Cross-Country Emission Tax Effect of Mergers[1]

Abstract

Recent studies show that mergers among polluting firms could affect the regulatory landscape of the industry and trigger a policy change. Using a two-country model, this study examines the effect of a merger size, as measured by the number of merging firms, on the optimal emission tax of another country. We show that, if pollution damages are not too large, a decline in the size of a merger reduces production and profits in that country, which affords a larger tax in the other country due to smaller profit-shifting concerns. On the other hand, if pollution damages are extremely large, a reduction in the size of a merger in one country reduces production in that country, but it also reduces production and emissions in the other country. Thus, the latter can induce a smaller emission tax. The change in the emission tax in both scenarios is consistent with cooperative outcomes.

JEL Classification: Q5, G34

Keywords: merger and acquisition, trans-boundary pollution, product differentiation, cooperative emission tax, non-cooperative emission tax

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1 Introduction

The literature has extensively examined the benefits and challenges posed by horizontal merger and acquisition deals (e.g., Salant et al., 1983; Deneckere and Davidson, 1985; Perry and Porter, 1985; Fauli-Oller, 2002; Qiu and Zhou, 2006; Kao and Menezes, 2010). According to Perry and Porter (1985), for instance, while mergers may improve efficiency and reduce redundant costs, there are concerns over reduced competition and higher prices for consumers. At the same time, several studies suggest that mergers among dominant firms could affect the regulatory landscape of the industry and trigger a policy change (e.g., Collie, 2003; Huck and Konard, 2004; Fikru and Lahiri, 2013; Fikru and Gautier, 2017; Creti and Sanin 2017). For example, Creti and Sanin (2017) show that a merger among large polluters in a cap-and-trade system, would reduce permit prices (i.e., a merger leads to less strict policies).

The contribution of this study is to examine the effect of a merger made of several firms on optimal environmental policy-making in an open economy model. We focus on the possibility where a merger in one country triggers a policy change in another country. We address two research questions: (1) What is the impact of a country's merger activities on another country's environmental policy setting? (2) Is policy setting, in turn, consistent with cooperative outcomes? Addressing these questions is appropriate because currently some countries are considering an emission tax to curb greenhouse gas emissions, while others have already instituted one. Additionally, there is evidence of merger deals taking place more frequently in some countries than others. For example, most countries in the European Union (EU) have implemented some kind of emission tax, while it is not the case for the United States (US). Evidences suggest that, since the formation of the EU, merger and acquistion deals have been more prevalent within the European single market. For example, in 2015 there were 15,880 deals in Europe versus 12,584 in the US (Institute for Mergers, Acquisitions and Alliances, 2020; Statista, 2020). Our framework provides insights on how countries can design/adjust emission taxes in light of merger decisions made by firms in other countries, but also on the design of international environmental agreements.

There is a nascent theoretical literature on the determinants and consequences of mergers among firms regulated on their pollution (Hennessy and Roosen, 1999; Fikru and Gautier, 2016, 2017; Benchekroun et al., 2019; Fikru and Gautier, 2020). Most of these studies examine merger incentives and the effect of environmental policy on the incentives to merge (Liu et al, 2015; Fikru and Gautier, 2016; Creti and Sanin, 2017).[2] However, only a few have examined the effect of mergers on optimal environmental policy-making (e.g., Fikru and Gautier, 2016, 2017). In a closed economy, Fikru and Gautier (2016) find that optimal emission tax is lower after a two-firm merger takes place as long as pollution intensity post-merger is not too large. Fikru and Gautier (2017) argue that the optimal emission tax declines post-merger, if the extent of output distortion post-merger is high. Unlike Fikru and Gautier (2016, 2017) we consider a merger made up of several not just two firms. We use a two-country model, and examine the effect of a relatively large sized merger on the optimal emission tax of another country. To the best of our knowledge, there are no studies that examine this *cross-country policy effect*, that is, the effect of firm strategy in one country on optimal policy of another country.

