal tax under the assumption of tax avoidance. Section 4 examines the use of the two-part tax schedule. In Section 5, we present a brief history intended to illustrate the reluctance of an environmental regulator to correct for the environmental externality because of tax avoidance. Section 6 concludes.

2 The model

The industry consists of a single polluting firm, the firm's shareholders, consumers and an environmental regulator.

The firm produces quantity q of a good that releases the amount $(1-e)\,q$ of polluting emissions, where parameter $e \in [0,1]$ represents the state of the abatement technology. If, for instance, polluting emissions are greenhouse gases and the good is electricity, e measures the use of non-emitting methods such as hydroelectric, nuclear, or geothermal, and $1-e$ the use of emitting methods through the combustion of coal, natural gas, or petroleum distillates. We restrict attention to short-run decisions, so that the level e is not a decision variable. If the abatement is at a maximum, the emissions are zero. If no abatement is undertaken, the emissions are equal to the output. The overall marginal cost of producing the good is $c(e)$, with $c'(e) > 0$, meaning that devoting more resources to abatement raises the overall cost of production. Industry-specific emissions cause environmental damage $d(q,e)$, which is assumed to be strictly proportional to the amount of polluting emissions: $d(q,e) = \delta\,(1-e)\,q$, where $\delta > 0$ measures the marginal damage from emissions.

The regulator is facing two market distortions due, respectively, to monopoly power and environmental externality. In that event, we know from Buchanan (1969) and Barnett (1980) that a second-best optimal policy strikes the balance between the need to correct for the monopolistic behavior and the Pigouvian task of internalizing the marginal social damage. To allow comparison with this literature, we assume that the regulator is benevolent and the only regulatory instrument available to correct for both distortions is a tax τ per unit of emissions. Hence, throughout the article, the environmental tax can be thought of as the application of a broader regulatory policy: besides being concerned with the environment, the regulator is also responsible for controlling the market price. In other terms, the regulator is wearing two hats, that of an environmental protection agency and a public utility commission. A tax will take negative values if it turns out to be a subsidy. Indeed, it is conceivable that the tax cut resulting from the need to correct for the firms' market power becomes so sharp that the optimal policy imposes to subsidize the product.

The firm is owned by a continuum of shareholders, holding one unit of profit each. We normalize the mass of shareholders to be one. For simplicity, we will assume, first, that a shareholder has valuation 1 for holding one unit of profit, and second, that a shareholder incurs a cost $\alpha \in [0,1]$ of fiscal optimization. Hence, a shareholder with a cost α gets the surplus $1-\alpha$ from tax dodging. Paying the cost α may help the shareholder economize on the amount $\tau(1-e)$ of the due tax. For instance, α is the cost of sourcing out for the best way of being tax exempt. In practice, there exists a market for tax optimization services. Banks offer their corporate and private clients services such as wealth management, which contain "recommendations" for organizing their fiscal obligations in the most beneficial way (Gravelle, 2013). Alternatively, an internal department of the firm may specialize in tax issues, screening for countries where a subsidiary would benefit from the most favorable tax regimes. From (Christian, 2014), there is evidence of a substantial heterogeneity in tax avoidance. This will be captured by assuming that shareholders differ according to α, which is uniformly distributed on $[0,1]$. Now consider the behavior of a shareholder whose objective is to maximize surplus. The shareholder $\widehat{\alpha}(\tau)$ who is indifferent between paying and avoiding the environmental tax is determined by

$$1 - \tau(1-e) = 1 - \widehat{\alpha}(\tau), \tag{1}$$

which implies that the fraction of shareholders who comply with taxation is given by $1-\widehat{\alpha}(\tau)$, provided that $0<\tau<\frac{1}{1-e}$. If $\tau\leq 0$, the environmental policy takes the form of a subsidy, and there is full compliance. Moreover, if $\tau\geq\frac{1}{1-e}$, then all the shareholders bypass taxation. Let $\beta\left(\tau\right)$ denote the compliance rate for taxation:

$$\beta\left(\tau\right)=\left\{\begin{array}{c} 1 \text{ if } \tau\leq 0, \\ 1-\tau(1-e) \text{ if } 0\leq\tau\leq\frac{1}{(1-e)}, \\ 0 \text{ if } \frac{1}{(1-e)}\leq\tau\leq\frac{v-c(e)}{1-e}. \end{array}\right. \tag{2}$$

The monopolist sells the polluting good to a continuum of risk-neutral consumers with heterogenous "green" preferences. Each consumer purchases at most one unit of the good, which thus indirectly generates the amount $1-e$ of polluting emissions via consumption. Although consumers have a common reservation price v, they differ in their tastes for the good due to their personal dislike of pollution. For a given consumer X, the dislike of pollution is measured by the monetary loss $(1-e)X$, which, besides psychic discomfort, may represent health care expenditure and all the adaptation costs to the polluted environment. The heterogeneity of preferences may also reflect various degrees of social environmental conscience among consumers. If, for instance, the good is fossil energy, consumers may differ in their aversion to the negative impact on global warming, and if it is nuclear energy, they may differ in their dislike of the potential risks imposed on future generations by nuclear repositories. To simplify the analysis, we make the assumption that X is uniformly distributed along a segment of unit length, which is convenient to generate a linear demand function. Hence, consumers distinct from 0 partly internalize the polluting externality, and none of them fully internalizes it as long as $1<\delta$. The total number of consumers is normalized to unity. Assuming that consumers receive zero surplus from consuming outside goods, consumer X derives a surplus $v-(1-e)X-p$ from purchasing the good at price p, which yields the demand function

$$D(p,e)=\left\{\begin{array}{c} 0 \text{ if } p\geq v, \\ \frac{v-p}{1-e} \text{ if } v-(1-e)\leq p\leq v, \\ 1 \text{ if } p\leq v-(1-e)\,. \end{array}\right. \tag{3}$$

Socially optimal allocation of the good.—The welfare function is the conventional one of gross benefits to consumers less production and pollution costs.

The welfare function is

$$
\begin{aligned}
W(X) &= \int_0^X [v - c(e) - (1-e)x - \delta(1-e)]dx \qquad (4)\\
&= [v - c(e) - \delta(1-e)]X - (1-e)\frac{X^2}{2}.
\end{aligned}
$$

The expression $\delta(1-e)X$ is the actual damage caused to the environment, while $(1-e)\frac{X^2}{2}$ represents the monetary equivalent of the consumer's dislike for pollution[2].

At the socially optimal solution, the marginal consumer X^* solves equation $v-(1-e)X^* = c(e)+\delta(1-e)$ so that the marginal social value of the good $v-(1-e)X^*$ must exactly offset the total social marginal cost $c(e)+\delta(1-e)$. Thus from the social standpoint, the market size should be

$$X^* = \frac{v - c(e)}{1-e} - \delta. \qquad (5)$$

To ensure that the good is socially desirable, we will restrict the parameters of the model to satisfy the following assumption:

$$(1-e)\,\delta \leq v - c(e). \qquad (6)$$

We will abbreviate the marginal social cost of pollution $(1-e)\,\delta$ by MSC, and $v-c(e)$, the marginal social value of the good, net of its production cost, absent any environmental consideration, by MSV.

Monopolist's behavior in the absence of regulation.— The monopoly profit is $\pi_e(p,e) = (p-c(e))D(p,e)$ and the first-order condition for the monopolist's optimization problem is given by

$$(p - c(e))\frac{\partial D(p,e)}{\partial p} + D(p,e) = 0. \qquad (7)$$

One can easily check that the second-order conditions are satisfied. Let $\varepsilon(p) = -\frac{\partial D(p,e)}{\partial p}\frac{p}{D(p,e)} = \frac{1}{1-e}\frac{p}{D(p,e)}$ denote the price elasticity of demand for the good. We further denote by $\hat{p}_e$ the price set by the unregulated monopolist. The first-order conditions can be rewritten in the usual way to show that the Lerner

[2] The model in Kurtyka and Mahenc (2011) with heterogeneous preferences for the environment.results in the same distinction between the actual damage to the environment and consumer adaptation costs.

index is equal to the inverse of the price elasticity of demand, which implies that market power is a decreasing function of the price elasticity of demand:

$$\frac{\hat{p}_e - c(e)}{\hat{p}_e} = \frac{1}{\varepsilon(\hat{p}_e)}, \tag{8}$$

where $\varepsilon(\hat{p}_e) = \frac{\hat{p}_e}{v-\hat{p}_e}$. Substituting this expression into the right-hand side of (8), we obtain the monopoly price $\hat{p}_e = \frac{v+c(e)}{2}$, and the resulting demand is $D(\hat{p}_e, e) = \frac{v-c(e)}{2(1-e)}$. Comparing this outcome to the socially optimal solution, two separate cases emerge within the parameter configuration defined by (6). In one case where $(1-e)\,\delta \leq \frac{v-c(e)}{2}$, the MSC is low relative to the MSV— say, because the monopolist is significantly clean and efficient —, and we have $D(\hat{p}_e, e) \leq X^*$: the monopolist's production is lower than that implied by the socially optimal solution. Following the policy recommendations from Buchanan (1969) or Barnett (1980), the regulator should rely on the monopolist's tendency to underproduce and scale down the environmental tax below the Pigouvian level (possibly until the tax turns into a subsidy paid to the firm for fairly low values of the MSC). In the other case where the MSC $(1-e)\,\delta$ exceeds $\frac{v-c(e)}{2}$— the monopolist is significantly dirty or moderately efficient —, we have $D(\hat{p}_e, e) > X^*$, so that the monopolist by itself produces too much of the polluting good. In that case, the monopolist is no longer 'the environmentalist's best friend'; the second-best optimal policy calls for a regulation more stringent than in the previous case.

