Emission Taxes, Relocation, and Quality Differences

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Abstract

This paper studies the effect of an emission tax on the relocation decision of firms, when a duopolistic market is characterized by vertical quality differentiation. Especially, we establish the relationship between quality difference, relocation cost and marginal damage of emissions in a two-country-setting for three cases: An environmental tax applied only by one country, uncoordinated environmental taxation in both countries, and coordinated environmental taxation. The Nash-equilibria of relocation choices depend discontinuously on the cost of relocation ϕ and the quality difference λ. The higher the quality difference is, the higher is the probability that at least one firm relocates to F. A lower marginal damage increases the area of λ and ϕ where both firms remain in H. If also the foreign country F applies an emission tax and both governments set taxes uncooperatively, the high quality firm never relocates to F in equilibrium.

1   Introduction

This paper studies the effect of an emission tax on the relocation decision of firms, when a duopolistic market is characterized by vertical quality differentiation. Especially, we establish the relationship between quality difference, relocation cost and marginal damage of emissions in a two-country-setting for three cases: An environmental tax

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applied only by one country, uncoordinated environmental taxation in both countries, and coordinated environmental taxation.

Negative external effects may give rise to environmental regulation which in turn may increase the cost of production 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 "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.

While the analysis of relocation decisions as the result of environmental policy has received some attention in the past, the consideration of vertical quality differences has not been studied in depth so far, to the best of our knowledge (see Reinaud 2008 for some basic intuitions). If products are less homogeneous, competition is weaker. Thus, quality differences may influence the relocation decisions by firms and the environmental policy decisions by governments. Our analysis shows that high quality firms and low quality firms may have different incentives to relocate. This result is an important insight that should be taken into consideration in decisions about the strictness of environmental policy instruments, having in mind the position of European firms in international vertical quality competition.

In the analysis of optimal domestic environmental policy when firms may relocate to a foreign country, the environmental policy decisions of that foreign country has to be considered. If production results in harmful emissions it is not easy to see why the foreign country should not react to relocation decisions. Our analysis shows that environmental taxation of the foreign country changes optimal relocation decisions of both firms compared to unilateral environmental taxation. If both governments set environmental taxes uncooperatively, no Nash-equilibrium exists where the high quality firm relocates to the foreign country. If, however, governments set environmental taxes cooperatively, such Nash-equilibria exist.

Our analysis is related to two different but complementary strands of economic literature: The effect of environmental regulation on the choice of firm location and the choice of entering markets via exports or via foreign direct investment.

The first strand of the literature is referred to as the pollution haven hypothesis

(PHH). The intuitive idea of PHH is that firms prefer to produce in countries with less stringent environmental standards, because this allows them to produce at lower cost. This intuitive idea has been challenged by theoretical as well as by empirical findings.

Markusen et al. (1996) develop a model with two regions and two firms. They show that optimal environmental policy in an open economy where firms decide on their location differs from the closed economy setting. In their setting, small changes in environmental policy may result in firm relocation and large changes in welfare. Motta & Thisse (1994) also show that strict environmental policy may result in a relocation of domestic firms. Rauscher (1995), however, shows that international tax competition for environmental taxes can result in tax rates that are either too low or too high from a welfare perspective. A similar finding is presented by Hoel (1997), who shows that international competition on environmental policy may result in a stricter environmental regulation than international cooperation. Greaker (2003) also shows that the possibility of firms to relocate may result in stricter environmental regulation and welfare.

Empirically, evidence of PHH is mixed. Xing and Kolstad (2002) find that for heavily polluting industries such as chemicals and primary metals the laxity of environmental regulation is an important factor for FDI decisions, but is not significant for other industries. Cole and Eliot (2005) confirm the PHH for FDI from the US to Brazil and Mexico for capital intensive industries.

Recently, Borghesi et al. (2016) have analyzed the effect of the EU-ETS on outward FDI with a special focus on Italian firms. While firms covered by the EU-ETS do not show a general tendency to relocate because of the ETS on average, firms that are exposed exceptionally to international carbon leakage show such a tendency. With respect to the effect of environmental policy on foreign direct investment (FDI), Elliot and Zhou (2012) present show in a theoretical framework that more stringent environmental standards may result in an increase in capital inflows. Dong et al. (2012) show that FDI decisions of firms may raise emission standards if market sizes of the two respective countries are small. But for large market sizes, FDI will have no effect on emission standards of the "South".

