

Emission Standards and Emission Taxes for Production and Consumption

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Abstract

This paper studies the effect of environmental standards for production and the consumption and environmental taxes in production and consumption on prices, quantities, and welfare in a duopolistic market. Governments can apply emission standards and emission taxes for production and/or for consumption of products. While the use of an emission standard or an emission tax during production affects the competitiveness of firms, a consumption standard or consumption tax is said to be neutral with respect to competition.

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1 Introduction

This paper studies the effect of environmental standards for production and the consumption and environmental taxes in production and consumption on prices, quantities, and welfare in a duopolistic market.

In the European Union, environmental policy is restricted to non-tax instruments, because the Treaties restrict the EU to non-tax instruments. Member states are free to choose between tax and non-tax instruments.

Environmental regulation may increase the production cost of firms. If firms compete internationally, strict domestic environmental policy such as emission standards, tradeable emission permits, or emission taxes create a competitive disadvantage that may

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result in a loss of market shares, in market exit, or the relocation of firms to economies where less strict standards are applied. In the European Union, firms as well as politicians are concerned about a phenomenon called "carbon leakage". Firms that are covered by the EU Emissions Trading System (EU-ETS) and that are exposed to international competition might relocate their sites to countries outside the EU. In order to prevent this, some firms are provided with emission allowances free of charge. Governments may also influence the emissions during the use of products by imposing product standards or by taxing energy use or emissions during use. This kind of regulation does not influence the competitiveness of local firms, because it affects all firms equivalently irrespective of the location of production sites. With the Ecodesign Directive the European Union regulates products such as light bulbs or dishwashers. The EU also imposes emission limits on new passenger cars, for instance.

EU member states are free to impose taxes on energy use or harmful emissions of the production process or of the products during use. So, the choice of environmental instruments is rather complex: They could be market based (tax) or non-market based (standards) and could be applied to the production process, the product use (consumption), or both.

In the economic literature, the effects of environmental taxes and non-tax instruments are discussed extensively. Requate (2005) surveys the dynamic incentives of market based instruments and command and control instruments. He finds that market based instruments perform better than command and control instruments under perfect competition. Under imperfect competition main conclusions on the superiority of instruments cannot easily be drawn.

Moner-Colonques & Rubio (2016) study the effect of taxes and environmental standards on the behavior of a polluting monopolist. They find that if the government is able to precommit, a tax and an environmental standard are equivalent. If, however, the government is not able to precommit but follows a time-consistent policy path, a tax results in more innovation and welfare gains compared to an environmental standard.

Environmental policy has an international dimension. Environmental regulation may increase the production cost of firms. If firms compete internationally, strict domestic environmental policy such as emission standards, tradeable emission permits, or emission taxes create a competitive disadvantage that may result in a loss of market shares, in market exit, or the relocation of firms to economies where less strict standards are applied. In the European Union, firms as well as politicians are concerned about a phenomenon called "carbon leakage". Firms that are covered by the EU Emissions Trading System (EU-ETS) and that are exposed to international competition might

relocate their sites to countries outside the EU. In order to prevent this, some firms are provided with emission allowances free of charge. The incentive to relocate may depend on the environmental policy instrument applied by governments.

Some products cause harmful emissions during production and during use. For instance vehicles with an internal combustion engine cause CO₂ emissions during production and during use. The product design and the production process determine those emissions in both phases. For instance in the automotive industry firms could invest in new production plants that emit less or produce lighter cars or to use cleaner power-train technologies. In some cases the harmful effect of emissions depends only on total emissions and not on the source of emissions, because both emissions sources are located at the same area or because only the global volume of emissions matter. In these cases total emissions should be reduced where reductions are possible at lowest cost. If the regulator is able to set emissions standards for the production of products as well as for the products itself, a cost-effective reduction of emissions might require to regulate the production process, the product design, or both, especially, if emissions in both phases influence each other.

The Ecodesign Directive (2009/125/EC) allows the European Commission to regulate the product design and the production process with regard to the environmental impact of energy-related products that are intended to be sold on the single market of the European Union considering the whole life cycle of a product (Art. 15). Energy-related products are products that have an impact on energy consumption during use (Directive 2009/125/EC, Art. 2) like light bulbs, computers, fans, washing machines, and thermal insulation products for buildings. They typically influence the pollution of harmful emissions like CO₂ during use indirectly. The production of those products regularly also causes harmful emissions. The product design and the production process may account for those emissions in both phases. Although those products typically do not emit directly, they influence emissions that are caused in power generation.