Lemma 1 summarizes this discussion.

Lemma 1 *Under Assumption* (6)*, in the absence of regulation, the monopolist underproduces relative to what would be socially desirable when* $(1-e)\,\delta < \frac{v-c(e)}{2}$*, and otherwise, the monopolist overproduces.*

3 Second-best optimal tax

We now consider the second-best problem faced by a welfare-maximizing regulator who can control the pollution emitted by the firm but not its monopolistic behavior. Hence, the regulator cannot ensure that the firm will behave as a price-taker. We further assume that the regulator is a Stackelberg leader who commits to a policy. Thus, we model the policy implementation as a two-stage game. In the first stage, the regulator specifies a tax τ on each unit of emissions that maximizes the social welfare $W(\tau)$ and generates the revenue $R(\tau)$. We allow τ to be negative, in which case it will be a subsidy paid to the firm instead of a tax. The regulator is also committed to transferring all tax yields to consumers. Stage two is the production period. In this stage, the monopolist sets the price of the good, the consumers decide whether to purchase the good, and the shareholders decide whether to comply with taxation. Should a shareholder decide to avoid taxation, it must incur its own cost of fiscal optimization. This sequence of play amounts to assuming that the regulatory policy has a commitment value, so that, once made, the choice of τ cannot be reversed in stage two, and the regulator cannot renege on his commitment to transfer the tax yields to consumers.

Denoting by $p_e(\tau)$ the monopoly price under regulation, the tax base is $(1-e)D\left(p_e\left(\tau\right),e\right) = v - p_e(\tau)$, and the expected emissions payments $R(\tau)$ correspond to the fiscal revenue corrected by the compliance rate

$$R(\tau) = \beta\left(\tau\right)\tau(v - p_e(\tau)). \tag{9}$$

As will be seen later, $R(\tau)$ plots the fiscal revenue as a function of the environmental tax, yielding a new variant of the Laffer curve. Furthermore, tax avoidance drives a wedge between $R(\tau)$ and the total amount of tax yields to be transferred to consumers, that is, $\tau(1-e)D\left(p_e\left(\tau\right),e\right) = \tau\left(v - p_e(\tau)\right)$.

Anticipating tax avoidance, the regulator recognizes that part of the corporate profit escapes the regulator's jurisdiction, which distorts the refund of the tax proceeds to consumers. Hence, the regulator only takes into consideration the complying part of producer surplus in the welfare function. The regulator's problem is to choose the tax that maximizes the social welfare function

$$\begin{aligned} W(\tau) = \int_0^{D(p_e(\tau),e)} & \left[v - (1-e)x - \delta(1-e) - p_e\left(\tau\right) + \tau\left(1-e\right)\right]dx \\ & + \beta\left(\tau\right)\pi_e\left(p_e\left(\tau\right),e\right), \end{aligned} \tag{10}$$

taking as given the firm's noncompetitive behavior. As will be shown, the regulator mobilizes the force of the monopoly power to generate a socially beneficial allocation of the good.

We concentrate first on the firm's monopolistic behavior. The profit is $\pi_e(p_e(\tau)) = (p_e(\tau) - c(e) - \tau(1-e))D(p_e(\tau), e)$, and the first-order condition for profit maximization can be rearranged to compute the Lerner index of the regulated monopolist

$$\frac{p_e(\tau) - c(e)}{p_e(\tau)} = \frac{\tau(1-e)}{p_e(\tau)} + \frac{1}{\varepsilon(p_e(\tau))}, \tag{11}$$

or, equivalently,

$$p_e(\tau) = \frac{v + c(e) + \tau(1-e)}{2}. \tag{12}$$

The regulator will take this monopoly price into consideration to implement the environmental policy. Clearly, we can see from (11) that, besides internalizing the environmental externality, the regulator will employ the environmental tax to correct for the externality exerted on the society by the monopolistic behavior. Moreover, the comparison between the monopoly prices $\hat{p}_e$ given by (8) and $p_e(\tau)$ given above shows that the environmental tax will be partly passed on to consumers in a higher price for their polluting good purchases.

Substituting (12) and (2) into (9) leads to the following relationship between tax rates and fiscal revenue:

$$R(\tau) = \begin{cases} \frac{\tau}{2}\left(1 - \tau\left(1-e\right)\right)\left(v - c\left(e\right) - \tau\left(1-e\right)\right) \text{ if } 0 \leq \tau \leq \frac{1}{(1-e)}, \\ 0 \text{ if } \frac{1}{(1-e)} \leq \tau \leq \frac{v-c(e)}{1-e}. \end{cases} \tag{13}$$

Some calculations given in Appendix 7.1 show that $R(\tau)$ reaches a maximum at $\widehat{\tau}$, falls to zero at $\tau = \frac{1}{(1-e)}$, and remains zero on the interval $\left[\frac{1}{1-e}, \frac{v-c(e)}{1-e}\right]$, where tax rates are so high that all the shareholders bypass taxation (see (2)). Figure 1 represents $R(\tau)$ with respect to τ as a solid line. This curve is always lower than the dotted curve $R_n(\tau)$ that depicts the fiscal revenue in the absence of tax avoidance, that is, when $\beta(\tau) = 1$ for all τ (the expression of $R_n(\tau)$ is relegated to Appendix 7.1). Interestingly enough, fiscal revenues in both regimes of avoidance and compliance are consistent with the statement by Jules Dupuit (1844):

"*By thus gradually increasing the tax it will reach a level at which the yield is at a maximum . . . Beyond, the yield of tax diminishes . . Lastly a tax will yield nothing*".

This early insight into the existence of a revenue maximizing tax was later illustrated by the Laffer curve.

Like the Laffer curve, the two curves in Figure 1 exhibit a downward-sloping segment for high tax rates,known as the "prohibitive" range because the same revenues can be collected at lower tax rates (see Fullerton, 1982). General

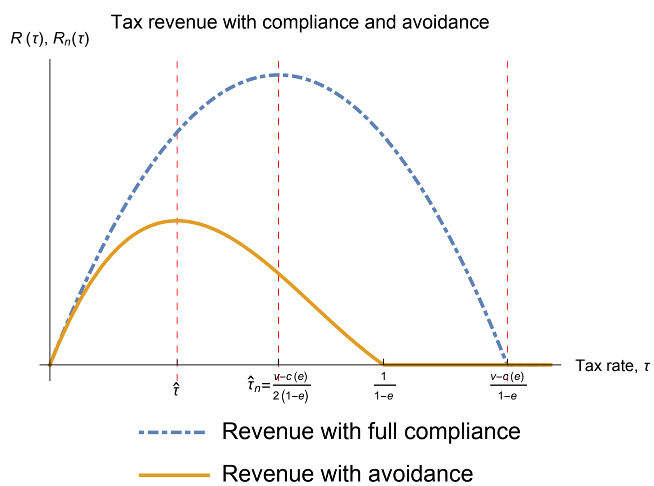

Figure 1: Laffer Curve

equilibrium models such as that used by Fullerton (1982) in a perfectly competitive regime, have highlighted the importance of income effects and substitution effects between labor and leisure in explaining the emergence of a negative relationship between tax rates and fiscal revenue. The reasons for this are clearly different in the present setting since our partial equilibrium approach focuses exclusively on the market for the polluting good while ignoring income effects. In the absence of tax avoidance, tax rates above $\widehat{\tau}_n$ lower the revenue $R_n(\tau)$ because they raise the monopoly price and, finally, shrink the sales volume, thereby reducing the tax base down toward zero at $\tau = \frac{v-c(e)}{1-e}$. When shareholders have the possibility to avoid taxation, tax rates above the maximum $\widehat{\tau}$ depress the revenue $R(\tau)$ even further because a growing number of shareholders with sufficiently low costs of fiscal optimization prefer to bypass rather than pay the tax, as its burden increases. Therefore, $R(\tau)$ falls gradually to zero, from $\widehat{\tau}$ to $\tau = \frac{1}{(1-e)}$, where all the shareholders find it less costly to bypass taxation. If the regulator raises the tax above this threshold, but below $\tau \leq \frac{v-c(e)}{1-e}$, so that at least one consumer purchases the good, environmental taxes have no benefit and the burden of environmental taxation is fully passed on to consumers through the price set by the monopolist. Finally, the comparison between $R_n(\tau)$ and $R(\tau)$ shows that tax avoidance extends the prohibitive range of the "environmental Laffer curve".