Thus, findings in the theoretical literature as well as on the empirical literature are somewhat ambiguous on the effect of environmental policy on firm relocation. The effect of vertical quality differentiation has not gained much attention in the literature on this topic so far.

The paper that is most closely to our analysis is Ikefuji et al. (2016). They analyse the effect of environmental tax policy and relocation choices in a two county-setting, where only in one country a market for the homogeneous output good exists. Only in

that market the government sets an environmental tax for production emissions. They find that the optimal emission tax in the home country is non-decreasing with the cost of relocation and welfare varies in a non-monotonic way. Ikefuji et al. (2016) in two ways. First, we include quality differences in our analysis. Second, we analyse the decision on environmental taxation in the foreign country.

Against this background, we analyze the effect of environmental policy on relocation decisions, when a duopolistic market is characterized by vertical quality differentiation. We assume that the governments cannot commit to an environmental tax ex ante, decide on taxation after the location choice by firms. We show that the incentive for the high quality firms to relocate differs from the incentive of the low quality firm. This result should be taken into account in decisions on the strictness of environmental policy.

If only the home county applies an environmental tax, various Nash-equilibria of location decisions exists depending on the quality difference and relocation cost. The Nash-equilibria depend discontinuously on the cost of relocation ϕ and the quality difference λ.

The higher the quality difference is, the higher is the probability that at least one firm relocates to F. A Nash-equilibrium in which both firms relocate to F only exists for a limited range of relocation cost and quality difference. A lower marginal damage increases the area of λ and ϕ where both firms remain in H. A higher marginal damage decreases the area of λ and ϕ where both firms remain in H.

If also the foreign country F applies an emission tax and both governments set taxes uncooperatively, the high quality firm never relocates to F in equilibrium.

The rest of the paper is organized as follows. In the next section, the basic model is presented. In section 3, we analyze the effect of an unilateral environmental tax on relocation decisions for both firms. Section 4 analyses the effect of alternative damage functions. Section 5 analyses uncoordinated and coordinated environmental tax setting in both countries. Section 6 concludes.

2 The Model

Consider two countries $j = H, F$. In country H, two (ex-ante) identical firms $i = 1, 2$ sell a product that comes in different quality levels s_i. There is no product market in country F. One firm is a high quality firm and the other is a low quality firm. Assume without loss of generality $s_1 > s_2$, so that 1 is the high quality firm and 2 is the low quality firm. We assume $s_1 = \lambda > s_2 = 1$.

Consumers are heterogeneous with respect to their preference for quality and are

characterized by a preference parameter θ that represents consumers' marginal willingness to pay for quality, which is uniformly distributed on the interval [0,1]. Each consumer buys at most one unit of the most preferred good. The utility derived from no purchase is zero, while a consumer who buys one unit of the good obtains a net utility of

$$U = \theta s_i - p_i, \ i = H, L. \tag{1}$$

The heterogeneity in preference parameter θ may be interpreted as differences in income, in taste, in frequency of usage, in environmental awareness, or risk aversion.

The marginal consumer indifferent between purchasing the high quality good from firm 1 and the low quality good from firm 2 is given by $\theta^* = \frac{p_1 - p_2}{\lambda - 1}$, the marginal consumer indifferent between purchasing the low quality good from firm 2 and not buying is given by $\theta^{**} = p_2$. Demand for both products is given as $q_1 = 1 - \frac{p_1 - p_2}{\lambda - 1}$ and $q_2 = \frac{p_1 - p_2}{\lambda - 1} - p_2$.

Production of products generates harmful emissions. Assume that one unit of the product results in one unit of emissions. Assume further for the baseline scenario that emissions cause damage according to $D = \frac{1}{2} q_i^2$.

The government in country H may levy an environmental tax τ_H on emissions.