So far, the European Commission has only regulated the product design, but not the production process based on the Ecodesign Directive. But the directive explicitly allows for the regulation of the production process, including "raw material selection and use" and "manufacturing" (Directive 2009/125/EC, Annex 1, Part 1). Amongst other things, the European Commission has to assess the "predicted consumption of materials, of energy and of other resources such as fresh water (...) [, the] anticipated emissions to air, water or soil (...) [, the], anticipated pollution through physical effects such as noise, vibration, radiation, electromagnetic fields (...) [, and the] expected generation of waste material" (Directive 2009/125/EC, Annex 1, Part 1). Typically, the European

Commission makes use of its regulatory leeway in the long run.

An interesting feature of the regulation of the production process would be that the European Union might regulate the emissions of production process irrespective of the location of production sites. So in future there might be a comprehensive legislative framework that regulates emissions of the production process and energy consumption during use. To the best of our knowledge there exists no economic analysis of whether the regulation of emissions should be based on the production process, the product design, or both.

Monero (2002) compares inter alia the incentives for environmental R&D of emission standards and performance standards. The emission standard limits the absolute volume of emissions per firm. A performance standard limits the emissions per unit of output. Monero (2002) concludes that under imperfect competition, performance standards can provide the same, more, or less R&D incentives than emission standards. The performance standard modelled by Monero (2002) is similar to the product standard modelled in this paper, where emissions per product depend on an efficiency parameter.

Under an emission standard a firm has two options to comply: It may restrict production or invest in abatement. Under a product standard the firm is less flexible: it has to comply with the standard. There is an interdependency between the emission regulation during production and emissions during use: If a firm decides to produce less then there exist less products that pollute during use.

The rest of the paper is organized as follows. In the next section, the model is presented and the case of no government intervention, the case of an emission standard, the case of a product standard, and environmental production and consumption taxes are analyzed. Section 3 concludes.

2 The Model

Consider two countries $j = H, F$. There are two firms $i = H, F$, one from each country, which sell a homogeneous product in country H . There is no market in country F .

Demand for the product is $p = a - (q_H + q_F)$. The firm F incurs trade cost t per unit sold in country H .

Assume that emissions are generated during production and during consumption of the product. Emissions are proportional to the quantity. Emissions generated during production $e_P = q_i$ for q_i produced in H . Emissions generated during consumption are $e_C = q_i$ for q_i consumed in H . Note that only firm H , which produces in country H , generates emission during production, but since both firms sell to country H , products of

both firms generate emissions during consumption. Damage caused by emissions is given as $D = (e_P)^2 + (e_C)^2$. Firms can undertake abatement for emissions generated during production (z_P) and abatement for emissions during consumption (z_C). Abatement cost for firms are given as $c(z) = \frac{1}{2}z_C^2 + \frac{1}{2}z_P^2 + \chi z_C z_P$ with $\chi \begin{matrix} \geq \\ \leq \end{matrix} 0$. If $\chi < (>) 0$, there are (dis)economies of scope in abatement. Consider the following timing: In the first stage, the government in country H may set a standard for emissions during consumption, production or both. In the second stage, firms choose abatement effort and set quantities.

2.1 No Regulation

Under no regulation, profits for both firms are given as

$$\begin{aligned}\pi_H &= q_H (a - (q_H + q_F)) - c(z), \\ \pi_F &= q_F (a - (q_H + q_F) - t) - c(z).\end{aligned}\tag{1}$$

Equilibrium quantities are given as

$$q_H = \frac{a+t}{3}, q_F = \frac{a-2t}{3}.\tag{2}$$

Emissions during production are

$$e_P = q_H = \frac{a+t}{3},\tag{3}$$

emissions during consumption are

$$e_C = q_H + q_F = \frac{2a-t}{3}.\tag{4}$$

2.2 Standards

2.2.1 Production Standard

Consider now that the government sets a standard for emissions during production $E_P < \frac{a+t}{3}$. Firms maximize profits subject to $e_{i,P} = q_i - z_{i,P} \leq E_P$. Equilibrium quantities are given as

$$q_H^{E_P} = \frac{a+t+2E_P}{5}, q_F^{E_P} = \frac{2a-3t-E_P}{5}.\tag{5}$$

The emission standard decreases the quantity of firm H and increases the quantity of firm F .