Let us now examine how consideration of tax avoidance shapes the social welfare function. For this, we plug (12) and (2) into (10). After some calculations given in Appendix 7.2, we obtain that $W(\tau)$ is made of three parts due to the shareholders' responses to taxation. When τ takes the form of a subsidy, no shareholder avoids taxation and $W(\tau)$ coincides with the function $W_n(\tau)$ on this range. For non-negative tax rates inside the interval $\left[0, \frac{1}{1-e}\right]$, the welfare $W(\tau)$ has a different functional form given by $W_p(\tau)$, due to the emergence of partial tax avoidance: some shareholders with sufficiently low costs of fiscal optimization prefer to bypass rather than pay the tax, and the foregone revenue entails a loss in social welfare. Finally, the welfare $W(\tau)$ turns into the function $W_f(\tau)$ for higher tax rates inside the interval $\left[\frac{1}{1-e}, \frac{v-c(e)}{1-e}\right]$, where there is full avoidance: in this range, the regulator has zero revenue from the tax since all the shareholders prefer to bypass it, and the burden of environmental taxation is fully passed on to consumers through the monopoly price.

Lemma 2 *The social welfare function can be decomposed into the following functions:*

$$W(\tau) = \begin{cases} W_n(\tau) \text{ if } \tau \leq 0 \text{ (no tax avoidance)}, \\ W_p(\tau) \text{ if } 0 < \tau \leq \frac{1}{(1-e)} \text{ (partial tax avoidance)}, \\ W_f(\tau) \text{ if } \frac{1}{(1-e)} < \tau \leq \frac{v-c(e)}{1-e} \text{ (full tax avoidance)}. \end{cases} \tag{14}$$

Figure 2 displays the various forms that $W(\tau)$ can take, depending on the relative values of the MSV of the good and the MSC of pollution. As can be seen, the welfare functions exhibit two local maxima.

When the shape of the welfare function is that depicted in the upper left of Figure 2, the global maximum is a subsidy. Intuitively, this situation occurs when the MSC of pollution is low relative to the MSV of the good, meaning that the monopolist is significantly clean and the good is cheap to produce. If $(1-e)\,\delta$ falls short of $\frac{v-c(e)}{2}$, Lemma 1 tells us that the unregulated monopolist has a tendency to underproduce relative to what would be socially desirable. Hence, a positive tax would have the undesirable effect of inflating the price of the good, leading to the aforementioned effects on consumption and monopoly power, both detrimental to welfare. Rather, a subsidy has a desirable effect on price. The dual benefit of boosting consumption on the demand side and mitigating the upward pressure that the monopolists puts on price on the supply side, balances the adverse effect of increasing pollution. In addition, with a subsidy, the regulator does not need to worry about tax avoidance.

Regarding the three other welfare functions displayed in Figure 2, we suspect

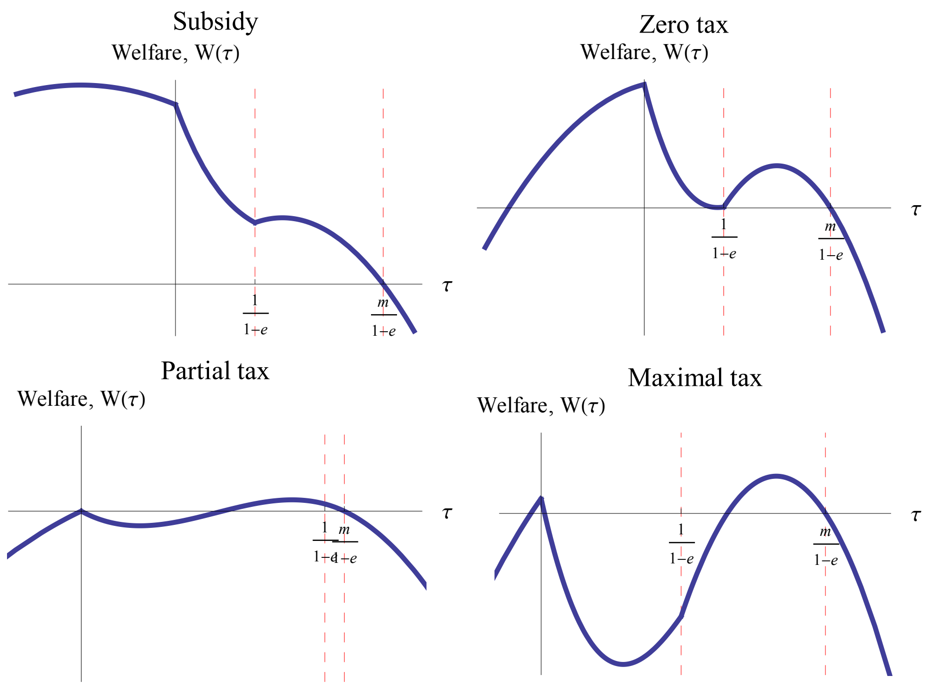

Figure 2: The forms of the Welfare function

that the MSC of pollution is now high enough so that $(1-e)\,\delta \geq \frac{v-c(e)}{2}$ holds, namely the monopolist is moderately clean or moderately efficient. For this parameter configuration, we know from Lemma 1 that the monopolist produces too much of the polluting good from the social standpoint, unless the MSC of pollution coincides with the MSV of the good. The regulator should now consider taxing the monopolist rather than subsidizing the polluting output. If, by chance, there is a coincidence between $(1-e)\,\delta$ and $\frac{v-c(e)}{2}$, Lemma 1 suggests that regulation is pointless since the monopolist is behaving in a socially efficient way on its own. It happens, however, that the three welfare functions other than that in the upper left of the figure depict situations in which there is a local maximum at zero tax, although the MSC of pollution exceeds the MSV of the good.

What is intriguing in the upper right of Figure 2 is that the local maximum at zero tax clearly dominates the local maximum resulting from positive taxation. This suggests that tax avoidance disrupts the previous balance between the environmental benefit of taxation and the detrimental upward pressure it puts on the monopoly price. We can guess that the fear of a novel adverse impact on welfare refrains the regulator from taxing the monopolist. From Proposition 1, we know that a positive tax, however light it is, induces the shareholders with the lowest costs of avoidance to bypass taxation. This immediately creates a welfare loss that can be seen at $\tau = 0$, where the slope of every welfare function turns from positive to negative. To offset this loss, the regulator must resort to a sharp increase in taxation, leading to the local maximum on the right-hand side of the welfare functions. The tax increase pays the bill for the free-riding of the tax avoiders, thereby enhancing welfare. However, this beneficial effect may not be sufficient to reach a welfare level higher than that obtained with the zero tax, as illustrated by the welfare function in the upper right of Figure 2. It is sufficient in the two remaining cases (the lower left and right of the figure), which suggests that the MSC of pollution is much greater than the MSV of the good, relative to the other cases. Although the positive tax fosters tax avoidance, it internalizes the externalities due to the tax avoiders' free-riding and the pollution as well.

Observe finally that, in the lower right of Figure 2, the monopolist is significantly dirty and the good is expensive to produce. This situation calls for such a severe taxation that it induces every shareholder to dodge paying tax.

We now analyze the second-best optimal tax on a case-by-case basis.

3.0.1 Low tax rates: the range of partial tax avoidance

The most interesting case of our analysis occurs when some, but not all, shareholders avoid taxation, that is, $W(\tau) = W_p(\tau)$. Assuming a solution inside the interval $\left[0, \frac{1}{1-e}\right]$, the first order-condition for welfare maximization is

$$\begin{aligned}(v - \delta (1-e) - p_e(\tau) - (1-e) D(p_e(\tau), e) + \tau(1-e))\frac{\partial D(p_e(\tau), e)}{\partial p_e(\tau)} \\ +((1-e) - \frac{dp_e(\tau)}{d\tau}))D(p_e(\tau), e) - \beta(\tau)(1-e) D(p_e(\tau), e) \\ + \frac{d\beta}{d\tau}(p_e(\tau) - c(e) - \tau(1-e)) D(p_e(\tau), e) = 0.\end{aligned} \tag{15}$$

A detailed analysis of welfare maximization is relegated to Appendix 7.3. Proposition 1 shows the extent to which tax avoidance affects the optimal tax design in the case where some shareholders still comply with the taxation.

Proposition 1 *The second-best optimal tax with partial avoidance satisfies*

$$\tau = \delta + \frac{p_e(\tau)}{\varepsilon(p_e(\tau))}\left[\frac{-1}{1-e} + \frac{2(1-\beta(\tau))}{1-e} + \frac{2d\beta}{d\tau}\frac{p_e(\tau) - c(e) - \tau(1-e)}{(1-e)^2}\right]$$

The tax departs from the first-best Pigouvian level (the first term in the right-hand side of the equation in Proposition 1) only if the producer possesses some market power, that is, $\frac{p_e(\tau)}{\varepsilon(p_e(\tau))} > 0$. Hence, the deviation from the Pigouvian level is higher in markets where consumers are less sensitive to price changes. The second term in the right-hand side of equation in Proposition 1 captures Buchanan's correction: the regulator reduces the tax to mitigate the monopolist's tendency to overprice.