Both firms are initially located in country H but may relocate to country F at fixed cost ϕ.

Consider the following timing: In the first stage, firms decide whether to relocate to country F. In the second stage, one (in sections 3 and 4) or both (in section 5) governments may set a tax for emissions. In the third stage, firms set prices.

3 Environmental Policy and Relocation Decision

In the following subsections we present the backward induction solution of the three stages.

3.1 Price Setting and Production

Assume that only the government in country H sets an environmental tax. Let Π denote total profits and π operating profits, with $\Pi_1^{Hj} = \pi_1^{Hj}$, $\Pi_2^{jH} = \pi_2^{jH}$ and $\Pi_1^{Fj} = \pi_1^{Fj} - \phi$, $\Pi_2^{jF} = \pi_2^{jF} - \phi$

If both firms remain in country H, firms' profits are

$$\Pi_1^{HH} = \left(p_1^{HH} - \tau_H \right) q_1^{HH}, \ \Pi_2^{HH} = \left(p_2^{HH} - \tau_H \right) q_2^{HH}. \tag{2}$$

Equilibrium prices and quantities are

$$
\begin{aligned}
p_1^{HH} &= \frac{2\lambda(\lambda-1)+3\lambda\tau_H}{4\lambda-1}, \quad p_2^{HH} = \frac{\lambda-1+\tau_H(1+2\lambda)}{4\lambda-1}, \\
q_1^{HH} &= \frac{2\lambda-\tau_H}{4\lambda-1}, \quad q_2^{HH} = \frac{(1-2\tau_H)\lambda}{4\lambda-1}.
\end{aligned}
\tag{3}
$$

Equilibrium profits are

$$
\Pi_1^{HH} = \frac{(\lambda-1)(\tau_H-2\lambda)^2}{(4\lambda-1)^2}, \quad \Pi_2^{HH} = \frac{\lambda(\lambda-1)(2\tau_H-1)^2}{(4\lambda-1)^2}.
\tag{4}
$$

The price difference $p_1 - p_2$ increases in the quality difference λ. The quantity difference $q_1 - q_2$ decreases in λ. The difference of profits $\Pi_1 - \Pi_2$ increases in λ.

If firm 1 remains in country H, but firm 2 relocates to country F, firms' profits are

$$
\Pi_1^{HF} = \left(p_1^{HF} - \tau_H\right)q_1^{HF}, \quad \Pi_2^{HF} = p_2^{HF}q_2^{HF} - \phi.
\tag{5}
$$

Equilibrium prices and quantities are

$$
\begin{aligned}
p_1^{HF} &= \frac{2\lambda(\lambda-1)+2\lambda\tau_H}{4\lambda-1}, \quad p_2^{HF} = \frac{(\lambda+\tau_H-1)}{4\lambda-1}, \\
q_1^{HF} &= \frac{2\lambda(\lambda-1)-\tau_H(2\lambda-1)}{4\lambda^2-5\lambda+1}, \quad q_2^{HF} = \lambda\frac{\lambda+\tau_H-1}{4\lambda^2-5\lambda+1}.
\end{aligned}
\tag{6}
$$

Equilibrium profits are

$$
\Pi_1^{HF} = \frac{(2\lambda(\lambda-1)-(2\lambda-1)\tau_H)^2}{(\lambda-1)(4\lambda-1)^2}, \quad \Pi_2^{HF} = \frac{\lambda(\lambda+\tau_H-1)^2}{(\lambda-1)(4\lambda-1)^2} - \phi.
\tag{7}
$$

If firm 1 relocates to country F, but firm 2 remains in country H, firms' profits are

$$
\Pi_1^{FH} = p_1^{FH}q_1^{FH} - \phi, \quad \Pi_2^{FH} = \left(p_2^{FH} - \tau_H\right)q_2^{FH}.
\tag{8}
$$

