

Induced vs. Voluntary Green Production: Which Is Better for Society?

Domenico Buccella ^a, Augustine Abakpa ^b

a Department of Economics, Kozminski University, Warsaw, Poland.

E-mail: buccella@kozminski.edu.pl (corresponding author)

b Justice Development and Peace Commission (JDPC)/CARITAS Nigeria, Jimeta-Yola, Nigeria.

E-mail: Aabakpa@ccfng.org

Abstract

This article studies the environmental and societal impacts of a polluting monopoly when a society strives for a clean environment. Two scenarios are considered: (1) the government levies an environmental tax to induce investment in emission-reducing technology, and (2) the monopolist engages in environmental corporate social responsibility (CSR). It is shown that taxation has a lower environmental impact, but the monopolist undertakes CSR activities only if the abatement technology is efficient. Social welfare is always higher under CSR; therefore, when the technology is not adequately efficient, the government should implement a second-best environmental tax policy to avoid the worst welfare outcome.

Keywords: Green production, abatement, environmental tax, environmental corporate social responsibility

JEL Classification: H23, L1, M5

1. Introduction

In recent decades, human activities such as industrial processes, fossil fuel combustion and changes in land use have increased greenhouse gas emissions extraordinarily. Consequently, climate change has become one of the most far-reaching environmental challenges. This has led to increasing economic discussions regarding green technological change, which places social pressure on governments and firms to find ways to reduce environmental damage (The Economist, 2019; The Economist, 2020).

Citation: Buccella, D., Abakpa, A. (2023). Induced vs. Voluntary Green Production: Which Is Better for Society? *Politická ekonomie*, 71 (1), 89–103, <https://doi.org/10.18267/j.polek.1368>

Copyright: © 2023 by the author(s). Licensee Prague University of Economics and Business, Czech Republic. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution License (CC BY NC ND 4.0).

Governments have generally (but not exclusively) responded to this pressure with the introduction of environmental taxes. Environmental pricing through taxation can incentivize a reduction of the environmental footprint, which enhances lowest-cost solutions, provides an incentive for innovation and minimizes the need for the government to attempt to “pick winners” (OECD, 2011).

On the other hand, companies have progressively taken action oriented towards environmental protection, such as reduction of carbon emissions. KPMG (2020) reveals that 65% (+15% with respect to 2017) of the companies included in the N100 index (a worldwide sample of 5200 companies which consists of the top 100 companies by revenue surveyed in 15 industries in 52 countries) have disclosed carbon reduction targets, with rates ranging from 40% (healthcare) to 80% (automotive), as have 76% (+9% with respect to 2017) of the companies listed on the G250 index (the world’s 250 largest companies by revenue as defined in the Fortune 500 ranking of 2019).

At this point, a question arises, namely if society is environmentally concerned, then which of the following ensures the best welfare outcome: a government’s intervention setting an optimal environmental tax or firms’ voluntary engagement in environmental corporate social responsibility (CSR)? In other words, if the overall welfare is an area of concern, upon whom should society place social pressure to abate emissions and undertake emission-reducing actions? This paper focuses on this issue, which is somehow absent from the environmental economics literature; it contributes to clarification of the non-trivial effects on welfare of society’s attitude towards environment-related actions.

For this purpose, the paper proposes a simple polluting monopoly model and analyses two alternative scenarios. In the first scenario, the government sets an optimal environmental tax that maximizes social welfare to incentivize the monopolist to cut emissions. In the second one, the monopolist engages in environmental CSR, cutting emissions voluntarily. The model develops a two-stage game. In the first scenario, the government fixes the environmental tax and then the monopolist chooses the output and abatement level. In the second scenario, the monopolist chooses the level of environmental CSR, and then it chooses the output and abatement level. The game is solved using backward induction.

This article relates to a branch of the environmental literature that investigates the impact of environmental policy on welfare. In particular, in a monopoly context, as that presented herein, scholars have concentrated their attention on the impact of an environmental tax on green production and welfare (*e.g.*, Endres, 1982) and the issue of time consistency (*i.e.*, government’s commitment) relative to the implementation of the environmental tax and the strategic use of innovation to affect environmental policy (Petrakis and Xepapadeas, 2001; Moner-Colonques and Rubio, 2016; Fukuda and Ouchida, 2020; Wang, 2021).

Endres (1982) studies how a polluting monopolist can respond to the application of an environmental tax. If output reduction is the firm’s sole means of controlling pollution, then an emissions tax leads to welfare losses when the difference between price and marginal private costs

exceeds the marginal external costs in the firm's unregulated equilibrium. However, if other pollution abatement methods exist, the impact of the environmental tax on welfare depends on their costs. Consequently, (1) when the government designs the environmental policy, it should consider dynamic aspects; (2) emission taxes do not induce the monopolist to use a mix of abatement methods which minimizes social abatement costs, thus failing to achieve the social cost-minimizing distribution of pollution.