Emissions during production are

$$e_P^{E_P} = E_P, \quad (6)$$

emissions during consumption are

$$e_C^{E_P} = q_H + q_F = \frac{3a - 2t + E_P}{5}. \quad (7)$$

Both emissions during consumption and production are lower under the standard.

2.2.2 Consumption Standard

Consider now that the government sets a standard for emissions during consumption $E_C < \frac{2a-t}{3}$. Firms maximize profits subject to $e_{i,C} = q_i - z_{i,C} \leq E_C$. Equilibrium quantities are given as

$$q_H^{E_C} = \frac{2a + t + 2E_C}{8}, q_F^{E_C} = \frac{2a - 3t + 2E_C}{8}. \quad (8)$$

The emission standard decreases both quantities.

Emissions during production are

$$e_P^{E_C} = \frac{2a + t + 2E_C}{8}, \quad (9)$$

emissions during consumption are

$$e_C^{E_C} = 2E_C. \quad (10)$$

2.2.3 Production Standard and Consumption Standard

Consider now that the government sets both a standard for emissions during production E_P and a standard for emissions during consumption E_C . Firms maximize profits subject to $e_{i,P} = q_i - z_{i,P} \leq E_P$ and $e_{i,C} = q_i - z_{i,C} \leq E_C$.

Equilibrium quantities are given as

$$\begin{aligned} q_H^{E_P E_C} &= \frac{2a + t + E_C (3\chi + 2) + 3E_P (\chi + 1)}{6\chi + 11}, \\ q_F^{E_P E_C} &= \frac{3a - 4t + 2\chi (a - t) - E_P (\chi + 1) + E_C (\chi + 3)}{6\chi + 11}. \end{aligned} \quad (11)$$

Emissions during production are

$$e_P^{E_P E_C} = E_P, \quad (12)$$

emissions during consumption are

$$e_C^{E_P E_C} = 2E_C. \quad (13)$$

2.3 Taxes

2.3.1 Production Tax

Consider now that the government sets a tax for emissions during production τ^P .

Equilibrium quantities are given as

$$q_H^{\tau^P} = \frac{a + t - 2\tau^P}{3}, q_F^{\tau^P} = \frac{a - 2t + \tau^P}{3}. \quad (14)$$

The emission tax decreases the quantity of firm H and increases the quantity of firm F .

Emissions during production are

$$e_P^{\tau^P} = \frac{a + t - 5\tau^P}{3}, \quad (15)$$

emissions during consumption are

$$e_C^{\tau^P} = q_H + q_F = \frac{2a - t - \tau^P}{3}. \quad (16)$$

Both emissions during consumption and production are lower under the tax.

2.3.2 Consumption Tax

Consider now that the government sets a tax for emissions during consumption τ^C .

Equilibrium quantities are given as

$$q_H^{\tau^C} = \frac{a + t - \tau^C}{3}, q_F^{\tau^C} = \frac{a - 2t - \tau^C}{3}. \quad (17)$$

The emission tax decreases both quantities.

Emissions during production are

$$e_P^{\tau^C} = \frac{a + t - \tau^C}{3}, \quad (18)$$

emissions during consumption are

$$e_C^{\tau_C} = \frac{2a - t - 8\tau_C}{3}. \quad (19)$$

2.3.3 Production Tax and Consumption Tax

Consider now that the government sets both a tax for emissions during production τ_P and a tax for emissions during consumption τ_C .

Equilibrium quantities are given as

$$\begin{aligned} q_H^{\tau_P\tau_C} &= \frac{a + t - 2\tau_P - \tau_C}{3}, \\ q_F^{E_P E_C} &= \frac{a - 2t + \tau_P - \tau_C}{3}. \end{aligned} \quad (20)$$

Emissions during production are

$$e_P^{\tau_P\tau_C} = \frac{a + t + \tau_P - \tau_C + 3\tau_C\chi + \chi^2(a + t - 2\tau_P - \tau_C)}{3(\chi^2 + 1)}, \quad (21)$$

emissions during consumption are

$$e_C^{\tau_P\tau_C} = \frac{2a - t - \tau_P - 8\tau_C + 3\tau_P\chi + \chi^2(2a - t - \tau_P - 5\tau_C)}{3(\chi^2 + 1)}. \quad (22)$$

2.4 Welfare

2.4.1 No Regulation

Under no regulation, consumer surplus is given as $CS = \frac{(2a-t)^2}{18}$, the domestic firm's profit is given as $\pi_H = \frac{(a+t)^2}{9}$, and environmental damage is given as $D = \frac{(5a^2 - 2at + 2t^2)}{9}$. Total welfare is given as $W = -\frac{(2a-t)^2}{18}$.