Equilibrium prices and quantities are

$$
\begin{aligned}
p_1^{FH} &= \frac{2\lambda(\lambda-1)+\lambda\tau_H}{4\lambda-1}, \quad p_2^{FH} = \frac{\lambda+2\lambda\tau_H-1}{4\lambda-1}, \\
q_1^{FH} &= \frac{\lambda(2(\lambda-1)+\tau_H)}{4\lambda^2-5\lambda+1}, \quad q_2^{FH} = \frac{\lambda(\lambda-1-\tau_H(2\lambda-1))}{4\lambda^2-5\lambda+1}.
\end{aligned}
\tag{9}
$$

Equilibrium profits are

$$\Pi_1^{FH} = \frac{\lambda^2 \left(2\left(\lambda - 1\right) + \tau_H\right)^2}{\left(\lambda - 1\right)\left(4\lambda - 1\right)^2} - \phi, \ \Pi_2^{FH} = \frac{\lambda\left(\lambda - 1 - \tau_H\left(2\lambda - 1\right)\right)^2}{\left(\lambda - 1\right)\left(4\lambda - 1\right)^2}. \tag{10}$$

If both firms relocate to country F, firms' profits are

$$\Pi_1^{FF} = p_1^{FF} q_1^{FF} - \phi, \ \Pi_2^{FF} = p_2^{FF} q_2^{FF} - \phi. \tag{11}$$

Equilibrium prices and quantities are

$$
\begin{aligned}
p_1^{FF} &= \frac{2\lambda\left(\lambda - 1\right)}{4\lambda - 1}, \ p_2^{FF} = \frac{\lambda - 1}{4\lambda - 1}, \\
q_1^{FF} &= \frac{2\lambda}{4\lambda - 1}, \ q_2^{FF} = \frac{\lambda}{4\lambda - 1}.
\end{aligned}
\tag{12}
$$

Equilibrium profits are

$$\Pi_1^{FF} = \frac{4\lambda^2\left(\lambda - 1\right)}{\left(4\lambda - 1\right)^2} - \phi, \ \Pi_2^{FF} = \frac{\lambda\left(\lambda - 1\right)}{\left(4\lambda - 1\right)^2} - \phi. \tag{13}$$

3.2 Environmental Policy

Assume that the government in country H sets the tax rate τ_H to maximize welfare, given as the sum of consumer surplus, firms' profits (firm's profit), tax revenue less the environmental damage. The environmental tax has two effects: It reduces quantities and may motivate a firm to relocate. Because emissions only result in local damage, relocation reduces the environmental damage in country H. The optimal tax rate depends on the quality difference between both products. Total welfare in H depends on the relocation decision of the firms.

3.2.1 Case HH

XXXHier Bedingungen noch näher erläutern?

If both firms remain in country H, welfare is given as

$$W_H^{HH} = CS_H^{HH} + \Pi_1^{HH} + \Pi_2^{HH} + \tau_H \left(q_1^{HH} + q_2^{HH}\right) - \frac{1}{2}\left(q_1^{HH} + q_2^{HH}\right)^2. \tag{14}$$

The resulting welfare maximizing tax rate is

$$\tau_H^{HH} = \frac{\left(2\lambda + 7\right)\lambda}{\left(\lambda + 1\right)\left(8\lambda + 1\right)}. \tag{15}$$

3.2.2 Case HF

If firm 1 remains in country H, but firm 2 relocates to country F, welfare is given as

$$W_H^{HF} = CS_H^{HF} + \Pi_1^{HF} + \tau_H \left(q_1^{HF} \right) - \frac{1}{2} \left(q_1^{HF} \right)^2. \tag{16}$$

ddddd

The government sets

$$\tau_H^{HF} = \begin{cases} \lambda \left(\lambda - 1 \right) \frac{9\lambda - 4\lambda^2 - 3}{-3\lambda - \lambda^2 + 4\lambda^3 + 1} & \text{if} \quad \lambda < \frac{1}{8}\sqrt{33} + \frac{9}{8} \\ 0 & \text{if} \quad \lambda \geq \frac{1}{8}\sqrt{33} + \frac{9}{8} \end{cases}. \tag{17}$$

3.2.3 FH

If firm 1 relocates to country F, but firm 2 remains in country H, welfare is given as

$$W_H^{FH} = CS_H^{FH} + \Pi_2^{FH} + \tau_H \left(q_2^{FH} \right) - \frac{1}{2} \left(q_2^{FH} \right)^2. \tag{18}$$