Studies such as Collie (2003), Huck and Konard (2004), and Fikru and Lahiri (2013) examine the effect of mergers on non-environmental types of policies. These studies examine own-country policy effects: the effect of firm strategy (merger) on the given country's optimal policy-making. The general consensus in this line of the literature is that optimally chosen policies are less strict post-merger due to market power effects. Collie (2003) shows that optimally set production subsidies increase after a merger takes place in order to offset anti-competitive effects of a merger. Huck and Konard (2004) show that the optimal policy

[2]One of the earliest models of mergers among polluting firms is by Hennessy and Roosen (1999) which examines the possibility that pollution permit systems motivate firms to merge. Canton et al. (2012) consider a waste management industry while Benchekroun et al. (2019) consider nonrenewable resource industries to show that environmental policy affects merger incentives.

response to a merger is to introduce subsidies after the merger takes place. Likewise, Fikru and Lahiri (2013) show that when a cross-border merger takes place the optimally chosen subsidy in both countries increases if the firm acquires a more efficient foreign firm. We contribute to this line of the literature by examining the previously unexplored cross-country environmental policy effect arising from a relatively large sized merger. Our results suggest that laxer policy post-merger may not always be consistent with cooperative outcomes.

We also contribute to the strategic trade literature where the overarching result is that countries set less stringent environmental policy to address profit-shifting in an increasingly globally competitive market (e.g., Brander and Spencer 1985; Ulph 1996; Ulph and Ulph 2007; Silva and Zhu 2009; Bhattacharya and Pal, 2010). [3] While our results are in line with this literature, we argue that less stringent environmental policy can address emissions but also concerns about profit shifting while achieving cooperative outcomes.

Our model is based on Fikru and Gautier (2020) which presents a two-country model with mergers among firms regulated by an emission tax. Their study derives a threshold number of firms that consolidate above (below) which a merger is defined as 'large' ('small') in size. They prove that this threshold size of merger is higher than 50% of existing firms in each country, and find also that as merger size increases, production level in that country increases up to the threshold level after which local production declines. The initial increase in production is due to the oligopolistic reaction from local non-merging firms (which increase production more than the reduction in per-firm output of the merging partners) and the subsequent decline in local production is due to the merger effect (each merger participant shrinks production significantly). In Fikru and Gautier (2020) an increase in the size of a merger (over the derived threshold) does not necessarily reduce welfare as long as pollution intensities are not too large. This is because even if local production declines, a large sized merger induces a larger oligopolistic interdependence from foreign firms leading to higher

[3] Other studies in the strategic tax policy literature include Mukherjee and Sinha (2019) which consider mergers and cooperative government policies in an open economy, and Iida and Mukherjee (2020) which examine non cooperative and cooperative policies in the presence of pollution.

global production. On the other hand, if pollution intensities are large, welfare will decline as the size of the merger increases over the derived threshold due to lower local production and pollution damage effects.

Our study, while very close to Fikru and Gautier (2020) in terms of the model set-up (two-country model, merger among several firms, and environmental externality) and use of a threshold size of merger, is significantly different in two important aspects. First, Fikru and Gautier (2020) characterize the non-cooperative tax, while we characterize and compare cooperative and non-cooperative taxation. Second, Fikru and Gautier (2020) examine the effect of size of a merger on welfare (given tax), while we examine the cross-country effect of size of a merger in one country on the optimal tax of another country.

Similar to the Fikru-Gautier model we consider a foreign country where some k out of a total of m firms have merged whereas the remaining $m-k$ firms operate independently. In contrast, we consider a home country where there are n independently operating firms. We start with the Nash equilibrium where governments in each country set an emission tax non-cooperatively. We show that a change in the size of the merged entity in the foreign country, that is a change in k, can affect the non-cooperative tax in the home country. Thus, the non-cooperative tax at home can diverge from or get closer to cooperative taxation.

Consistent with the environmental economics literature (e.g., Requate, 2006) if damages are not large enough, the home country's non-cooperative tax is below the cooperative tax. In this case, we show that a decrease in k brings the home country's non-cooperative tax closer to the cooperative tax (that is, the non-cooperative tax at home increases). The channel through which this possibility works is as follows: a decline in the size of the foreign merger reduces foreign production and profits in that country, which affords a larger home tax due to smaller profit-shifting concerns. The case where the size of the foreign merger falls, prompting a home-tax increase is consistent with cooperative taxation. On the other hand, if pollution damages are extremely large, then the non-cooperative tax could be higher than the cooperative tax (e.g., Requate 2006, Gautier 2019). In particular, if local damages are large enough, then the home country's non-cooperative tax can exceed the cooperative tax. We show that a reduction in the foreign merger size leads to a reduction in the home-tax and this gets the non-cooperative tax closer to the cooperative outcome. This occurs because local emissions (local production) fall when the foreign merger size declines. The case where the size of the foreign merger falls, prompting a tax decline at home is consistent with cooperative taxation.