The remaining two terms represent two opposite effects of tax avoidance on social welfare: a *free-riding effect* and a *tax base erosion effect.* The shareholders with avoidance costs lower than $\tau(1-e)$ free-ride on those with higher costs, who thus find it worthwhile to comply with taxation. The regulator must strengthen the tax to internalize this externality. Therefore, the tax is increased by an amount exactly equal to the term $\frac{p_e(\tau)}{\varepsilon}2\frac{1-\beta(\tau)}{1-e}$, which is positive when $\beta(\tau)$ falls below 1. On the other hand, the regulator knows that every tax increase makes fiscal avoidance attractive for some more shareholders, and every lost taxpayer worsens the fiscal imbalance between consumers and shareholders. To offset this welfare loss, the regulator decreases the tax by an amount corresponding to the fourth term in the right hand side of equation in Proposition 1, i.e., $\frac{p_e(\tau)}{\varepsilon}\frac{2(1-\beta(\tau))}{1-e}$. Like the correction for the monopolist's overpricing, the overall correction for tax avoidance, whether positive or negative, is greater when price demand is less elastic.

3.0.2 Subsidies: the range of no avoidance

We now turn to the case where τ is a subsidy, so that social welfare is given by the function $W_n(\tau)$. The shape of this function depends upon three forces appearing in the following derivative:

$$\frac{dW_n(\tau)}{d\tau} = \frac{\partial D(\cdot)}{\partial p}\frac{dp_e}{d\tau}\left[(1-e)\tau - (1-e)\delta + \frac{p_e}{\varepsilon(\cdot)}\right]. \tag{16}$$

Raising the tax tends to push the monopoly price up, which both curtails consumption and reinforces the monopolist's tendency to overprice. These two adverse effects on welfare are reflected in, respectively, the first and the third terms in the right-hand side of (16), which are negative since $\frac{\partial D(.)}{\partial p}\frac{dp_e}{d\tau} < 0$. It turns out, however, that increasing the emission tax to combat pollution lowers aggregate emissions. This ameliorating effect on welfare is captured by the second positive term in the right-hand side of (16). The final outcome ultimately depends on the balance of these conflicting forces. It clearly involves a subsidy when the shape of the welfare function is that depicted in the upper left of Figure 2.

3.0.3 High tax rates: the range of full avoidance

Finally, we consider the case where $\frac{1}{(1-e)} \leq \tau \leq \frac{v-c(e)}{1-e}$, so that no shareholder complies with taxation, i.e., $\beta(\tau) = 0$. In that case, the environmental tax is fully passed on to the consumers in a very high price for the polluting good. Social welfare reduces to consumer surplus less the environmental damage. One can check that

$$\frac{dW_f(\tau)}{d\tau} = \frac{\partial D(\cdot)}{\partial p}\frac{dp_e}{d\tau}\left[(1-e)(\tau-\delta) - \frac{p_e}{\varepsilon(\cdot)}\right]. \tag{17}$$

Here again, there is no welfare impact of taxation through tax avoidance because the tax base has completely vanished. Taxing polluting emissions boils down to manipulating the consumer price in order to achieve the desired allocation of the good.

In Appendix 7.2, we explicitly define τ_n, τ_2 and τ_f as the tax levels that respectively maximize $W_n(\tau)$, $W_p(\tau)$, and $W_f(\tau)$.

Note that τ_n would be the optimal choice for the regulator if there were no tax avoidance in the economy. Hence, τ_n is the traditional tax on emissions under monopoly, as stated by Buchanan (1969) and later computed by Lee (1975) and Barnett (1980). Equating (16) to zero yields

$$\tau_n = \delta - \frac{p_e}{(1-e)\,\varepsilon(\cdot)}. \tag{18}$$

Without tax avoidance, the standard result holds in the present setting: the regulator reduces the tax below the Pigouvian level δ to offset the welfare loss due to the monopolistic behavior, which corresponds to $\frac{p_e}{(1-e)\varepsilon(\cdot)}$. By substituting (18) into (11), we immediately see that τ_n leads to the price (**??**) that achieves the first-best outcome. This is due to the assumption that the amount of polluting emissions is strictly proportional to the output. As the regulator can mechanically control the output through the tax applied on emissions, this tool is sufficient by itself to correct both the environmental distortion and the monopoly distortion.

We now equate (17) to zero and get the following result:

$$\tau_f = \delta + \frac{p_e}{(1-e)\,\varepsilon(\cdot)}, \tag{19}$$

which clearly exceeds τ_n. The second term in the right-hand side of the equation above suggests that when all the shareholders avoid taxation, the regulator is facing externalities other than pollution. We provide a detailed analysis of these externalities in the remainder of the article. For the moment, one synthetic interpretation is that $\frac{p_e}{(1-e)\varepsilon(.)}$ reflects the net cost of the tax avoiders' free-riding, borne by consumers.

To provide an explicit solution for the second-best optimal tax under tax avoidance, we need to divide the parameter configuration into the four regions defined in Table 1.

Region	**Boundaries**
I	$\delta \leq \frac{v-c(e)}{2(1-e)}$
II	$\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$ and $\delta \in \left[\frac{v-c(e)}{2(1-e)}, \min\left\{\frac{24(v-c(e))-1}{32(1-e)}, \frac{(\sqrt{6}-1)(v-c(e))}{2(1-e)}\right\}\right]$
	or $\frac{v-c(e)}{(1-e)} \leq \frac{1}{4}$ and $\delta \in \left[\frac{v-c(e)}{2(1-e)}, \frac{v-c(e)+(v-c(e))^2}{2(1-e)}\right]$
III	$\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$ and
	$\delta \in \left[\frac{24(v-c(e))-1}{32(1-e)}, \min\left\{\frac{v-c(e)}{1-e}, \frac{5+\sqrt{(3-2(v-c(e)))(2(v-c(e))-3)^2}}{6(1-e)}\right\}\right]$
	or $\frac{v-c(e)}{(1-e)} \leq \frac{1}{4}$ and $\delta \in \left[\frac{v-c(e)+(v-c(e))^2}{2(1-e)}, \frac{v-c(e)}{1-e}\right]$
IV	$\delta \in \left[\max\left\{\frac{5+\sqrt{(3-2(v-c(e)))(2(v-c(e))-3)^2}}{6(1-e)}, \frac{(\sqrt{6}-1)(v-c(e))}{2(1-e)}\right\}, \frac{v-c(e)}{1-e}\right]$

Table 1: Parameter configuration

The four regions are depicted in Figure 3. This figure can be read as a map of the regulator's priorities. Region I represents a situation where the environment has a low rank in the agenda of economic priorities because the monopolist is sufficiently clean and efficient. Furthermore, Lemma 1 shows that, in Region I, the unregulated industry is not producing a sufficient amount of the good, from the social standpoint. In contrast, in Region IV, the regulator is very concerned about the environmental damage and, besides the environmental issue, the monopolist has a tendency to produce too much output given consumer preference for the polluting good. The next lemma compares the welfare levels reached at

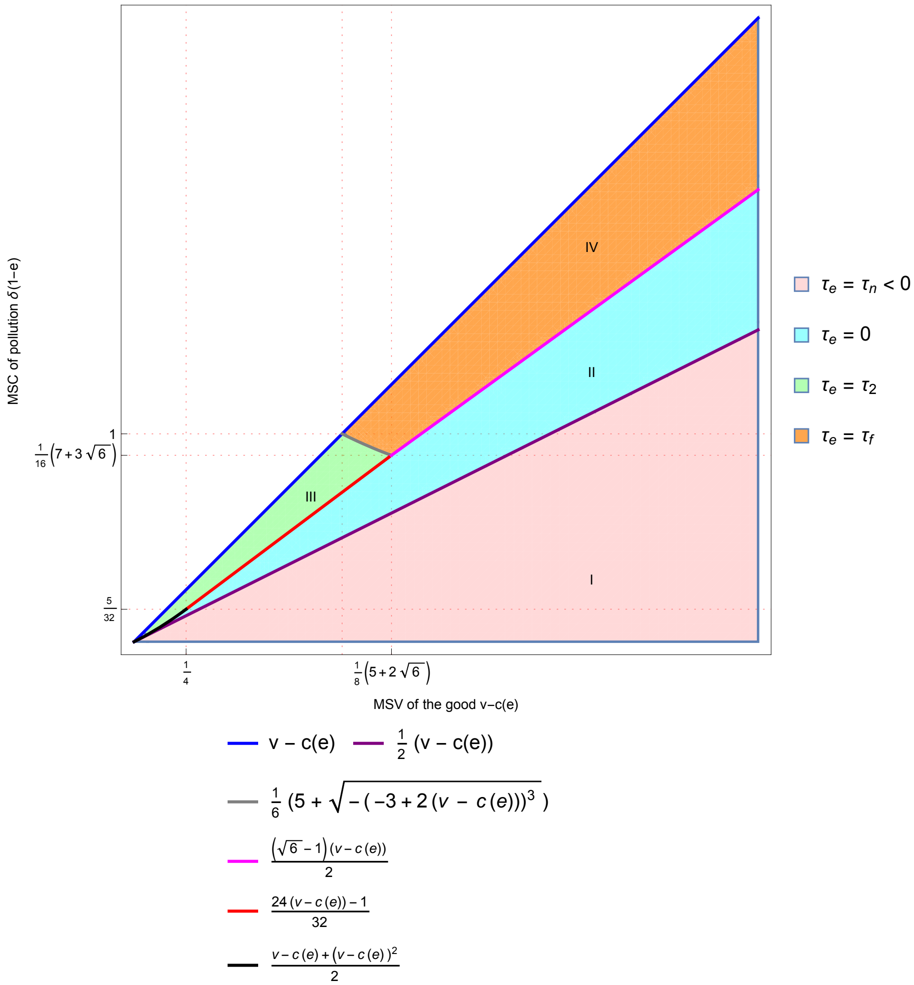

Figure 3: Optimal taxation

the different local maxima on a case by case basis.