The government sets

$$\tau_H^{FH} = \begin{cases} \left(\lambda - 1 \right) \frac{4\lambda - 2\lambda^2 - 1}{\lambda \left(-9\lambda + 8\lambda^2 + 2 \right)} & \text{if} \quad \lambda < \frac{1}{2}\sqrt{2} + 1 \\ 0 & \text{if} \quad \lambda \geq \frac{1}{2}\sqrt{2} + 1 \end{cases}. \tag{19}$$

3.2.4 FF

If both firms relocate to country F, there is no tax rate in country H.

3.3 Location Decision

In the first stage, firms decide (uncooperatively) simultane ously whether to stay in country H or to relocate to F. For this decision they compare the expected profits in both cases, given the decision of the other firm. Four combinations of location choice are possible: HH, FH, HF, and FF. If a firm stays at home, it has to pay the tax τ_H. If it relocates to F, it has to pay the fixed cost of relocation ϕ. So for each firm the relocation decision is characterized by a trade-off whether to incur higher variable cost or to incur fixed cost of relocation and produce at zero marginal cost. For both firms the cost of relocation ϕ is crucial for their relocation decision. For prohibitively high values of ϕ, both firms remain in H. Very low values of ϕ make it more likely that both firms relocate to F.
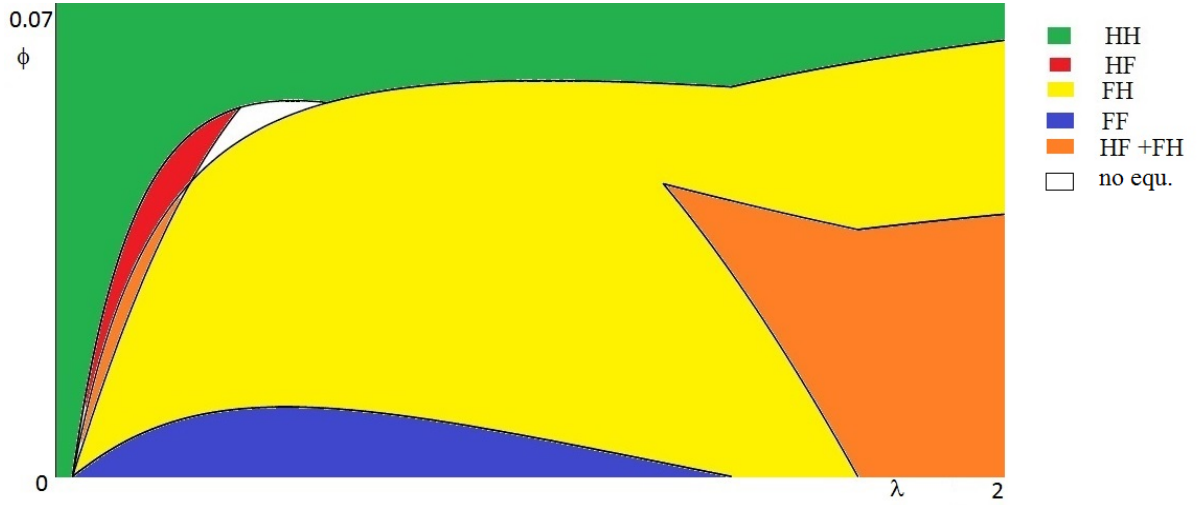
Figure 1: Location equilibria

In addition, the quality difference λ is important for the relocation decision. The lower the quality difference, the stronger is competition between firms, resulting in lower prices and similar quantities for both firms. An increase in the quality difference λ weakens competition and makes it more likely that at least one firm relocates to country F.

The third important parameter is the tax rate that is determined endogenously by the government. Note that the optimal tax rate is zero for high quality differences if at least one firm decides to relocate to country F. If one firm relocates to F, the welfare enhancing effect of a tax is lower, because emissions in H are already lowered due to relocation and tax revenue is lower.

Figure 1 illustrates the resulting Nash-equilibria depending on the quality difference λ and the cost of relocation ϕ.