Section 2 presents the model and some comparative statics. Section 3 presents the characterization of the cooperative and non-cooperative taxes. Section 4 examines different scenarios in which a change in the size of merger in the foreign country affects the optimal tax in the home country. Section 4 also explores the role of production differentiation on optimal policy making. Section 5 concludes by presenting a discussion on policy implications.

2 The Model

Consider two countries, namely, a home and foreign country. Suppose there are n (m) fixed number of firms operating in the home (foreign) country. In the post-merger equilibrium, k number of firms have merged in the foreign country and the remaining $m - k$ firms operate independently. Following Salant et al. (1983), we refer to independent firms as outsiders and firms which are part of the merged entity are referred to as insiders. All the n firms in the home country are independent and there are no mergers in the home country. We use subscript $l = 1, 2, \ldots, k$ to represent the foreign firms which merge (insiders) and $z = k + 1, \ldots, m$ to represent the outsider firms in the foreign country. Each plant owned by the merged entity in the foreign country produces output, q^f, and each outsider firm in that country produces output $\tilde{q}^f$. Each home firm produces output q^h. We use subscript $j = 1, 2, \ldots, n$ to represent firms in the home country .

Each firm within each country has an end-of-the-pipe-type technology where costs are given by $c(q, e) = cq + (sq - e)^2/2$, where e denotes per-firm net emissions, the constant $s > 0$ the pollution intensity coefficient, and $c > 0$ constant marginal costs. We shall follow Requate (2006) and assume the cost function satisfies $c_e < 0$, $c_q > 0$, $c_{qq} > 0$, $c_{ee} > 0$, $c_{qe} = c_{eq} < 0$, $c_{qq}c_{ee} - c_{qe}c_{eq} \geq 0$, where subscripts denote partial derivatives. Additionally, each firm operating in the home (foreign) country faces an identical per-unit tax, t^h (t^f), for each unit of emissions it fails to abate, which is set by the government in the home (foreign) country. The cost function implies that a higher emission (lower abatement) reduces abatement related costs but increases tax payments, and a lower emission (higher abatement) increases abatement related costs but lowers tax payments.

Demand faced by each firm in the home and foreign country is given, respectively, by

$$p^h = a - \beta\left(q_1^h + \cdots + q_n^h\right) - \gamma\left(q_1^f + \ldots + q_k^f + \tilde{q}_{k+1}^f + \ldots + \tilde{q}_m^f\right) \tag{1}$$

$$p^f = a - \beta\left(q_1^f + \ldots + q_k^f + \tilde{q}_{k+1}^f + \ldots + \tilde{q}_m^f\right) - \gamma\left(q_1^h + \cdots + q_n^h\right) \tag{2}$$

where $q_1^h + \ldots + q_n^h$ denotes output of firms operating in the home country, $q_1^f + \ldots + q_k^f$ represents output of the merged entity in the foreign country, and $\tilde{q}_{k+1}^f + \ldots + \tilde{q}_m^f$ represents output of outsider firms in the foreign country. The demand structure implies that within-country effects are identical, and there is product differentiation across countries, where $\gamma \in [0, \beta]$ denotes the degree of product differentiation. The degree of product differentiation helps track and capture the extent of cross-country effects. This is consistent with scenarios where consumers are able to distinguish between locally produced and imported goods.

It is noteworthy that, in the foreign country there are two types of firms (the merged entity made of k plants/insiders and the $m-k$ outsiders) while in the home country all firms are independent. Thus, the merged entity chooses the level of output and emissions which maximize *joint* profits, while outsiders choose the level of output and emissions to maximize *each* firm's profits.

The profit of each firm in the home country is defined as:

$$\pi_j^h = p_j^h q_j^h - c_j^h(q_j^h, e_j^h) - t^h e_j^h \quad where \quad j = 1, \ldots, n \tag{3}$$

In the foreign country, the joint profit of the merged entity and the profit of each outsider firm is given, respectively, by

$$\sum_{l=1}^{k} \pi_l^f = \sum_{l=1}^{k} (p_l^f q_l^f - c_l^f(q_l^f, e_l^f) - t^f e_l^f) \quad where \quad l = 1, \ldots, k \tag{4}$$

$$\tilde{\pi}_z^f = \tilde{p}_z^f \tilde{q}_z^f - \tilde{c}_z^f(\tilde{q}_z^f, \tilde{e}_z^f) - t^f \tilde{e}_z^f \quad where \quad z = k+1, \ldots, m \tag{5}$$

The post-merger equilibrium is solved using backward induction. First, the government in each country chooses the level of emission tax in a Cournot-Nash fashion. Second, firms in each country take policy as given in their profit-maximization behavior. Firms operating in the home and foreign country behave in a Cournot-Nash fashion. We assume interior solutions and a symmetric equilibrium within each type of firms (insiders versus outsiders) within each country.