In an environmental policy game in which the regulator sets the environmental tax and the polluting monopolist chooses the abatement effort, Petrakis and Xepapadeas (2001) show that the firm's strategic behaviour can benefit social welfare. This occurs when the regulator is unable to commit to a specific environmental tax because it can induce the monopolist to undertake more green innovation than under regulatory commitment. In fact, if the monopolist acts as a first mover in the policy game, it can strategically select its abatement effort to influence the emission tax that the regulator will eventually implement.

The work of Moner-Colonques and Rubio (2016) also analyses a polluting monopolist's strategic behaviour regarding its environmental innovation choice to shape the government's environmental policy, either with taxes or with standards. Like Petrakis and Xepapadeas (2001), the authors assess two different policy games, one in which the regulator commits *ex ante* to the environmental policy instrument (*i.e.*, prior to the monopolist's innovation choice) and another in which the regulator intervenes *ex post* (*i.e.*, after the monopolist's choice, the time-consistent policy game). The key result is that, if the government establishes an environmental tax to limit pollution, then the monopolist's strategic behaviour enhances welfare and results in more green innovation than under regulatory commitment. The opposite holds in the case of an emission standard. Under commitment, the two policies generate tantamount effects. Thus, to set an emission tax is the optimal policy; in fact, for a committed regulator, it leads to identical welfare as an emission standard does. However, for a non-committed regulator, the tax policy yields a higher level of welfare.

To the best of our knowledge, the only papers that embed CSR considerations in a polluting monopoly market are Fukuda and Ouchida (2020) and Wang (2021). Fukuda and Ouchida (2020) build a monopoly model in the presence of a time-consistent emission tax and study the impact of CSR adoption on social welfare and the environment. The main findings are as follows. Backing CSR always increases social welfare. When the environmental damage is significant and the emission reduction cost efficiency is low, then a profit-maximizing monopolist can have incentives to engage in CSR because its net profitability improves. However, in contrast to the *locus communis*, CSR can raise emissions; that is, CSR can actually harm the environment.

Wang (2021) analyses a market on which the monopolist engages in CSR, product differentiation and environmental R&D. The author develops a three-stage game in which, at stage one, the regulator sets the welfare-maximizing emissions tax; at stage two, the monopolist chooses the level of environmental R&D that maximizes its objective function; at the final stage, the monopolist

chooses output. The main findings of Wang (2021) are as follows. Firstly, environmental R&D technology advances improve social welfare. Consumer surplus and R&D activities are higher and the environmental damage is lower; however, profits decrease. Secondly, an increase in CSR leads to an increase in R&D and welfare; consumer surplus and profit improves, but the environmental damage increases as well. Thirdly, product differentiation boosts profits, environmental R&D and welfare; however, it harms consumer surplus and environmental damage rises.

The main results of our paper are as follows. Concerning the environmental impact, taxation leads to a healthier environment than under CSR (lower pollution and environmental damage). However, when the technology is inefficient, the monopolist does not engage in CSR. Considering overall welfare, environmental CSR leads to first-best outcomes, regardless of the available technology. Therefore, when green technology is inefficient, the government should implement a second-best environmental tax policy to avoid the worst social welfare outcome.

The remainder of the article is organized as follows. Section 2 first presents the basic ingredients of the model. Then, it derives and compares the equilibrium outcomes under the two scenarios of environmental taxation and environmental CSR. Section 3 summarizes the results and closes with an outline for future research.

2. Model

Consider a polluting monopoly industry. The monopolist faces a standard inverse linear demand function $p = a - q$, where $a > 0$ is the parameter of the market size, here normalized to the unity without loss of generality (Fukuda and Ouchida, 2020).

The production process generates emissions. For simplicity, the assumption that one unit of output causes one unit of pollutant is made. Thus, net emissions are defined as $e = q - k$, where $0 \leq k < q$ is the abatement level for environmental protection that stems from the available cleaning technology. However, this technology cannot entirely eliminate pollution (Asproudis and Gil-Moltó, 2015; Buccella *et al.*, 2021).

The monopolist's emission abatement costs are $CA(k) = zk^2/2$, where the exogenous scale parameter, $z > 0$, represents a technological progress index. A decreasing value of z measures, for instance, the arrival of an innovative, cost-effective technology that makes abatement more economical. However, the clean end-of-pipeline technology shows decreasing returns (increasing costs) to the green production investment, which always sustains some costs. To ease the burden on mathematics and without loss of generality, it is assumed that the monopolist faces constant null average and marginal costs, $c = 0$.

Following the well-established body of literature, industrial activity generates environmental damage. The index $ED = ge^2/2$ quantifies this damage, assumed to be exogenous for consumers, and convex in (total) pollution (see, *e.g.*, van der Ploeg and de Zeeuw, 1992; Ulph, 1996). The exogenous parameter $g > 0$ is the weight attributed by the government to environmental damage,

measuring society's environmental awareness; higher values of g reflect society's increasing environmental consciousness.