We identify several combinations of λ and ϕ with unique Nash-equilibria HH, FH, HF, and FF. In addition, there are regions with two Nash-equilibria FH and HF. There is also a region with no Nash-equilibrium in pure strategies. For a given value of λ, each region is defined by a critical lower bound and/or upper bound of ϕ.

3.3.1 Equilibrium HH

A Nash-equilibrium HH exists if for both firms profits after relocation to F are lower, given that the other firm remains in H. If $\Pi_1^{HH} > \Pi_1^{FH}$ than ϕ exceeds the difference of

operating profits $\pi_1^{FH} - \pi_1^{HH}$. The same holds for the other firm: If $\Pi_2^{HH} > \Pi_2^{HF}$ than ϕ_2^{HH} exceeds the difference of operating profits $\pi_2^{HF} - \pi_2^{HH}$. A Nash-equilibrium in HH exists if $\phi > \phi^{HH} = \max\{\phi_1^{HH}, \phi_2^{HH}\}$ (see Appendix).

Given the endogenous choice of the tax rate, there exist three functions of ϕ^{HH} depending on the quality difference λ that result in an equilibrium where both firms remain in country H (see Appendix):

$$\phi^{HH} = \begin{cases} \phi_{\lambda<1.274}^{HH} \\ \phi_{1.274<\lambda<1.7071}^{HH} \\ \phi_{1.7071<\lambda}^{HH} \end{cases}$$

3.3.2 Equilibrium HF

A Nash-equilibrium HF exists if for firm 1 profits after relocation to F are lower, given that the other firm is located in F ($\Pi_1^{HF} > \Pi_1^{FF}$) and if the profits for firm 2 are higher in F than in H, given that firm 1 remains in H ($\Pi_2^{HF} > \Pi_2^{HH}$). For this equilibrium, the crucial cost of relocation depend on the quality difference. Depending on the quality difference λ, the critical cost of relocation is bounded by a lower and/or upper bar (see Appendix).

$$\phi^{HF} : \begin{cases} \underline{\phi}_{\lambda<1.180 \wedge 1.634<\lambda<\frac{1}{8}\sqrt{33}+\frac{9}{8}}^{HF} < \phi^{HF} < \overline{\phi}_{\lambda<1.180 \wedge 1.634<\lambda<\frac{1}{8}\sqrt{33}+\frac{9}{8}}^{HF} \\ \phi^{HF} < \overline{\phi}_{\lambda>\frac{1}{8}\sqrt{33}+\frac{9}{8}}^{HF} \end{cases}$$

3.3.3 Equilibrium FH

A Nash-equilibrium FH exists, if the profit for firm 1 if it relocates to country F exceeds the profit if it stays in the home country, given that firm 2 stays in H ($\Pi_1^{FH} > \Pi_1^{HH}$). For firm 2 it has to pay off to stay in H, given that firm 1 relocates to F. We therefore can identify critical values of ϕ, depending on the quality difference λ (see Appendix).

$$\phi^{FH} : \begin{cases} \underline{\phi}_{\lambda<\frac{1}{2}\sqrt{2}+1}^{FH} < \phi^{FH} < \overline{\phi}_{\lambda<\frac{1}{2}\sqrt{2}+1}^{FH} \\ \phi^{FH} < \overline{\phi}_{\lambda>\frac{1}{2}\sqrt{2}+1}^{FH} \end{cases}$$

3.3.4 Equilibrium FF

A Nash-equilibrium FF exists, if profits in country F exceed profits in country H for both firms, given that the other firm has also relocated to F ($\Pi_1^{FF} > \Pi_1^{HF}$ and $\Pi_2^{FF} > \Pi_2^{FH}$). We can identify upper limits for the relocation cost ϕ depending on the quality difference λ for this equilibrium to exist (see Appendix).

$$\phi < \phi^{FF} = \begin{cases} \overline{\phi}^{FF}_{\lambda < \frac{1}{2}\sqrt{2}+1} \\ \overline{\phi}^{FF}_{\lambda > \frac{1}{2}\sqrt{2}+1} = 0 \end{cases}$$

In figure 1, the equilibrium HH results only for very low values of λ or very high values of ϕ. The area of the pure equilibrium HF is rather limited. For relatively low and relatively high values of λ the orange areas indicate two equilibria, HF and FH. The most likely outcome is an equilibrium where at least one firm relocates to F. From the perspective of the government in H, the relocation of at least one firm may be beneficial, because it reduces emissions and damages at home. The white area indicates combinations of λ and ϕ, where no Nash-equilibrium in pure strategies exists.