Lemma 3 *In Region I,* $\tau_n \leq 0$ *and* $W_n(\tau_n) \geq \max\{W_p(\tau_2), W_f(\tau_f)\}$.

In Region II, $W_n(0) \geq \max\{W_p(\tau_2), W_f(\tau_f)\}$.

In Region III, $W_p(\tau_2) \geq \max\{W_f(\tau_f)), W_n(0)\}$.

In Region IV, $W_f(\tau_f) \geq \max\{W_p(\tau_2), W_n(0)\}$.

From this lemma, it is straightforward to characterize explicitly the optimal tax τ_e under the threat of fiscal avoidance, and compare it to Buchanan's tax τ_n.

Proposition 2 *The optimal solution for the regulator is to set τ_e such that:*

(i) τ_e coincides with the subsidy τ_n in Region I;

(ii) $\tau_e = 0 < \tau_n$ in Region II;

(iii) $\tau_e = \tau_2 > \tau_n > 0$ in Region III;

(iv) $\tau_e = \tau_f > \tau_n > 0$ in Region IV.

In Region I, the monopolist is so clean and efficient that the regulator is mainly concerned to correct the monopolist's tendency to overprice and produce too little output from the social standpoint. The optimal policy is to decrease the consumer price through a subsidy in order to boost consumption and mitigate the monopolist's market power. The subsidy is designed in accordance with Buchanan's rule. Clearly, tax avoidance is not an issue in this case. However, the idea that a firm gets paid to pollute may be politically unacceptable, as pointed out by Lee (1975).

In Region II, the environmental issue is more serious and/or the good is more costly to produce than in Region I. Left to itself, the monopolist would produce a too large amount of the polluting good. Observe that this holds true for all parameter values outside Region I: the imperfect competition distortion fails to offset the externality distortion. To combat pollution and correct the monopolist's behavior as well, the regulator, in the absence of tax avoidance, should set the positive tax τ_n on emissions consistent with Buchanan's rule. Under the threat of tax avoidance, however, the regulator prefers to withhold tax in Region II, worrying about the following chain reaction: a positive tax would have a knock-on effect on tax avoidance, creating a shortfall in tax revenue that would, in turn, call for a further increase in the tax. This chain reaction would create a welfare loss relative to the zero-tax decision. To some extent, the optimal policy in Region II boils down to letting the monopolist regulate the market for the regulator. The internalization of the environmental externality is passed on to consumers through the monopoly price premium they have to pay for the polluting good. Tax avoidance is an issue in that it is a deterring threat directed against taxation.

In Regions III and IV, the severity of the environmental damage as well as significant production costs require a positive tax τ_e, which exceeds Buchanan's tax. In Region III, the tax $\tau_e = \tau_2$ induces a number of shareholders with low costs of tax avoidance to avoid taxation. Not all of the shareholders avoid taxation, but those who do exert a negative externality on the rest of society in terms of lost fiscal revenue. To offset this welfare loss, the regulator can only hit the remaining taxpayers harder than if there were no tax avoidance, through a tax increase that also inflates the consumer price. The optimal solution strikes the balance between the need to collect tax yields and the dual correction for the pollution and the monopolistic behavior. In Region IV, taxation is so severe that the regulator completely loses the tax base, thereby losing the fiscal revenue to correct for distortions in the economy. The regulator leaves the whole burden of the tax on the consumers through the price at which they purchase the good. All the regulatory corrections rely on the manipulation of the monopoly price through taxation. The regulator chooses the tax τ_f that raises the monopoly price up to the level at which the consumers' purchase decisions fully internalize the environmental externality.

Figure 4 illustrates how the optimal tax regimes change with the severity of the environmental damage and the firms' efficiency. The bold curves plot τ_e as a function of $(1-e)\delta$, whereas the dashed line depicts τ_n as a function of $(1-e)\delta$. The three cases are drawn for low, intermediate and high MSVs of the good. The function τ_e remains flat at level zero, below τ_n, reflecting that, to prevent tax avoidance, the regulator refrains from taxing emissions. At some critical level of the MSC, however, τ_e jumps above τ_n to correct for the free-riding of the tax avoiders.

4 The two-part tax schedule

We now assume that the regulator is not restricted to linear taxation, as is traditionally the case. Instead, we let the regulator use the affine (but nonlinear) tax schedule $\tau q + T$, where τ is a unit tax for the firm's emission and T is a lump-sum tax T— an "entry-fee" into the market — that the firm must pay regardless of the number of units of the polluting emissions.

Social welfare is now

$$\begin{aligned} W(\tau, T) &= \int_0^{D(p_e,e)} [v-(1-e)x-\delta(1-e)-p_e(\tau)+\tau(1-e)]dx+T \\ &\quad +\beta(\tau)\,\pi_e(p_e(\tau),e), \end{aligned} \tag{20}$$

where the monopoly profit is $\pi_e(p_e(\tau)) = (p_e(\tau)-c(e)-\tau(1-e))D(p_e(\tau),e)-T$.

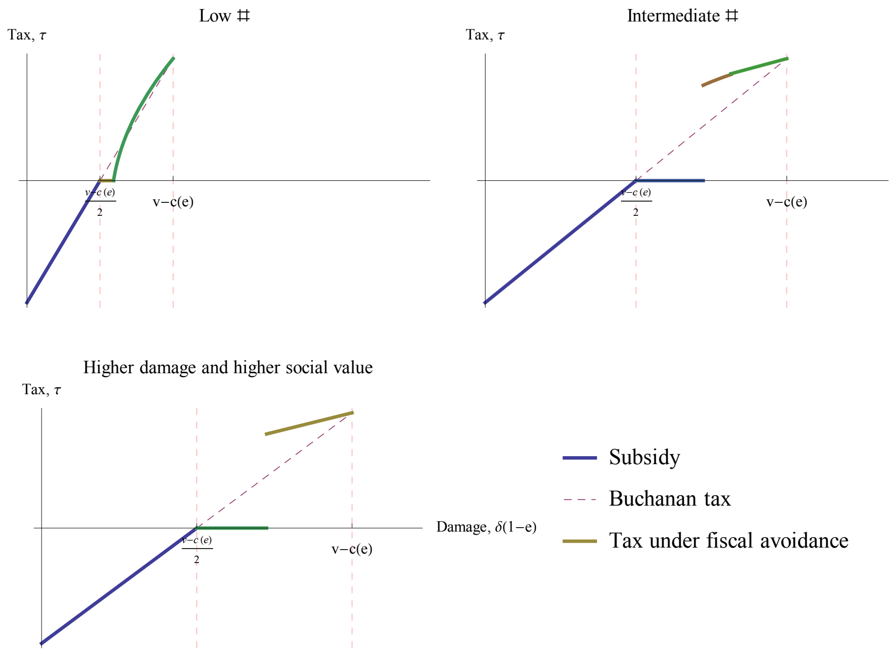

Figure 4: Comparison between Buchanan's and optimal taxation with avoidance

Substituting this expression into (20), we have

$$\begin{aligned} W(\tau, T) &= [v - p_e(\tau) + (\tau - \delta)(1-e) + \beta(\tau)(p_e(\tau) - c(e) - \tau(1-e))] \\ & \quad D(p_e(\tau), e) - \frac{(1-e) D(p_e(\tau), e)^2}{2} + (1 - \beta(\tau)) T \end{aligned} \tag{21}$$

The welfare maximization problem of the regulator is

$$\max_{\tau, T} W(\tau, T)$$

$$\text{s. t. } \pi_e(p_e(\tau)) \geq 0$$

The participation constraint in the regulator's optimization program requires that the firm gets no rent. This constraint is binding at the optimal solution since the regulator wants T to be as large as possible:

$$(p_e(\tau) - c(e) - \tau(1-e)) D(p_e(\tau), e) = T \tag{22}$$

We substitute the expression for T into (21) and use (12). This yields the following reduced form

$$W(\tau) = [v - c(e) - \delta(1-e)] D(p_e(\tau), e) - \frac{(1-e)D(p_e(\tau), e)^2}{2} \tag{23}$$

The first-order condition for welfare maximization is

$$\frac{\partial D(\cdot)}{\partial p}\frac{dp_e}{d\tau}\left[(1-e)\tau - (1-e)\delta + \frac{p_e}{\varepsilon(\cdot)}\right] = 0 \tag{24}$$

From (18), we can see that τ_n solves (24).