The consumer surplus is given by the change in the utility from the consumption of the polluting good (measured by the integral under the demand curve) minus the expenditure on that good, that is:

$$CS = \int_0^q (1-t) dt - pq = q - \frac{q^2}{2} - (1-q)q = \frac{q^2}{2}. \quad (1)$$

2.1 Environmental taxation

First, we consider a case in which the government incentivizes emission reduction through an environmental tax. The game has the following two-stage game structure. At stage 1, the government fixes the optimal environmental tax to maximize social welfare. At stage 2, the monopolist simultaneously chooses the output and abatement level. Applying the backward induction logic, we solve first for stage 2 of the game and then for stage 1.

Stage 2: output and abatement level choices

The monopolist aims at maximizing profits. However, to incentivize emission cuts, the government sets an environmental tax, $t \in (0, 1)$ per unit of polluting output. Consequently, the monopolist's profit function is:

$$\pi = (1-q)q - t(q-k) - \frac{zk^2}{2}. \quad (2)$$

where $(q-k)$ is the tax base and, thus, $TR = t(q-k)$ is the corresponding government's tax revenues. Therefore, when the monopolist undertakes an abatement effort, it mitigates its emission level and reduces its tax base.

Differentiation of Equation (2) with respect to output and abatement levels leads to the following first-order conditions (FOCs):

$$\frac{\partial \pi}{\partial q} = 0 \rightarrow 1-t-2q=0; \quad \frac{\partial \pi}{\partial k} = 0 \rightarrow t-kz=0. \quad (3)$$

From the Hessian matrix, one gets:

$$H = \begin{pmatrix} \frac{\partial^2 \pi}{\partial q^2} & \frac{\partial^2 \pi}{\partial q \partial k} \\ \frac{\partial^2 \pi}{\partial k \partial q} & \frac{\partial^2 \pi}{\partial k^2} \end{pmatrix} = \begin{pmatrix} -2 & 0 \\ 0 & -z \end{pmatrix}, \quad (4)$$

whose successive principal minors $|H_1| < 0$, and $|H_2| > 0$ indicate that H is negative definite, *i.e.*, the stationary point is a maximum. Therefore, solving the FOCs, one gets the optimal output and emission abatement levels, $q = (1-t)/2$ and $k = t/z$. Substitutions of the optimal values into the profit function (2) yield the monopoly profits, consumer surplus and tax revenues as well as

environmental damage as a function of the environmental tax (the superscript “*et*” stands for environmental taxation).

$$\pi^{et} = \frac{(1-t)^2 z + 2t^2}{4z}, \quad (5)$$

$$CS^{et} = \frac{(1-t)^2}{8}, \quad (6)$$

$$TR^{et} = \frac{t[z - t(2+z)]}{2z}, \quad (7)$$

$$ED^{et} = \frac{g[2t - (1-t)z]^2}{8z^2}. \quad (8)$$

Stage 1: Optimal environmental tax and equilibrium values

At stage 1, the government sets the optimal environmental tax to maximize social welfare, given by the sum of the monopolist's profits, consumer surplus and tax revenue minus environmental damage. Algebraically, the government's objective function is:

$$SW^{et} = \pi^{et} + CS^{et} + TR^{et} - ED^{et} = \frac{(1-t)[(1+g)t + 3 - g]z^2 - 4t[(1+g)t - g]z - 4gt^2}{8z^2}. \quad (9)$$

Maximization of (9) leads to:

$$\frac{\partial SW^{et}}{\partial t} = 0; \frac{\partial^2 SW^{et}}{\partial t^2} = \frac{[(1+g)z^2 + 4(1+g)z + 4g]}{4z^2} < 0 \forall g \wedge z \in (0, \infty) \rightarrow t^{*et} = \frac{z[2g - z(1-g)]}{z(1+g)(z+4) + 4g}. \quad (10)$$

from which one obtains that a positive optimal emission tax exists (*i.e.*, $t^{*et} > 0$) if and only if the social environmental awareness is adequately large, that is: $g > z/(2+z) \equiv g^{et}$. Direct analytical inspection reveals that $\partial t^{*et}/\partial g > 0$, whose economic intuition is straightforward. As g represents society's environmental awareness, an increase in its value means that society is willing to pay higher taxes to allocate additional resources to protect the environment through the adoption of green technologies.

Further substitutions show that, for $g > g^{et}$, the non-negativity constraint on output as well as the condition $q^{et} > e^{et}$ is always fulfilled. Making use of the optimal tax in Equation (10), one obtains the first-stage equilibrium values under environmental taxation, as reported in Table 1.