4 Alternative Damage Functions

So far, we have considered a damage function $D = dq_i^2$, with $d_H = \frac{1}{2}$ as the baseline case. In this section we explore the effect of different damage functions. Because of the discontinuous effect of quality differences we restrict our analysis to the comparison of $d_H = \frac{1}{4}$ and $d_H = \frac{3}{4}$.

Consider first a damage parameter $d_H = \frac{1}{4}$. The government then maximizes the social welfare function, taking into account the damage function $D = \frac{1}{4}q_i^2$ (see Appendix).

Figure 2 illustrates the resulting Nash-equilibria depending on the quality difference λ and the cost of relocation ϕ for $d_H = \frac{1}{4}$. Compared to the baseline case, the lower parameter value in the damage function does not change the appearance of the location equilibria drastically. The area of the HH-equilibrium has increased (note the different scaling of the axes). In addition, the area of the FF-equilibrium is smaller, because a lower damage of emissions makes it less beneficial for H that both firms relocate to F. There is now a larger area for which no Nash-equilibrium exists. In addition, the area where HF is an equilibrium has increased.

Consider now $d_H = \frac{3}{4}$. Figure 3 illustrates the resulting Nash-equilibria depending on the quality difference λ and the cost of relocation ϕ for $d_H = \frac{3}{4}$. Again, the overall pattern of the equilibria is similar to the baseline case. The area where no Nash-equilibrium exists is smaller compared to the baseline case. The area of the HH-equilibrium is smaller (note again the different scaling of the axes), the area of the FF-equilibrium has increased compared to the baseline case. This is a result of the higher marginal damage of emissions and hence the welfare-enhancing effect of relocation.

In all three cases a higher value for λ increases the probability that at least one firm relocates, given optimal emission taxes set by the government in H. A higher quality

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Figure 2: Location equilibria for $d_H = \frac{1}{4}$
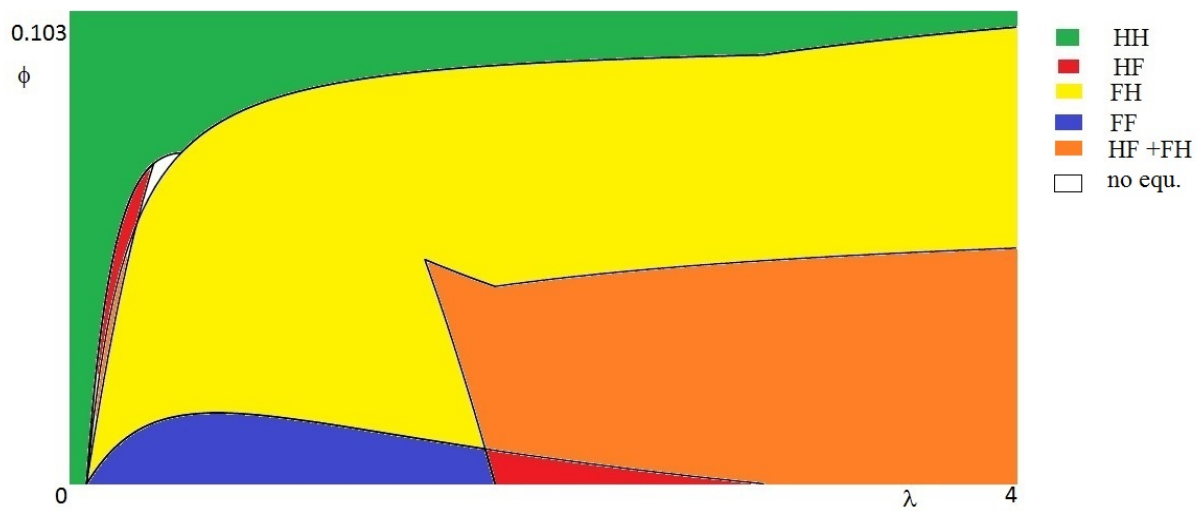

Figure 3: Location equilibria for $d_H = \frac{3}{4}$

difference weakens competition between both firms. For relocation cost being sufficiently low, it pays off for at least one firm to trade fixed cost of relocation for lower variable cost.