2.1 Profit maximization

Each outsider firm in the home country chooses the level of output, q^h, and emissions, e^h, simultaneously in a Cournot-Nash fashion. That is, the profit function for each firm, π^h yields, under symmetry ($q_1^h = \ldots = q_n^h$, $e_1^h = \ldots = e_n^h$), the following two first-order conditions (subscripts denote partial derivatives):

$$p^h - \beta q^h - c_{q^h}^h = 0 \tag{6}$$

$$-c_{e^h}^h - t^h = 0 \tag{7}$$

The merged entity maximizes joint profits, $\pi_1^f + \cdots + \pi_k^f$, by choosing the level of output, q_l^f, and emissions, e_l^f, simultaneously in a Cournot-Nash fashion. This maximization problem yields $2k$ first-order conditions, whence under the assumption of symmetry ($q_1^f = \ldots = q_k^f$,

$e^f_1 = \ldots = e^h_k$, $s^f_1 = \cdots = s^f_k$) gives

$$p^f - \beta q^f k - c^f_{q^f} = 0 \quad (8)$$

$$c^f_{e^f} - t^f = 0 \quad (9)$$

Each outsider firm, z, in the foreign country maximizes $\tilde{\pi}^f_z$ by simultaneously choosing $\tilde{e}^f_z$ and $\tilde{q}^f_z$ taking all other firms output and net emissions as given. With the assumption of symmetry ($\tilde{q}^f_1 = \ldots = \tilde{q}^f_k$, $\tilde{e}^f_1 = \ldots = \tilde{e}^f_k$, $\tilde{s}^f_1 = \cdots = \tilde{s}^h_n$) this gives

$$\tilde{p}^f - \beta \tilde{q}^f - \tilde{c}^f_{\tilde{q}^f} = 0 \quad (10)$$

$$-\tilde{c}^f_{\tilde{e}^f} - t^h = 0 \quad (11)$$

Equations (6)-(11) characterize the post-merger equilibrium output and emissions, q^h, q^f, $\tilde{q}^f$, e^h, e^f, $\tilde{e}^f$. Consequently, demand functions in (1) and (2) under symmetry are given by

$$p^h = a - \beta n q^h - \gamma(q^f k + (m-k)\tilde{q}^f) \quad (12)$$

$$p^f = a - \beta(q^f k + (m-k)\tilde{q}^f) - \gamma n q^h \quad (13)$$

We complete the setup of the model by stating the assumption that, in equilibrium, pollution intensities within the foreign country are identical across foreign firms i.e., $\tilde{s}^f = s^f$. We make this assumption to focus on the role of asymmetries across countries, but also put aside issues arising from cost asymmetries across outsiders and insiders in the foreign country.

2.2 Comparative statics

In this sub-section, we examine the effects of k on per-firm output, total output in each country, and emissions. Appendix A presents the full comparative static exercise. Results are consistent with the literature and highlight the oligopolistic interdependence nature of the model *across* and *within* countries.

Total output in the foreign country is the sum of output by outsiders' and the merged entity, $Q^f = kq^f + (m-k)\tilde{q}^f$. First, an increase in k lowers total output in the foreign country, Q^f, via a reduction in q^f since an increase in the number of insiders reduces each insider's output. But an increase in k also increases total output for a given q^f. Second, total foreign output increases because outsider per-firm output, $\tilde{q}^f$, rises via the oligopolistic interdependence between outsiders and insiders in that country. But an increase in k lowers the number of outsider firms and so foreign output falls (for a given $\tilde{q}^f$).