2.2 Environmental corporate social responsibility

Here, we consider the case in which the monopolist voluntarily engages in environmental CSR. This game also has a two-stage structure. At stage 1, the monopolist chooses the level of environmental CSR maximizing its objective function, which comprises its profit plus the consumers' benefit. In other words, the level of ECSR is chosen not to maximize only the monopolist's profit;

this assumption seeks to capture the idea of a socially responsible firm that fully integrates social, environmental, ethical and consumer concerns into its business operation (Crifo and Forget, 2015). At Stage 2, the monopolist simultaneously chooses output and abatement level. Again, the game is solved making use of the backward induction logic.

Stage 2: Monopolist chooses output and abatement level

At this stage, the monopolist chooses output and abatement level to maximize its objective function, which includes, in addition to its own profit, the consumer net benefit; *i.e.*, the difference between consumer surplus (consumer friendliness) and environmental harm due to the polluting production (Fukuda and Ouchida, 2020). Hence, the monopolist's objective function is represented by

$$V = \pi + \theta(CNB), \quad (11)$$

where $CNB = CS - ED$ denotes the consumer net benefit, which is the measure representing the monopolist's social concern. The parameter $\theta \in [0, 1]$ is the extent of CSR. Increasing values of θ indicates higher CSR engagement. When $\theta = 0$, the monopolist maximises only his profit, while when $\theta = 1$, the monopolist is said to be fully socially responsible.

To find equilibrium values, we substitute in (11) the expressions of π , CS and ED to obtain:

$$V = (1-q)q - \frac{zk^2}{2} + \frac{\theta}{2} [q^2 - g(q-k)^2]. \quad (12)$$

Differentiation of (12) with respect to output and abatement level leads to the following FOCs:

$$\frac{\partial V}{\partial q} = 0 \rightarrow 1 + \theta [q - g(q-k)] - 2q = 0; \quad \frac{\partial V}{\partial k} = 0 \rightarrow \theta g(q-k) - zk = 0. \quad (13)$$

The Hessian matrix yields:

$$H = \begin{pmatrix} \frac{\partial^2 V}{\partial q^2} & \frac{\partial^2 V}{\partial q \partial k} \\ \frac{\partial^2 V}{\partial k \partial q} & \frac{\partial^2 V}{\partial k^2} \end{pmatrix} = \begin{pmatrix} -2 + \theta(1-g) & 0 \\ 0 & -z - g\theta \end{pmatrix}, \quad (14)$$

with the successive principal minors leading to $|H_1| < 0$, and $|H_2| > 0$, which reveal that H is negative definite; *i.e.*, the stationary point is a maximum. As a result, the optimal output and emissions levels are $q = (1 + gk\theta) / [2 + \theta(g-1)]$ and $k = \theta g q / (\theta g + z)$, respectively. Solving the system of FOCs, one gets the following monopolist's equilibrium values:

$$k = \frac{\theta g}{2z - g\theta^2 + \theta[(2+z)g - z]}, \quad (15)$$

$$q = \frac{\theta g + z}{2z - g\theta^2 + \theta[(2+z)g - z]}. \quad (16)$$

Stage 1: Choice of environmental CSR

At stage 1, the monopolist chooses its engagement in environmental CSR. Substituting k from (15), and q from (16) into (14) we obtain:

$$V^{ecsr} = \frac{\theta g + z}{2\{2z - g\theta^2 + \theta[(2+z)g - z]\}}. \quad (17)$$

The superscript “*ecsr*” stands for environmental CSR. Therefore, the monopolist’s objective maximization problem is represented as follows:

$$\begin{aligned} \max_{\theta} V^{ecsr}(\theta; g, z) = & \left\{ [1 - q(\theta; g, z)]q(\theta; g, z) - \frac{zk^2(\theta; g, z)}{2} + \frac{\theta}{2}q^2(\theta; g, z) - \right. \\ & \left. - g[q(\theta; g, z) - k(\theta; g, z)]^2 \right\} \\ \text{s. t. } & \theta \geq 0 \\ & \theta \leq 1, \end{aligned} \quad (18)$$

which leads to the following result.

Lemma 1: *The monopolist engages in full ECSR ($\theta^{*ecsr} = 1$) if $z \leq z^T \equiv g/(g-1)$, while it does not engage in ECSR ($\theta^{*n} = 1$) if $z > z^T$.*

Proof: See the Appendix.

Note that, to have non-negative values of the CSR parameter, society’s environmental sensitivity must be adequately high, that is, $g > 1$. Moreover, Lemma 1 shows that the monopolist engages in ECSR if $z \leq z^T$. The intuition behind this restriction is straightforward: if the available technology is efficient to a high degree, the monopolist’s abatement costs become negligible and, therefore, the firm can adopt a fully socially responsible behaviour.