2.4.2 Standards

Production Standard Under the production standard, consumer surplus is given as $CS^{E_P} = \frac{(3a-2t+E_P)^2}{25}$, the domestic firm's profit is given as $\pi_H^{E_P} = \frac{3(a+t)^2 + E_P(12a+12t-13E_P)}{50}$, and environmental damage is given as $D^{E_P} = \frac{(3a-2t)^2 + 2E_P(3a-2t+13E_P)}{25}$. Total welfare is given as $W^{E_P} = \frac{-30a+20t-6at+12a^2+7t^2+2E_P(9a+4t-31E_P-5)}{50}$.

The welfare-maximizing emission standard is

$$E_P = \frac{3a + 8t}{64}. \quad (23)$$

Emissions are $e_P^{EP} = \frac{3a+8t}{64}$ and $e_C^{EP} = \frac{3(13a-8t)}{64}$. Welfare is $W^{EP} = \frac{3(-832a+512t-112at+347a^2+192t^2)}{4096}$.

Consumption Standard Under the consumption standard, consumer surplus is given as $CS^{EC} = \frac{(2E_C+2a-t)^2}{32}$, the domestic firm's profit is given as $\pi_H^{EC} = \frac{3(2a+t)^2-4E_C(13F-6a-3t)}{128}$, and environmental damage is given as $D^{EC} = \frac{4E_C(65E_C+2a+t)+(2a+t)^2}{64}$. Total welfare is given as $W^{EC} = \frac{20a^2-12at+5t^2-4E_C(139E_C-10a+3t)}{128}$.

The welfare-maximizing emission standard is

$$E_C = \frac{10a-3t}{278}. \quad (24)$$

Emissions are $e_P^{EC} = \frac{(36a+17t)}{139}$ and $e_C^{EC} = \frac{(10a-3t)}{139}$. Welfare is $W^{EC} = \frac{(-27at+45a^2+11t^2)}{278}$.

Production Standard and Consumption Standard Under the combination of production standard and consumption standard, consumer surplus is given as $CS^{EP,EC} = \frac{(5a-3t+2\chi(a-t)+2E_P(\chi+1)+E_C(4\chi+5))^2}{2(6\chi+11)^2}$, the domestic firm's profit is given as $\pi_H^{EP,EC} = \frac{2(2a+t)^2(\chi+2)+12E_P(\chi+2)(\chi+1)(2a+t)+E_P^2(-42\chi+36\chi^2+18\chi^3-85)}{2(6\chi+11)^2} + \frac{4E_C(\chi+2)(3\chi+2)(2a+t)+E_C^2(-76\chi+24\chi^2+18\chi^3-105)-2E_C E_P(49\chi+66\chi^2+18\chi^3-24)}{2(6\chi+11)^2}$, and environmental damage is given as $D^{EP,EC} = E_P^2 + 2E_C^2$. Total welfare is given as $W^{EP,EC} = \frac{4a^2\chi^2+28a^2\chi+41a^2-8at\chi^2-24at\chi-14at+4t^2\chi^2+14t^2\chi+13t^2+4E_P(\chi+1)(17a+3t+8a\chi+t\chi)}{2(6\chi+11)^2} + \frac{E_P^2(-298\chi-32\chi^2+18\chi^3-323)+2E_C(41a-7t+62a\chi-6t\chi+20a\chi^2-2t\chi^2)}{2(6\chi+11)^2} + \frac{2E_C^2(\chi+2)(-142\chi+9\chi^2-262)-2E_C E_P(31\chi+58\chi^2+18\chi^3-34)}{2(6\chi+11)^2}$.