Fikru and Gautier (2020) show that total output in the foreign country falls (rises) with an increase in the size of the merger if the size of the merger is sufficiently large (small). This is because for a given size of merger, k, the reduction (increase) in the output of merged firms, q^f, generates a sufficiently large reduction (increase) in total output. This result implies that there is a threshold merger size for which Q^f is stable i.e., $Q^f_k = 0$. Total home output is given by $Q^h = nq^h$ where Fikru and Gautier (2020) show that $\partial Q^h / \partial k > 0, \forall k$. This result holds due to the oligopolistic interdependence across countries and does not depend on the size of the merger in the foreign country, k.

A change in k does not affect abatement and therefore changes in emissions take place exclusively via changes in output. Since we are assuming asymmetry in pollution intensities across but not within countries, changes in global emissions due to a change in k, depend on asymmetries in pollution intensities across countries and changes in output within and across countries. Consistent with previous studies, emission tax in one country lower emissions in that country (via lower output and higher abatement induced by the tax), but raises emissions in the other country via higher output in that country (e.g., Lahiri and Symeonidis, 2007; Gautier, 2013, 2014, 2016). We summarize these results in the following remark.

Remark 2.1. *For a given tax, (i) An increase in the size of the merger in the foreign country: (a) raises output by each firm in the home country, (b) lowers output by each merged firm in the foreign country and (c) raises output by each outsider firm in the foreign country; (ii) There is a threshold size of merger such that total output in the foreign country is stable;*

and (iii) An increase in the size of the merger in the foreign country affects emissions within and across countries via changes in output and asymmetries in pollution intensities across countries. (iv) An increase in one country's tax lowers per-firm output in that country, but raises per-firm output in the other country.

3 Cooperative and Non-Cooperative Outcomes

In this section, we derive and characterize the cooperative and non-cooperative emission tax. The welfare function in each country is defined as the sum of consumer surplus, profits, tax revenue, and damages from global pollution. Consequently, in the home country we have:

$$W^h = CS + n\pi^h + t^h n e^h - \varphi^h \tag{14}$$

where $CS = CS(nq^h, kq^f + (m-k)\tilde{q}^f)$, $\varphi^h = \varphi^h(E)$ where $E = E^h + E^f$, and $E^h = ne^h$, $E^f = ke^f + \tilde{e}^f(m-k)$. The function φ^h is assumed to be increasing and strictly convex in emissions i.e., $\varphi^{h'} > 0$, $\varphi^{h''} > 0$. Emissions from each country affect the home country equally: marginal damages arising from changes in total emissions from the foreign country (i.e., transboundary pollution) is equal to marginal damages arising from total emissions from the home country.

The welfare function for the foreign country is:

$$W^f = CS + k\pi^f + (m-k)\tilde{\pi}^f + t^f e^f k + t^f (m-k)\tilde{e}^f - \varphi^f \tag{15}$$

where as before $\varphi^{f'} > 0$, $\varphi^{f''} > 0$.

3.1 Non-cooperative emission tax

This sub-section characterizes the non-cooperative optimal emission tax. The government in the home and foreign country choose, respectively, t^h and t^f, simultaneously taking the other country's tax as given. Differentiation of (14) and (15) with respect to t^h and t^f, respectively, gives

$$\frac{\partial W^h}{\partial t^h} = -nq^h \frac{\partial p^h}{\partial t^h} - Q^f \frac{\partial p^f}{\partial t^h} + n\frac{\partial \pi^h}{\partial t^h} + (t^h - \varphi^{h'})\frac{\partial E^h}{\partial t^h} - \varphi^{h'}\frac{\partial E^f}{\partial t^h} + E^h \quad (16)$$

$$\frac{\partial W^f}{\partial t^f} = -nq^h \frac{\partial p^h}{\partial t^f} - Q^f \frac{\partial p^f}{\partial t^f} + k\frac{\partial \pi^f}{\partial t^f} + (m-k)\frac{\partial \tilde{\pi}^f}{\partial t^f} + (t^f - \varphi^{f'})k\frac{\partial E^f}{\partial t^f} - \varphi^{f'}\frac{\partial E^h}{\partial t^f} + E^f \quad (17)$$

where $Q^f = kq^f + (m-k)\tilde{q}^f$. Setting (16) and (17) equal to zero characterize the non-cooperative (Nash) home and foreign tax, $t^h_{NC}(k)$, $t^f_{NC}(k)$. It is noteworthy that the non-cooperative tax is below marginal damages, which is an established result in the literature.