Substituting (15) and (16) into the profit part of the objective function in (12), one obtains

$$\pi^{ecsr} = \frac{2z^2 - 2g^2\theta^3 + g\theta^2[(2+z)g - 4z] + 2z\theta[(2+z)g - z]}{\{2z - g\theta^2 + \theta[(2+z)g - z]\}^2}. \quad (19)$$

Substituting θ^{*ecsr} and θ^{*n} (the superscript n stands for no ECSR) in (19), one gets

$$\pi^n = \frac{1}{4} \text{ for } z > z^T; \quad \pi^{ecsr} = \frac{gz(g+2z)}{[(1+g)z + g]^2} \text{ for } z \leq z^T. \quad (20)$$

An analytical inspection reveals that, for $g > 1$, the monopolist’s profits under full ECSR are positive, ensuring (long-term) sustainability of the CSR engagement.

Social welfare is now defined as $SW^n = \pi^n + CS^n - ED^n$ in the case of no ECSR engagement, while $SW^{ecsr} = \pi^{ecsr} + CS^{ecsr} - ED^{ecsr}$ with ECSR. Making use of the optimal values of the CSR parameter, one obtains the first-stage equilibrium values under no ECSR/ECSR for output, abatement, the monopolist profits, consumer surplus, environmental damage and social welfare, respectively, as presented in Table 1.

2.3 Outcome comparison

In this subsection, the equilibrium outcomes under taxation and CSR are compared to analyse the environmental and welfare impact, both on single components and on its overall value.

First, we note that $g > 1$ is a more stringent condition than $g > g^{et}$. Therefore, in the remainder of the work, we restrict the analysis to $g > 1$.

Table 1: Equilibrium outcomes

| | Environmental taxation | No Environ- mental CSR $\left(z > \frac{g}{g-1}\right)$ | Full Environmental CSR $\left(z \leq \frac{g}{g-1}\right)$ |
|---------------------------------------|--|---|---|
| output | $q^{*et} = \frac{(2+z)(z+g)}{z(1+g)(z+g)+4g}$ | $q^{*n} = \frac{1}{2}$ | $q^{*ecsr} = \frac{g+z}{(2+z)g+z-g}$ |
| abatement level | $k^{*et} = \frac{2g-z(1-g)}{z(1+g)(z+4)+4g}$ | $k^{*n} = 0$ | $k^{*ecsr} = \frac{g}{g+z+gz}$ |
| profits | $\pi^{*et} = \frac{2z^4 + z^3(g^2 + 2g + 9) + 2z^2(3g^2 + 6g + 4) + 4zg(3g + 4) + 8g^2}{[z(1+g)(z+4)+4g]^2}$ | $\pi^{*n} = \frac{1}{4}$ | $\pi^{*ecsr} = \frac{gz(g+2z)}{[(1+g)z+g]^2}$ |
| consumer surplus | $CS^{*et} = \frac{(2+z)(z+g)^2}{2[z(1+g)(z+4)+4g]^2}$ | $CS^{*n} = \frac{1}{8}$ | $CS^{*ecsr} = \frac{(g+z)^2}{2[(2+z)g+z-g]^2}$ |
| environ- mental damage | $ED^{*et} = \frac{gz^2(3+z)^2}{2[z(1+g)(z+4)+4g]^2}$ | $ED^{*n} = \frac{g}{8}$ | $ED^{*ecsr} = \frac{gz^2}{2[(1+g)z+g]^2}$ |
| tax revenues | $TR^{*et} = \frac{z^2(3+z)[2g-z(1-g)]}{[z(1+g)(z+4)+4g]^2}$ | 0 | 0 |
| social welfare | $SW^{*et} = \frac{(3+z)(g+z)}{2[z(1+g)(z+4)+4g]}$ | $SW^{*ecsr} = \frac{3-g}{8}$ | $SW^{*ecsr} = \frac{g+z}{2(gz+g+z)}$ |

To begin with, let us consider the environmental impact. Preliminarily, an analytical inspection of the outcomes in Table 1 reveals the following Lemma.

Lemma 2: *Output under environmental taxation is always lower than under no ECSR and full ECSR, while abatement levels are higher under environmental CSR engagement than under environmental taxation.*

Proof: Simple payoff comparison in Table 1 shows that $q^{*et} < q^{*ecsr}$, $q^{*et} < q^{*n}$, and $k^{*et} < k^{*ecsr}$.

The rationale for the first result in Lemma 2 is as follows. In the presence of an environmental tax, the monopolist unambiguously reduces production, because taxation increases the marginal costs of production. Instead, when the monopolist engages in environmental CSR, the consumer surplus part of the social concern pushes towards more production; on the other hand, the environmental damage part of the objective function tends to shrink production to reduce pollution. However, in the case of ECSR engagement, the CSR parameter softens the negative impact of socially responsible initiatives on production, so that output is larger than when an environmental tax is set. Regarding abatement, the reason for the result in Lemma 2 is as follows. The inclusion of the consumer surplus in the objective function leads to output expansion and thus more pollution. Therefore, the socially responsible monopolist needs to increase abatement activities to reduce the environmental damage part of its objective. This fact yields higher abatement levels under ECSR than when an environmental tax is set, regardless of the efficiency of the available technology.