Proposition 3 *The optimal two-part tax schedule entails*
(i) the unit tax τ_n*,*
(ii) and the lump-sum tax $T = (p_e(\tau_n) - c(e) - \tau_n(1-e))D(p_e(\tau_n), e)$*.*

As a result, the two-part tax schedule can solve the problem of tax avoidance. The lump-sum tax enables the regulator to capture the whole profit of the polluting firm, thereby eliminating any incentive on the part of the shareholders to avoid taxation. The regulator can then set the unit tax in accordance with Buchanan's rule to correct the two remaining distortions caused by pollution and market power. In the present setting, this combination helps the regulator achieve the first-best outcome.

5 The example of BHPP

The following example is one among others[3] that may illustrate the reluctance of the environmental regulator to correct for the environmental externality presumably because of tax avoidance. In the Far Eastern region of Krasnoyarsk, the Russian government has allowed Boges Limited to operate a hydro power station called the Boguchany Hydroelectric Power Plant (BHPP). This large business enjoys a natural monopoly position. The construction of the dam reservoir has been largely deplored as a threat to the environment. The reservoir floods villages, forests, agricultural land, meadows and pastures, bringing about significant changes in the geographical landscape. According to Jagus and Rzetala (2013), the main environmental hazards stem from rising water levels which alter the landform, raising the ground water table, and compromising the water quality. The flooding of lands and forests affects the local climate, which

[3] See, for instance, Mambondiyani (2012), The Economist (2013).

in turn leads to a loss of natural eco-systems and habitats. On the other hand, the government aims to develop and urbanize the region, increasing living standards. The commission of BHPP should collect 2.4 billion rubles (84 million USD) of tax revenues in the public budget and provide at least ten thousand jobs in the region (Khotuleva and al., 2006), p. 16). However, more than 95% of the shareholders of Boges Ltd. are registered in Cyprus— a well-known tax haven (Baranova, 2013). In what follows, we provide a detailed analysis of this real-world situation in the light of our findings.

Annual Report of OJSC "Boguchanskaya HPP" for the year 2012

4. Economy and Finance

4.1. Main financial and economic indicators

Table 15 (in thousands of rubles)

Number	Indicator	2010	2011	2012	The growth rate, (4/5)%
(1)	(2)	(3)	(4)	(5)	(6)
1	Revenues from sales	2 148 547	2 029 271	1 412 899	70%
2	Prime cost	-2 069 294	-1 938 693	-1 573 157	81%
3	Gain / loss from sales	79 253	90 578	-160 258	-277%
4	Other income	38 353	678 756	117 412	17%
5	Other expenses	-145 788	-496 684	-485 919	98%
6	Profit before taxation	-28 182	272 650	-528 765	-194%
7	**Current income tax**	**0**	**0**	**0**	**0%**
8	Change in deferred tax liabilities	-181 428	-115 496	-305 165	264%
9	Change in deferred tax assets	105 372	117 348	382 143	326%
10	Other / miscellaneous	37 786	-1 711	-121	7%
11	Net profit	-66 452	272 791	-451 908	-266%

Figure 5: Boges Ltd. pays zero tax on current income

The table in Figure 5 displays the annual report of Boges Ltd. for the year 2012[4]. It represents the main indicators of economic activity of the firm. The highlighted row gives a piece of evidence that although the Russian law on water use, water and air pollution, land-retirement and such, provides for the existence of enforceable taxes, Boges Ltd. has paid no taxes, whether revenues be positive in 2011 or negative in 2010 and 2012. This is the actual outcome corresponding to Region II of Figure 3.

Given the large number of Boges Ltd. shareholders registered in Cyprus, the

[4] The original Russian version can be consulted at: http://www.boges.ru/files/fin_otchet/2012/Otchet_2012_2.pdf, page 33.

regulator is highly exposed to fiscal avoidance. Compared to the overwhelming task of fostering economic growth in the region of Krasnoyarsk, environmental issues are at the bottom of the regulator's agenda. The government has still not achieved the construction of an aluminum plant which is expected to become the major client of the dam and one of the main employers in the region. In the meantime, Boges Ltd. is producing in excess of the environmental requirement in the region— this situation fits the parameter configuration delimited by $(1-e)\,\delta > \frac{v-c(e)}{2}$ in Figure 3. On the basis of Shishikin and Sirotsky (2009)'s report, Baranova (2013) claims that "the damage caused by the power station to the area in terms of forest, land, water and fishing resources, as well as birds and animals, will amount to 4.5 billion rubles (£90 million)— that is assuming an outflow head of only 185 metres". Besides, the damage from the project also encompasses the loss of local cultural amenities such as archeological monuments, wooden architecture, nonmaterial heritage like local dialects, songs, and customs (Khotuleva and al., 2007), p.428). In this context, the monopolist's tendency to underproduce can hardly offset the distortion due to the various externalities caused by the dam, so that a sound environmental regulation calls for a positive tax along Buchanan's line. However, with no device to ensure tax compliance, the regulator has no leeway: a positive tax would exacerbate the free-riding of the tax avoiders without yielding enough revenue to outweigh the further welfare loss. As a result, the regulator finds it optimal to set a zero tax on pollution.

6 Conclusion

If the purpose of environmental taxation is to induce a firm to consider the full set of consequences of polluting emissions, the tax should also internalize the externality caused by those shareholders who avoid taxation. The novelty of our approach is to allow the environmental regulator to endogenize tax avoidance and examine how this framework affects traditional policy recommendations. In a monopoly setting without allowing for tax avoidance, the standard environmental taxation follows Buchanan's rule: as the monopoly distortion partly outweighs the externality distortion, the tax on polluting emissions must be set below the Pigouvian level; the tax cut resulting from the need to correct for the firms' market power may be so sharp that the optimal policy imposes to subsidize the product when the monopolist is significantly clean and the good is cheap to produce.

Outside these circumstances, we find that tax avoidance biases the second-best environmental tax away from Buchanan's tax in two opposite directions.

First, in situations where Buchanan's tax would be positive, it may happen that the fear of triggering tax avoidance compels the regulator to refrain from taxing the polluting emissions. This occurs when the monopolist is moderately clean and/or moderately efficient. In that case, the revenue raised from a positive tax would not fully offset the welfare loss produced by those shareholders who avoid taxation. Then, tax avoidance proves to be a deterrent threat against taxation.

Second, when the monopolist is significantly dirty and moderately efficient, the regulator must internalize the free-riding of tax avoiders by taxing emissions more severely than if there were no tax avoidance. The shareholders who comply with taxation pay the bill for the free-riding of those who bypass taxation. In the extreme case where all the shareholders avoid taxation, the tax increase inflates the monopoly price so that the whole burden of internalizing the environmental externality is passed on to the consumers.

Ultimately, we show that the problem of tax avoidance can be solved by the combination of a lump-sum tax that captures the whole profit of the polluting monopolist and Buchanan's tax on emissions.

The policy implications of our findings are rather grim. When the environmental regulator is restricted to linear taxation, tax avoidance is a serious stone in the regulator's shoe, forcing the regulator to be either impotent or unfair. The regulator proves impotent when the threat of tax avoidance deters the regulator from taxing emissions. In this case, the best policy is to let the monopolist charge the consumers a price that under-internalizes the environmental externality. On the other hand, the regulator proves unfair when tax avoidance forces the regulator either to overtax those who comply with taxation, or to drastically inflate the monopoly price with a tax that everyone avoids. In both cases, one objective is to internalize the externality caused by the free-riding of the tax avoiders. However, unlike the environmental externality, those who pay the bill for the free-riding are not those who generate the externality. This may be seen as politically unacceptable both by taxpayers and consumers.

The two-part tax schedule seems, on paper, an attractive solution to the problem of tax avoidance. Nevertheless, the literature on environmental taxation usually considers that lump-sum taxes and transfers are not available in practice (see, for instance, Bovenberg and van der Ploeg, 1994). We have also demonstrated how tax avoidance makes it difficult to design a linear tax on polluting emissions, which finally argues in favour of implementing specific enforcement measures against tax avoidance.