3.2 Cooperative emission tax

This sub-section characterizes the cooperative optimal emission tax, and compares the non-cooperative taxation with its cooperative counterpart (see Appendix B for additional steps in the calculations). Global welfare is the sum of home and foreign welfare: $W = W^h + W^f$, where differentiation with respect to t^h and t^f gives

$$\frac{\partial W}{\partial t^h} = \frac{\partial W^h}{\partial t^h} + \frac{\partial W^f}{\partial t^h} = 0$$

$$\frac{\partial W}{\partial t^f} = \frac{\partial W^h}{\partial t^f} + \frac{\partial W^f}{\partial t^f} = 0$$

which characterize the optimal cooperative tax vector $t^h_C(k)$, $t^f_C(k)$.

To compare non-cooperative taxation at home with its cooperative counterpart we differentiate W with respect to t^h and evaluate at the Nash equilibrium. If the sign is positive (negative), then the non-cooperative tax is below (above) the cooperative tax.

$$\left.\frac{\partial W}{\partial t^h}\right|_{Nash} = \left.\frac{\partial W^h}{\partial t^h}\right|_{Nash} + \left.\frac{\partial W^f}{\partial t^h}\right|_{Nash} \quad (18)$$

where the first term vanishes at the Nash equilibrium and whence[4]

$$\left.\frac{\partial W^f}{\partial t^h}\right|_{Nash} = \Pi + \left(t^f\frac{\partial E^f}{\partial t^h} - t^h\frac{\partial E^h}{\partial t^h}\right) + \left(-\varphi^{f'}\frac{\partial E}{\partial t^h} + \varphi^{h'}\frac{\partial E}{\partial t^h}\right) \quad (19)$$

[4]We find $\partial W^f/\partial t^h$ at the Nash equilibrium using (15), and substituting $\partial W^h/\partial t^h = 0$ into it.

The first,[5] second, and third terms capture, respectively, profit effects (home profits and profit-shifting), abatement effects associated with foreign and home emissions, and damages to the home and foreign countries. The first two terms are each positive, meaning that a non-cooperative tax at home falls below its cooperative level to offset profit shifting and pollution abatement costs. In the third term, damages to the foreign country are positive, meaning that cooperative home taxation exceeds the non-cooperative level since now the home country is accounting for the presence of damages to the foreign country i.e., $-\varphi^{f'}(\partial E/\partial t^h) > 0$. However, damages to the home country (i.e., $\varphi^{h'}(\partial E/\partial t^h) < 0$) are negative, which means that, if large enough, non-cooperative home taxation could exceed the cooperative level since now the home government addresses larger damages to that country. Overall, profit and damages to the foreign country put a downward pressure on taxation, while damages to the home country exert an upward pressure. With these effects in mind we state the following remark.

Remark 3.1. *The non-cooperative home tax falls below (exceeds) the cooperative level if and only if damages from emissions to the home country are sufficiently small (large) i.e.,* $t^h_{NC} < (>) t^h_C$.

An analogous result applies to foreign country's taxation. Remark 3.1 is consisent with the literature (Requate, 2006; Gautier, 2019). It is noteworthy that the result in remark 3.1 is not contingent on the size of the merger (e.g., size of merger is small or large).

4 Size of the Merger and Taxation

This section identifies the factors affecting the non-cooperative tax in the home country given a change in the size of the merger in the foreign country starting at the Nash equilibrium. The goal is to analyze inefficiencies associated with the non-cooperative equilibrium (e.g.,

[5] $\Pi = \left(-n\frac{\partial \pi^h}{\partial t^h} + k\frac{\partial \pi^f}{\partial t^f} + (m-k)\frac{\partial \tilde{\pi}^f}{\partial t^f} - E^h\right) > 0.$

Hatziparatayou et al., 2005; Kayalica and Lahiri, 2005; Gautier, 2019). We note the role of damages from pollution in the adjustments in home taxation, but also adjustments in taxation consistent with the cooperative equilibrium. There are two key builiding blocks in the analysis. First, to track changes in output in the foreign country and make comparisons with the existing literature, we consider changes in k starting at the threshold size of merger mentioned in section 2.2 i.e., k such that $Q^f_k = 0$. Second, we consider changes in k starting at the Nash equilibrium.

With these in mind, we argue that an increase in the size of the merger results in a higher home non-cooperative tax, if damages from emissions are sufficiently large. This is because an increase in k results in higher home output and emissions, and therefore higher damages to home but also the foreign country, which the home government tackle with higher taxation. Similarly, if damages coming specifically from home emissions are sufficienly large, then a reduction in the size of the merger reduces the home non-cooperative tax consistent with the cooperative equilibrium. The reason is that a reduction in k lowers home output and thus emissions, which allows the home government to lower its tax since damages from home emissions have decreased. In both cases the adjustment in the non-cooperative tax at home is consistent with cooperative taxation.