Now, we assess the environmental impact under the two scenarios. Making use of the standard definition of pollution, *i.e.*, $P = q - k$, from the relative expressions for the case of environmental taxation and environmental CSR in Table 1, one derives the following result.

Result 1: *As expected, pollution and environmental damage are maximal under no ECSR. However, pollution and environmental damage are higher under environmental CSR than under environmental taxation.*

Proof: See the Appendix.

Concerning the environmental impact, Result 1 reveals that the imposition of a tax leads to a healthier environment. The intuition behind this finding stems from Lemma 2. Larger output under environmental CSR than under environmental taxation leads to higher emissions, and even if, in the presence of a less efficient technology, the abatement under CSR is larger than under taxation, the increase in emissions outweighs the increase in abatement levels.

Let us now compare welfare components and the overall social welfare. First, we compare the monopolist's profits.

Result 2: *(1) Monopolist's profits without ECSR are maximal, (2) Monopolist's profits under environmental CSR are higher than under environmental taxation if $z \geq z^{TT}(g)$, and (3) Monopolist's objective value under environmental CSR is higher than under environmental taxation.*

Proof: See the Appendix.

As known, output expansions have a direct, positive effect on monopoly revenues and profits and an indirect, negative effect on price that reduces them. Result 2 informs us that the positive direct effect of output expansion on revenues, due to the monopolist's embedment of the consumer net benefit in its objective value, outweighs the indirect (increasing) price effect due to output contraction and the imposition of the environmental tax only if the abatement technology is not adequately efficient.

Then, we make a comparison of the consumer welfare under the two scenarios. The result follows.

Result 3: *Consumer surplus under environmental taxation is always the lowest, while under environmental CSR, consumer surplus is larger than without CSR if $z \geq z^T$. However, the consumer net benefit is always positive under environmental CSR and environmental taxation and always higher in the former case than in the latter, while it is always negative without CSR.*

Proof: See the Appendix.

The explanation of Result 3 qualitatively follows the line of reasoning of Lemma 2. However, it is worth remarking that, without ECSR, for $z \geq z^T$, the consumer surplus part of the consumer net benefit is greater than that of the socially concerned monopolist. However, without ECSR, the environmental damage is significant and more than offsets the consumer friendliness, ultimately damaging consumers. On the other hand, the socially concerned monopolist, even if it expands production and consequently increases pollution, it also engages in abatement activities that reduce environmental damage to such an extent that, through this part of its objective, maximizes the consumers' overall well-being.

Finally, the following result emerges regarding the overall social welfare.

Result 4: *Social welfare under environmental CSR is always higher than under environmental taxation and higher than without CSR.*

Proof: See the Appendix.

Qualitatively, this result derives from the line of reasoning in Lemma 2. The environmental tax decreases the monopolist's profits and consumer surplus because of lower production, and this also yields lower emissions. Nonetheless, if the available technology is efficient, the environmental tax incentivizes the monopolist's emission abatement. This incentive decreases if the abatement technology is not efficient. On the other hand, the adoption of environmental CSR expands both the monopolist's output and emissions; if the available technology is not efficient, consideration of the overall consumer net benefit in its objective (*i.e.*, engagement in social actions) allows the monopolist to avoid payment of the environmental tax. The combination of (1) output expansion and (2) sufficiently low negative environmental impact due to emission reduction yields the result that the consumer net benefit part of the social welfare is higher with environmental CSR than with taxation, also when the technology is efficient; this fact drives Result 4.

From the policy perspective, the government knows that the monopolist does not engage in any environmental action when the technology is not efficient (*i.e.*, for $z \geq z^T$); this would lead to the worst welfare outcome. Consequently, in the presence of an inefficient available technology, the government should implement a second-best environmental tax.

3. Conclusions

In light of societal awareness towards a clean environment, this article has investigated the environmental impact and the overall social welfare of a polluting monopoly industry under two alternative scenarios: (1) the government levies an emission tax to incentivize firms to undertake

emission-reducing actions, and (2) the monopolist voluntarily engages in environmental CSR (green production).

The analysis shows that the environmental impact (pollution and environmental damage) under environmental taxation is lower (*i.e.*, a healthier environment) than under environmental CSR. However, taxation contracts output and, therefore, profits and consumer surplus. Moreover, if the available abatement technology is efficient, the environmental tax incentivizes the monopolist to cut emissions, which lowers significantly the negative environmental impact. Under environmental CSR, pollution and environmental damage are higher than under taxation. However, the combination of output expansion and abatement actions (due to the inclusion of the consumer net benefit in the objective) is such that social welfare is always higher than in the presence of the environmental tax, regardless of the state of technology. If the available abatement technology is not adequately efficient, also the private profits of the monopolist are higher under ECSR than under environmental taxation. Nonetheless, knowing that the monopolist does not engage in any socially responsible action when the technology is not adequately efficient and that this would lead to the worst welfare outcome, in such a case, the government should implement a second-best environmental tax policy.