5 Environmental Tax in Countries H and F

So far, we have assumed that only the government in H applies an environmental tax. The government in F was assumed to be passive. This is in line with the analysis of Ikefuji et al. (2016). While this analysis facilitates some insights in the interaction of environmental damage, quality differences, and relocation cost, it is straightforward to assume that also the government in F maximizes welfare and applies environmental taxes. The relocation to F results in harmful emissions in F. At this stage of analysis we abstract from consumers in F and assume that only in H an output market exists. With respect to the damage function we assume the damage function of the baseline case in both countries.

5.1 Uncoordinated Taxation

Assume that the governments in H and F set environmental taxes uncooperatively. From the perspective of governments hosting a firm results in harmful emissions and potentially tax revenues. The relocation trade-off for firms has now changed, because relocation does not imply necessarily being not taxed. Figure 4 illustrates the resulting Nash-equilibria depending on the quality difference λ and the cost of relocation ϕ. If both governments apply an environmental tax, there is no FF-equilibrium, no FH-equilibrium, and no area characterized by multiple equilibria. For low values of λ there is an area, where no equilibrium exists. The area of an HF-equilibrium has increased drastically (note the different scaling of the axes) compared to the case where only H applies an environmental tax. If also the government in F applies a tax, it repels excessive relocation of both firms. But because firm location does not only imply harmful emissions, but also tax revenue, relocation is not prevented completely. There exists no equilibrium in which the high quality firm relocates to F.

5.2 Coordinated Taxation

Assume that the governments in H and F set environmental taxes cooperatively to maximize joint welfare. Figure 5 illustrates the resulting Nash-equilibria depending on the quality difference λ and the cost of relocation ϕ.

Figure 4: Environmental taxes in countries H and F

Figure 5: Location equilibria with coordinated taxation in H and F

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Compared to uncoordinated taxation, the area of HH-equilibria has increased, and there is a large area, where the high quality firm relocates to F. Note that governments do not tax profits and that consumer surplus only results in H. Therefore for the quality difference sufficiently large (and the relocation cost being sufficiently low), the high quality firm may relocate to F.

6 Conclusion

This paper has analyzed the effect of an emission tax on the relocation decision of firms, when a duopolistic market is characterized by vertical quality differentiation. Especially, we have focused on the relationship between quality difference, relocation cost and marginal damage of emissions in a two-country-setting for three cases: An environmental tax applied only by one country, uncoordinated environmental taxation in both countries, and coordinated environmental taxation.

If only the home county applies an environmental tax, various Nash-equilibria of location decisions exists depending on the quality difference and relocation cost. The Nash-equilibria depend discontinuously on the cost of relocation ϕ and the quality difference λ. The higher the quality difference is, the higher is the probability that at least one firm relocates to F. A Nash-equilibrium where both firms relocate to F only exists for a limited range of relocation cost and quality difference. A lower marginal damage increases the area of λ and ϕ where both firms remain in H. A higher marginal damage decreases the area of λ and ϕ where both firms remain in H.

If also the foreign country F applies an emission tax and both governments set taxes uncooperatively, the high quality firm never relocates to F in equilibrium. If they cooperate, the high quality firm is likely to relocate to the country where no output market exists. This result depends on the assumption that governments are not able to tax profits or consumer surplus and thus are restricted in using side-payments.

Our analysis shows the importance of the consideration of quality differences and taxing decisions in foreign countries. With respect to the pollution haven hypothesis (PHH), our analysis shows that in the unilateral case only a limited are exists where both firms relocate to country F. If also the foreign countries applies an environmental tax no such equilibrium exists.

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