To see these results, we differentiate the welfare-maximizing first-order conditions (subscripts denote partial derivatives) $W^h_{t^h}(t^h(k), t^f(k), k) = 0$ and $W^f_{t^f}(t^h(k), t^f(k), k) = 0$, which yields the expressions for changes in the tax t^h_k and t^f_k with respect to the size of the merger. In particular, $-W^h_{t^h t^h} t^h_k = W^h_{t^h k}$, where $W^h_{t^h t^f} = 0$, $W^f_{t^f t^f} < 0$.[6] Differentiation of (16) gives

$$W^h_{t^h k}\big|_{Q^f_k=0,Nash} \quad = \quad \Psi + \Theta + \left(E^h_{t^h k}(t^h - \varphi^{h'}) - \varphi^{h''} E^h_{t^h} E^h_k\right) - E^f_{t^h k}\varphi^{h'} \tag{20}$$

where $\Psi > 0$, $\Theta < 0$ denote, respectively, consumer surplus and profit effects.[7] The third

[6] $W^h_{t^h t^f} = 0$ arises from the linearity assumptions in the model, and $W^h_{t^h t^h} < 0$ strict concavity assumption of the welfare function.

[7] $\Psi = -Q^f(\beta(q^f_{t^h} - \tilde{q}^f_{t^h}) + \gamma q^h_{t^h k} n) > 0$, $\Theta = \beta n(q^h_{t^h} n q^h_k + q^h q^h_{t^h k}) < 0$.

term (positive) captures adjustments in the home tax from damages coming from home emissions and the fourth term (negative) damages to the home country coming from foreign emissions. The reason the fourth term is negative is because lower home taxation controls foreign output and thus emissions from that country. The sign of (20) is in general ambiguous, but we consider two broad cases to characterize adjustments in the home tax.

Consider the case where damages from emissions are large, particularly large enough damages coming from home emissions i.e., third term in (20). In this case home non-cooperative taxation exceeds its cooperative counterpart (remark 3.1). Then, starting at the Nash equilibrium and threshold size of merger, a reduction in the size of the merger lowers taxation at home (i.e., $t_k^h > 0$) which gets taxation closer to the cooperative outcome. The reduction in taxation is because emissions at home fall due to the lower size of merger in foreign. It is noteworthy that if damages to the home country coming from foreign emissions are relatively large, then by remark 3.1 the home non-cooperative tax falls below its cooperative counterpart. In this case a reduction in the size of the merger raises the non-cooperative tax at home i.e., $t_k^h < 0$ (fourth term in 20), meaning taxation gets closer to its cooperative counterpart. This is because a reduction in the size of the merger lowers foreign emissions and so the need to lower taxation by the home country is less.

As a second case, suppose profit effects are sufficiently large (i.e., damages are small). In this case the home non-cooperative tax falls below its cooperative counterpart, and an increase in the size of merger lowers the tax at home. This is because an increase in size of the merger raises profits in the foreign country and so the home country lowers its tax to offset this effect. As a result, reductions in the size of the merger prompt a tax increase consistent with cooperative taxation.

We also point to the role of product differentiation. In the case of complete product differentiation ($\gamma = 0$) cross-country effects vanish, i.e., cross-border pollution from the foreign to the home country and consumer surplus effects cancel out. The non-cooperative vis-à-vis cooperative taxation still follows remark 3.1. As a result, a decrease (increase) in k reduces (raises) home taxation *if and only if* damages coming from home emissions are large (small) enough. Different from the case where $\gamma \neq 0$ the tax adjustment is larger since now the home government does not have to deal with changes in damages coming from foreign emissions, but it still accounts for the damages it exerts on the foreign country. In the case where profit effects are large enough results hold as before when products are completely differentiated.