As alternative policies, the government should consider (1) the design of regulations incentivizing firms' abatement activities and therefore their engagement in ECSR, and (2) funding research activities to improve the progress and efficiency of "green" technologies.

Nevertheless, the current results are based on a set of simplifying assumptions. Therefore, a robustness check under different model specifications such as convex functional forms for the demand and technology is required. Moreover, cost-reducing investment in green technology is another suitable topic of investigation. Furthermore, the analysis should be extended to an oligopolistic framework to study whether and how strategic interactions may affect the current results. Those extensions are left for future research.

Appendix

Proof of Lemma 1

The monopolist's maximisation problem at stage 1 of the game can be re-arranged as follows:

$$\begin{aligned} \max_{\theta} V^{ecsr}(\theta; g, z) &= \frac{\theta g + z}{2\{2z - g\theta^2 + \theta[(2+z)g - z]\}} \\ \text{s. t. } \theta &\geq 0 \\ 1 - \theta &\geq 0. \end{aligned}$$

The Lagrangian function for this problem is:

$$L = \frac{\theta g + z}{2\{2z - g\theta^2 + \theta[(2+z)g - z]\}} + \lambda_1 \theta + \lambda_2 (1 - \theta).$$

According to the Kuhn-Tucker conditions, the optimal level of ECSR engagement must satisfy the following constraints:

$$\begin{aligned} \frac{\partial L}{\partial \theta} &= \frac{\partial V}{\partial \theta} + \lambda_1 - \lambda_2 \leq 0, \quad \theta \geq 0 \quad \text{and} \quad \theta \frac{\partial L}{\partial \theta} = 0 \\ \frac{\partial L}{\partial \lambda_1} &= \theta \geq 0, \quad \lambda_1 \geq 0, \quad \text{and} \quad \lambda_1 \frac{\partial L}{\partial \lambda_1} = 0 \\ \frac{\partial L}{\partial \lambda_2} &= 1 - \theta \geq 0, \quad \lambda_2 \geq 0, \quad \text{and} \quad \lambda_2 \frac{\partial L}{\partial \lambda_2} = 0 \end{aligned}$$

If $\lambda_1 > 0$, then $\frac{\partial L}{\partial \lambda_1} = 0$ so that $\theta = 0$, and $\frac{\partial V}{\partial \theta} < 0$. If $\lambda_2 > 0$, then $\frac{\partial L}{\partial \lambda_2} = 0$ so that

$1 - \theta = 0 \Rightarrow \theta = 1$, and $\frac{\partial V}{\partial \theta} < 0$. If $\lambda_1 = 0$, then $\frac{\partial L}{\partial \lambda_1} > 0$ so that $\theta > 0$, and $\frac{\partial V}{\partial \theta} = 0$. If $\lambda_2 = 0$,

then $\frac{\partial L}{\partial \lambda_2} > 0$ so that $1 < \theta$, and $\frac{\partial V}{\partial \theta} = 0$.

Therefore, given the Kuhn-Tucker conditions, the monopolist's maximisation with respect to θ enables one to derive the following critical points:

$$1) \quad \frac{\partial V}{\partial \theta} = 0 \Rightarrow \theta = \frac{z(\sqrt{g}-1)}{g}; \quad 2) \quad \frac{\partial L}{\partial \lambda_1} = 0 \Rightarrow \theta = 0; \quad 3) \quad \frac{\partial L}{\partial \lambda_2} = 0 \Rightarrow \theta = 1.$$

The first solution represents an interior solution of the problem, whereas the second and the third are corner solutions. However, the first solution fails to meet the SOC's for a maximum. Indeed, the second-order derivative test leads to $\frac{\partial^2 V}{\partial \theta^2} > 0$, revealing the presence of a local minimum. On the other hand, the second-order derivatives evaluated in the second and third solutions, the corner points, reveal that $\frac{\partial^2 V}{\partial \theta^2} < 0$, therefore having two local maxima. Substituting $\theta_1^* = 0$ and $\theta_2^* = 1$ into the objective function, one gets the values

$$V|_{\theta_1^*=0} = \frac{1}{4}, \quad \text{and} \quad V|_{\theta_1^*=1} = \frac{g+z}{2(z-g)+2g(2+z)}.$$

Direct comparison shows that

$$V|_{\theta_1^*=0} \begin{matrix} > \\ < \end{matrix} V|_{\theta_1^*=1} \quad \text{if} \quad z \begin{matrix} > \\ < \end{matrix} z^T \equiv \frac{g}{g-1}.$$

Proof of Result 1

Given the expressions in Table 1, one can easily obtain that, concerning pollution

$$(1) \quad P^{et} = \frac{z(3+z)}{z(4+z)(1+g)+4g};$$

$$(2) \quad P^n = \frac{1}{2} \text{ for } z > z^T \text{ and } P^{ecsr} = \frac{z}{g(1+z)+z} \text{ for } z \leq z^T,$$

while, concerning environmental damage

$$(1) \quad ED^{et} = \frac{gz^2(3+z)^2}{2[z(1+g)(4+z)+4g]^2};$$

$$(2) \quad ED^{ecsr} = \frac{g}{8} \text{ for } z > z^T \text{ and } ED^{ecsr} = \frac{gz^2}{2[g(1+z)+z]^2} \text{ for } z \leq z^T.$$

A simple comparison leads to the result.