The welfare-maximizing emission standards are

$$E_P = \frac{306a + 50t + 413a\chi + 69t\chi + 88a\chi^2 - 18a\chi^3 + 16t\chi^2}{2472\chi + 127\chi^2 - 198\chi^3 + 2788},$$

$$E_C = \frac{-119a + 17t - 142a\chi + 14t\chi - 2a\chi^2 + 18a\chi^3 + 6t\chi^2}{-2472\chi - 127\chi^2 + 198\chi^3 - 2788}.$$

Emissions are $e_P^{EP,EC} = \frac{306a+50t+413a\chi+69t\chi+88a\chi^2-18a\chi^3+16t\chi^2}{2472\chi+127\chi^2-198\chi^3+2788}$ and $e_C^{EP,EC} = \frac{-119a+17t-142a\chi+14t\chi-2a\chi^2+18a\chi^3+6t\chi^2}{-2472\chi-127\chi^2+198\chi^3-2788}$.

Welfare is

$$W^{EP,EC} = \frac{3(-102at+357a^2+101t^2)+2\chi(-226at+333a^2+133t^2)-\chi^2(50at+9a^2-19t^2)-2\chi^3(-22at+20a^2+11t^2)}{2(-198\chi^3+127\chi^2+2472\chi+2788)}.$$

For independent abatement efforts ($\chi = 0$), the following ranking of emissions can be established: $e_P^{EP,EC} \geq e_P^{EP} < e_P^{EC} < e_P$ and $e_C^{EC} < e_C^{EP,EC} < e_C^{EP} < e_C$. For total emissions $E = e_C + e_P$, the following ranking of emissions can be established: $E^{EP,EC} <$

$E^{EC} < E^{EP} < E$. For welfare, the following ranking of emissions can be established:
 $W^{EPE_C} > W^{EC} > W^{EP} > W$.

2.4.3 Taxes

Production Tax Under the production tax, consumer surplus is given as $CS^{\tau_P} = \frac{(t-2a+\tau_P)^2}{18}$, the domestic firm's profit is given as $\pi_H^{\tau_P} = \frac{2(a+t)^2+17\tau_P^2-8\tau_P(a+t)}{18}$, and environmental damage is given as $D^{\tau_P} = \frac{(-14a\tau_P-8t\tau_P+26\tau_P^2-2at+5a^2+2t^2)}{9}$. Total welfare is given as $W^{\tau_P} = \frac{-4a^2+4at+22a\tau_P-t^2+16t\tau_P-55\tau_P^2}{18}$.

The welfare-maximizing emission tax is

$$\tau_P = \frac{(11a + 8t)}{55}. \quad (25)$$

Emissions are $e_P^{\tau_P} = \frac{t^2}{121}$ and $e_C^{\tau_P} = \frac{9(11a-7t)^2}{3025}$. Welfare is $W^{\tau_P} = \frac{-11a^2+44at+t^2}{110}$.

Consumption Tax Under the consumption standard, consumer surplus is given as $CS^{\tau_C} = \frac{(t-2a+2\tau_C)^2}{18}$, the domestic firm's profit is given as $\pi_H^{\tau_C} = \frac{(-4a\tau_C-4t\tau_C+11\tau_C^2+4at+2a^2+2t^2)}{18}$, and environmental damage is given as $D^{\tau_C} = \frac{(-34a\tau_C+14t\tau_C+65\tau_C^2-2at+5a^2+2t^2)}{9}$. Total welfare is given as $W^{\tau_C} = -\frac{(-62a\tau_C+22t\tau_C+139\tau_C^2-4at+4a^2+t^2)}{18}$.

The welfare-maximizing emission standard is

$$\tau_C = \frac{(31a - 11t)}{139}. \quad (26)$$

emissions are $e_P^{\tau_C} = \frac{2(18a+25t)}{139}$ and $e_C^{\tau_C} = \frac{(10a-17t)}{139}$. Welfare is $W^{\tau_C} = \frac{(-14at+45a^2-2t^2)}{278}$.

Production Tax and Consumption Tax

3 Conclusion

This paper has studied the effect of environmental standards for production and the consumption and environmental taxes in production and consumption on prices, quantities, and welfare. ...

Limitation: emissions in production are independent from the product quality. An interesting trade-off might appear, if a higher energy efficiency of a product leads to higher emissions of production.

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Appendix