7 Appendix

7.1 Laffer curve

Consider first the case where all the shareholders comply with taxation, that is, $\beta(\tau) = 1$ for all τ. Using (3) and (12), the fiscal revenue with respect to τ is given by

$$\begin{aligned} R_n(\tau) &= \tau(1-e)\,D(p_e(\tau)) \\ &= \frac{\tau}{2}\left(v - c(e) - \tau(1-e)\right) \end{aligned} \quad (25)$$

This function is an inversely u-shaped parabola in τ, which takes zero value at $\tau = 0$ and $\tau = \frac{v-c(e)}{1-e}$, and which reaches a maximum at $\widehat{\tau}_n = \frac{v-c(e)}{2(1-e)}$.

We now take tax avoidance into account and obtain the revenue function $R(\tau)$ given by (13). For all $\tau \in \left[0, \frac{1}{(1-e)}\right]$, the first derivative is

$$\frac{\partial R(\tau)}{\partial \tau} = \frac{1}{2}\left(3\tau^2(1-e)^2 - 2(v - c(e) + 1)\tau(1-e) + v - c(e)\right). \quad (26)$$

The first-order condition yields only one admissible extremum inside $\left[0, \frac{1}{(1-e)}\right]$, namely $\widehat{\tau} = \frac{v-c(e)+1-\sqrt{(v-c(e))^2-(v-c(e))+1}}{3(1-e)}$. One can check that the upper solution of equation $\frac{\partial R(\tau)}{\partial \tau} = 0$ is $\frac{v-c(e)+1+\sqrt{(v-c(e))^2-(v-c(e))+1}}{3(1-e)}$, which exceeds $\frac{1}{(1-e)}$.

The second derivative is

$$\frac{\partial^2 R(\tau)}{\partial \tau^2} = 3\tau(1-e) - (v - c(e)) - 1, \quad (27)$$

which takes the following value at τ_2

$$\left.\frac{\partial^2 R(\tau)}{\partial \tau^2}\right|_{\widehat{\tau}} = -\sqrt{(v - c(e))^2 - (v - c(e)) + 1} < 0. \quad (28)$$

Thus, $\widehat{\tau}$ is a maximum. Straightforward calculations show that the maximum of $R(\tau)$ is always lower than that of $R_n(\tau)$, that is, $\widehat{\tau} < \frac{v-c(e)}{2(1-e)}$.

7.2 Proof of Lemma 2

The proportion of shareholders who comply with taxation depends on the tax level. As a result, the social welfare function can be decomposed as follows:

- If $\tau \leq 0$, no shareholder avoids taxation, hence $\beta(\tau) = 1$. From (10), $W(\tau)$ is then given by

$$W_n(\tau) = (1-e)\left[3D\left(p_e\left(\tau\right), e\right)^2/2 + (\tau - \delta)\, D\left(p_e\left(\tau\right), e\right)\right], \tag{29}$$

  which reaches a maximum at $\tau_n = 2\delta - \frac{v-c(e)}{1-e}$, so that $W_n(\tau_n) = \frac{(v-c(e)-\delta(1-e))^2}{2(1-e)}$.

- If $0 \leq \tau \leq \frac{1}{(1-e)}$, the proportion of shareholders who comply with taxation is $\beta(\tau) = 1 - \tau(1-e)$. From (10), $W(\tau)$ is then given by

$$W_p(\tau) = (1-e)\left[\left(\frac{3}{2} - \tau(1-e)\right) D\left(p_e\left(\tau\right), e\right)^2 + (\tau - \delta)\, D\left(p_e\left(\tau\right), e\right)\right], \tag{30}$$

  with a minimum at $\tau_1 = \frac{4(v-c(e))-1-\sqrt{4(v-c(e))^2-20(v-c(e))+1+24\delta(1-e)}}{6(1-e)}$ and a maximum at $\tau_2 = \frac{4(v-c(e))-1+\sqrt{4(v-c(e))^2-20(v-c(e))+1+24\delta(1-e)}}{6(1-e)}$, provided that the discriminant $\Delta_p = 4\left(v-c(e)\right)^2 - 20\left(v-c(e)\right) + 1 + 24\delta(1-e) \geq 0$; otherwise, $W_p(\tau)$ is a decreasing function of τ. Notice that $\tau_1 \times \tau_2 \geq 0$ if and only if $\delta \leq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$. Moreover, if $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$, then $\tau_2 \geq 0$, and if $\frac{v-c(e)}{(1-e)} \leq \frac{1}{4}$, then $\tau_1 \leq 0$. Thus, we have

  - $\tau_2 \geq 0$ for all $\delta \geq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$ or $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$,
  - $\tau_1 \leq 0$ for all $\delta \geq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$ or $\frac{v-c(e)}{(1-e)} \leq \frac{1}{4}$.

- If $\frac{1}{(1-e)} \leq \tau \leq \frac{v-c(e)}{1-e}$, no shareholder complies with taxation, hence $\beta(\tau) = 0$. From (10), $W(\tau)$ is then given by

$$W_f(\tau) = (1-e)\left[\frac{D\left(p_e\left(\tau\right), e\right)^2}{2} + (\tau - \delta)\, D\left(p_e\left(\tau\right), e\right)\right], \tag{31}$$

  which reaches a maximum at $\tau_f = \frac{2}{3}\delta + \frac{v-c(e)}{3(1-e)}$, so that $W_f(\tau_f) = \frac{(v-c(e)-\delta(1-e))^2}{6(1-e)}$.

7.3 First-order condition for welfare maximization

Using the fact that $(1-e)D\left(p_e\left(\tau\right),e\right) = v - p_e\left(\tau\right)$, Equation (15) turns into

$$(\tau-\delta)(1-e)\frac{\partial D(p_e\left(\tau\right),e)}{\partial p_e\left(\tau\right)}\frac{dp_e\left(\tau\right)}{d\tau} - \frac{dp_e\left(\tau\right)}{d\tau}D(p_e\left(\tau\right),e) + (1-\beta(\tau)) \tag{32}$$
$$(1-e)D(p_e(\tau),e) + \frac{d\beta(\tau)}{d\tau}[p_e\left(\tau\right) - c(e) - \tau(1-e)]D(p_e\left(\tau\right),e) = 0.$$

Substituting $\varepsilon\left(p_e\left(\tau\right)\right) = -\frac{\partial D(p_e(\tau),e)}{\partial p_e(\tau)}\frac{p_e(\tau)}{D(p_e(\tau),e)}$ into the left-hand side above, we have

$$\tau - \delta + \frac{p_e\left(\tau\right)}{(1-e)\varepsilon\left(\cdot\right)} - (1-\beta(\tau))\frac{p_e\left(\tau\right)}{\frac{dp_e(\tau)}{d\tau}\varepsilon\left(\cdot\right)} - \frac{d\beta}{d\tau}(p_e\left(\tau\right) - c(e) \tag{33}$$
$$-\tau(1-e))\frac{p_e\left(\tau\right)}{(1-e)\frac{dp_e(\tau)}{d\tau}\varepsilon\left(\cdot\right)} = 0,$$

which reduces to the expression from Proposition 1 after substituting $\frac{1-e}{2}$ for $\frac{dp_e(\tau)}{d\tau}$.

7.4 Proof of Lemma 3

1. We first concentrate on Region I, where $\delta \leq \frac{v-c(e)}{2(1-e)}$. The inequality $\tau_n \leq 0$ is equivalent to $\delta \leq \frac{v-c(e)}{2(1-e)}$. It follows that τ_n is a local maximum for this parameter configuration. Furthermore, two cases can be distinguished, depending on the sign of Δ_p. First, if $\Delta_p < 0$, then $W_p(\tau)$ is decreasing on the interval $\left[0, \frac{1}{1-e}\right]$, and τ_f is also a local maximum provided that $\tau_f > \frac{1}{1-e}$, which amounts to $\delta > \frac{3-(v-c(e))}{2(1-e)}$. Nevertheless, it is straightforward that $W_n(\tau_n) > W_f(\tau_f)$ always holds, hence τ_n is always more beneficial than τ_f from the social standpoint. The second case corresponds to parameter values such that $\Delta_p \geq 0$, or equivalently, $\delta \leq \frac{-4(v-c(e))^2+20(v-c(e))-1}{24(1-e)}$. Then, τ_2 may be another local maximum because $\tau_2 \leq \frac{1}{1-e}$ when $\delta \leq \frac{v-c(e)}{2(1-e)}$. Indeed, for all parameter values in Region I, $\delta \leq \frac{(v-c(e))^2-3(v-c(e))+4}{2(1-e)}$, which is equivalent to $\tau_2 \leq \frac{1}{1-e}$ and less restrictive than $\delta \leq \frac{v-c(e)}{2(1-e)}$. As previously seen, a further condition for τ_2 to be a local maximum is that $\delta \geq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$ or $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$. After some calculations, we find that $W_n(\tau_n) \leq W_p(\tau_2)$ if and only if $\delta \geq \frac{v-c(e)}{1-e}$ or $\frac{1}{54(1-e)}\left(36\left(v-c(e)\right) - 1 - \sqrt{(1-6(v-c(e)))(1-6(v-c(e)))^2}\right) \leq \delta \leq$

$\frac{1}{54(1-e)}\left(36\,(v-c(e))-1+\sqrt{(1-6(v-c(e)))(1-6(v-c(e)))^2}\right)$. It turns out that these parameter values are outside Region I, hence $W_n(\tau_n) > W_p(\tau_2)$ holds in this parameter configuration.