Proof of Result 2

A direct comparison of the payoffs in Table 1 reveals that, in the range $z < z^{TT}(g)$, the monopolist's payoff ranking is $\pi^n > \pi^{et} > \pi^{ecsr}$ while, for $z \geq z^{TT}(g)$, the monopolist's profit ranking is $\pi^n > \pi^{ecsr} \geq \pi^{et}$. The expression of the threshold level $z = z^{TT}(g)$ is analytical, long and complex, and therefore omitted here (available upon request).

Proof of Result 3

Given that $CS = \frac{q^2}{2}$ the first statement directly follows from Lemma 1. Concerning the consumer net benefits, using the equilibrium expressions in Table 1, one gets that

$$(1) \quad CNB^{et} = \frac{(1-g)z^3(4+z) + (4-g+g^2) + 4g[z(2+g)+g]}{2[z(1+g)(4+z)+4g]^2};$$

$$(2) \quad CNB^n = \frac{1-g}{8} \text{ for } z > z^T \text{ and } CNB^{ecsr} = \frac{(1-g)z^2 + 2gz + g^2}{2[(1+g)z+g]^2} \leq 0 \text{ for } z \leq z^T.$$

A simple analytical comparison leads to the result.

Proof of Result 4

A simple analytical comparison of the payoffs in Table 1 reveals that, in the relevant parametric space $z > 0$ and $g > 1$, the following ranking holds $SW^{ecsr} > SW^{et} > SW^n$.

References

- Asproudis, E., Gil-Moltó, M. J. (2015). Green Trade Unions: Structure, Wages and Environmental Technology. *Environmental and Resource Economics*, 60(2), 165–189, <https://doi.org/10.1007/s10640-014-9768-x>
- Buccella, D., Fanti, L., Gori, L. (2021). To abate, or not to abate? A strategic approach on green production in Cournot and Bertrand duopolies. *Energy Economics*, 96(3), <https://doi.org/10.1016/j.eneco.2021.105164>
- Crifo, P., Forget, V. D. (2015). The economics of corporate social responsibility: A firm-level perspective survey. *Journal of Economic Surveys*, 29(1), 112–130, <https://doi.org/10.1111/joes.12055>
- Endres, A. (1982). Taxing the monopolistic polluter: a reconsideration. *Nebraska Journal of Economics and Business*, 21(3), 15–26.
- Fukuda, K., Ouchida, Y. (2020). Corporate social responsibility and the environment: Does CSR Increase Emission? *Energy Economics*, 92, <https://doi.org/10.1016/j.eneco.2020.104933>
- KPMG (2020). *The time has come. KPMG Survey of sustainability reporting 2020*. London: KPMG. Available online at: <https://assets.kpmg/content/dam/kpmg/xx/pdf/2020/11/the-time-has-come.pdf>
- Moner-Colonques, R., Rubio, J. S. (2016). The strategic use of innovation to influence environmental policy: Taxes versus Standard. *B.E. Journal of Economic Analysis & Policy*, 16(2), 973–1000, <https://doi.org/10.1515/bejeap-2015-0009>
- OECD (2011). *Environmental taxation: a guide for policy makers*. Paris: OECD. Available online at <https://www.oecd.org/env/tools-evaluation/48164926.pdf>
- Petrakis, E., Xepapadeas, A. (2001). *To Commit or Not to Commit: Environmental Policy in Imperfectly Competitive Markets*. University of Crete Working Paper No. 110.
- The Economist (2019). *The climate issue*, 177(38). London: The Economist Newspaper Ltd., September 21, 2019. ISSN 0013-0613.
- The Economist (2020). *Special report: Business and climate change “The great disrupter”*. *Economist.com* [online]. September 19, 2020. Available at: <https://www.economist.com/special-report/2020/09/17/the-great-disrupter>
- Ulph, A. (1996). Environmental policy and international trade when governments and producers act strategically. *Journal of Environmental Economics and Management*, 30(3), 265–281, <https://doi.org/10.1006/jeem.1996.0018>
- van der Ploeg, F., de Zeeuw, A. J. (1992). International aspects of pollution control. *Environmental and Resource Economics*, 2(2), 117–139, <https://doi.org/10.1007/BF00338239>
- Wang, C. (2021). Monopoly with corporate social responsibility, product differentiation, and environmental R&D: Implications for economic, environmental, and social sustainability. *Journal of Cleaner Production*, 287, <https://doi.org/10.1016/j.jclepro.2020.125433>