2. We now turn to Region II. If $\delta \geq \frac{v-c(e)}{2(1-e)}$, then $W_n(\tau)$ is increasing for negative values of τ up to zero, which makes $\tau = 0$ a local maximum provided that $W_p(\tau)$ decreases at this value, which amounts to $\tau_1 \geq 0$. In addition, τ_2 may also be a local maximum provided that, first, $\Delta_p \geq 0$ (which guarantees the existence of τ_2), second, $\delta \geq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$ or $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$ (in which case $\tau_2 \geq 0$), and third, $\tau_2 \leq \frac{1}{1-e}$ (or, equivalently, $\delta \leq \frac{(v-c(e))^2-3(v-c(e))+4}{2(1-e)}$) as previously mentioned. Furthermore, τ_f happens to be a local maximum too when $\tau_f \geq \frac{1}{1-e}$ (i.e., for parameter values such that $\delta \geq \frac{3-(v-c(e))}{2(1-e)}$).

   Let us first assume that $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$ and $\delta \in [\frac{v-c(e)}{2(1-e)}, \min\{\frac{24(v-c(e))-1}{32(1-e)}, \frac{(\sqrt{6}-1)(v-c(e))}{2(1-e)}\}]$. Assume $\Delta_p \geq 0$ so that τ_2 does exist. As $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$, we know that $\tau_2 \geq 0$, and moreover, $\tau_2 \leq \frac{1}{1-e}$ only if $\delta \leq \frac{(v-c(e))^2-3(v-c(e))+4}{2(1-e)}$. Assuming this to be the case, τ_2 is a local maximum. In addition, $\tau_1 \geq 0$ because $\delta \leq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$ is less restrictive than $\delta \leq \min\{\frac{24(v-c(e))-1}{32(1-e)}, \frac{(\sqrt{6}-1)(v-c(e))}{2(1-e)}\}$. Thus, $\tau = 0$ is a local maximum too, and routine calculations show that $W_n(0) \geq W_f(\tau_2)$ when $\delta \leq \frac{24(v-c(e))-1}{32(1-e)} (< \frac{v-c(e)}{1-e})$. Further calculations yield that $W_n(0) \geq W_f(\tau_f)$ when $\delta \leq \frac{(\sqrt{6}-1)(v-c(e))}{2(1-e)} (< \frac{v-c(e)}{1-e})$. As a result, $W_n(0) \geq \max\{W_p(\tau_2), W_f(\tau_f)\}$ for all parameter values in this configuration.

   Examine now the part of Region II where $\frac{v-c(e)}{(1-e)} \leq \frac{1}{4}$ and $\delta \in [\frac{v-c(e)}{2(1-e)}, \frac{v-c(e)+(v-c(e))^2}{2(1-e)}]$. In this parameter configuration, $\delta < \frac{3-(v-c(e))}{2(1-e)}$, and so $W_f(\tau)$ is a decreasing function of τ on the interval $\left[\frac{1}{1-e}, \frac{v-c(e)}{1-e}\right]$. Moreover, we know that $\tau_2 \leq 0$ when $\delta \leq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$, hence $W_p(\tau)$ is also decreasing on $\left[0, \frac{1}{1-e}\right]$. Thus, $\tau = 0$ is a global maximum in this parameter configuration.

   We can conclude that $W_n(0) \geq \max\{W_p(\tau_2), W_f(\tau_f)\}$ for parameter values inside Region II.

3. Consider now Region III. One can check that $\Delta_p > 0$ for these parameter values, because $\frac{-4(v-c(e))^2+20(v-c(e))-1}{24(1-e)} < \frac{24(v-c(e))-1}{32(1-e)} < \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$. It follows that τ_2 exists and is positive when either $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$ or $\frac{v-c(e)}{(1-e)} \leq$

$\frac{1}{4}$ and $\delta \geq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$. Moreover, it turns out that $\tau_2 < \frac{1}{1-e}$ because, first, when $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$, we have $\frac{5+\sqrt{(3-2(v-c(e)))(2(v-c(e))-3)^2}}{6(1-e)} < \frac{(v-c(e))^2-3(v-c(e))+4}{2(1-e)}$, and second, when $\frac{v-c(e)}{(1-e)} \leq \frac{1}{4}$, we have $\frac{v-c(e)}{(1-e)} < \frac{(v-c(e))^2-3(v-c(e))+4}{2(1-e)}$. Hence, τ_2 is a local maximum.

Furthermore, $\tau = 0$ may be a local maximum too, because $\frac{v-c(e)}{2(1-e)} < \delta$ holds, and so $\tau_n > 0$. Indeed, one can check, first, that $\frac{v-c(e)}{2(1-e)} < \frac{24(v-c(e))-1}{32(1-e)}$ when $\frac{v-c(e)}{(1-e)} \geq \frac{1}{4}$, and second, that $\frac{v-c(e)}{2(1-e)} < \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$ when $\frac{v-c(e)}{(1-e)} \leq \frac{1}{4}$, thereby implying $\frac{v-c(e)}{2(1-e)} < \delta$. However, in the case where $\frac{v-c(e)}{(1-e)} \leq \frac{1}{4}$ or $\delta \geq \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$, we know that $\tau_1 \leq 0$, meaning that $W_p(\tau)$ is increasing at $\tau = 0$, so this tax is not a local maximum.

In addition, τ_f happens to be a local maximum when $\tau_f \geq \frac{1}{1-e}(\delta \geq \frac{3-(v-c(e))}{2(1-e)})$.

Assuming $\frac{v-c(e)}{(1-e)} > \frac{1}{4}$ and $\delta < \frac{v-c(e)+(v-c(e))^2}{2(1-e)}$, so that $\tau = 0$ is actually a local maximum, routine calculations show that $W_n(0) \leq W_p(\tau_2)$ for all δ inside $\left[\frac{24(v-c(e))-1}{32(1-e)}, \frac{(v-c(e))^2+(v-c(e))}{2(1-e)}\right]$. Finally, one can check that parameter values inside Region III also belong to the interval

$$\left[\frac{5-\sqrt{(3-2(v-c(e)))(2(v-c(e))-3)^2}}{6(1-e)}, \frac{5+\sqrt{(3-2(v-c(e)))(2(v-c(e))-3)^2}}{6(1-e)}\right]$$

for which $W_p(\tau_2) \geq W_f(\tau_f)$.

We conclude that $W_p(\tau_2) \geq \max\{W_f(\tau_f)), W_n(0)\}$ in Region III. Moreover, straightforward calculations yield that $\tau_2 > \tau_n$ for all δ inside $\left[\frac{2(v-c(e))}{3(1-e)}, \frac{v-c(e)}{(1-e)}\right]$, which includes all the parameter values inside Region III unless $v - c(e) \in \left(0; \frac{1}{3}\right)$.

4. We finally turn to Region IV. All $\delta > \max\{\frac{5+\sqrt{(3-2(v-c(e)))(2(v-c(e))-3)^2}}{6(1-e)}, \frac{(\sqrt{6}-1)(v-c(e))}{2(1-e)}\}$ is also greater than $\frac{3-(v-c(e))}{2(1-e)}$. This inequality guarantees that $\tau_f > \frac{1}{1-e}$, meaning that τ_f is a local maximum. In the same parameter configuration, one can check that $\Delta_p \geq 0$, hence τ_2 exists, and moreover τ_2 is positive since $\frac{v-c(e)}{(1-e)} > \frac{1}{4}$. It follows that τ_2 is a local maximum too, unless $\tau_2 > \frac{1}{1-e}$, which amounts to $\delta > \frac{(v-c(e))^2-3(v-c(e))+4}{2(1-e)}$. Suppose this is the case. Then $\tau = 0$ is a local maximum because, first, $\delta \geq \frac{v-c(e)}{2(1-e)}(\tau_1 \geq 0)$, and second, $\frac{v-c(e)}{(1-e)} > \frac{1}{4}$ and $\delta < \frac{v-c(e)+(v-c(e))^2}{2(1-e)}(\tau_1 > 0)$ for parameter values inside Region IV. In this case, $\delta \geq \frac{(\sqrt{6}-1)(v-c(e))}{2(1-e)}$ implies that $W_f(\tau_f) \geq W_n(0)$. Otherwise, $\tau_2 \leq \frac{1}{1-e}$, hence τ_2 is a local

maximum and, for all δ inside $\left[\frac{5+\sqrt{(3-2(v-c(e)))(2(v-c(e))-3)^2}}{6(1-e)}, \frac{v-c(e)}{1-e}\right]$, we have $W_f(\tau_f) \geq W_p(\tau_2)$.

To sum up, $W_f(\tau_f) \geq \max\{W_p(\tau_2), W_n(0)\}$ in Region IV.

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