Proposition 4.1. *Consider a change in the size of the merger, k, starting at the Nash equilibrium and threshold size of merger. Then, the government in the home and foreign country can adjust taxation in each country consistent with the cooperative equilibrium for any degree of product differentiation, i.e., for all $\gamma \in [0, \beta]$.*

Lemma 4.2. *Suppose products are very differentiated. Consider a change in the size of the merger, starting at the Nash equilibrium and threshold size of merger. Then, adjustments (either upwards or downwards) in home taxation follow Proposition 4.1, but such adjustments are larger because the home government does not have to account for damages coming from foreign emissions.*

5 Discussion and Conclusion

Recent empirical evidence suggests that firms in pollution-intensive industries consider merger and acquisition strategies with objectives other than just gaining synergies or reducing redundant costs. Berchicci et al. (2012) examine over 2,000 merger deals during 1991- 2005 and these deals are among firms regulated for the disclosure of toxic chemical releases in the United States (US). Berchicci et al. (2012) argue that managers in pollution-intensive industries strategically choose merger partners that are closer in proximity as well as have better environmental capability. This is expected to facilitate the transfer and sharing of cleaner technologies among merger participants. Kwon et al. (2018) examine merger and acquisition deals in the US energy sector and argues that firms in environmentally sensitive industries could benefit from acquiring a start-up company due to the possibility of gaining eco-friendly technologies. Eng and Fikru (2020) find that the environmental performance of merger participants in the US food processing industry is significantly different from each other, creating the potential for improving environmental performance post-merger. Creti and Sanin (2017) argue that mergers among power generators in the US power industry may have been triggered by tightening environmental regulation, in particular due to the introduction of a permit system and the subsequent tightening of the cap.

In light of the rising importance of strategically motivated mergers in polluting sectors, it is important to consider whether environmental policy-makers ought to revise policies/regulations and how, in response to these firm strategies. Our study looks at the optimal environmental policy response of a country due to merger activities in another country. We show that firms' restructuring decisions could alter policy-making in other countries consistent with the cooperative equilibrium.

Creti and Sanin (2017) find evidence that a merger among large polluters in a cap-and-trade system, would reduce permit prices (i.e. a merger leads to less strict policies), suggesting that firms would consider a merger to reduce the cost-implications of stricter environmental policy. Although our analysis is consistent with this result within a closed-economy setting (larger size of merger among large polluters is associated with higher non-cooperative taxation in the country where the merger originated), our analytical framework suggests that neither higher taxation abroad nor locally, due to a larger merger by local large polluters, may be consistent with cooperative outcomes. This points to the need for policy coordination across countries in the presence of mergers.

In the context of international environmental agreements, negotiating parties normally focus on *inter alia* whether countries can stay competitive while addressing environmental concerns. Our analysis indicates that in the context of mergers and large damages, environmental policy can be consistent with cooperative outcomes, while allowing some countries to remain competitive via lower taxation. Further, building from the analysis in Fikru and Gautier (2020) our results indicate that welfare-enhancing anti-trust policy can be consistent with cooperative taxation.

Appendix

Appendix A

We derive the system for the comparative statics exercise and some of the expressions presented in the text. Consider (6)-(11). Using the end-of-pipe cost function within each set of firms we substitute the first-order condition associated with net emissions into the first-order condition associated with per-firm output. This gives three equations, which we differentiate along with (12) and (13), which yields three equations in three unknowns dq^h, dq^f, $d\tilde{q}^f$. That is,

$$\begin{bmatrix} \beta(n+1) & \gamma k & \gamma(m-k) \\ \gamma n & 2\beta k & \beta(m-k) \\ \gamma n & 2k & \beta(m-k+1) \end{bmatrix} \begin{bmatrix} dq^h \\ dq^f \\ d\tilde{q}^f \end{bmatrix} = \begin{bmatrix} -s^h dt^h - \gamma(q^f - \tilde{q}^f)dk \\ -s^f dt^f - \beta(2q^f - \tilde{q}^f)dk \\ -s^f dt^f - \beta(q^f - \tilde{q}^f)dk \end{bmatrix}$$

where the determinant of the coefficient matrix is $\Delta > 0$. Hence, the effects with respect home output:

$$\Delta \frac{\partial q^h}{\partial t^h} = s^h \beta^2 k\,(m-k+2) < 0$$

$$\Delta \frac{\partial q^h}{\partial t^f} = s^f \beta\gamma k(m-k+1) > 0$$

$$\Delta \frac{\partial q^h}{\partial k} = \beta^2 \gamma k \tilde{q}^f > 0$$

The effects with respect to each firm within the merged entity in the foreign country are given by

$$\Delta \frac{\partial q^f}{\partial t^h} = s^h \beta\gamma n > 0$$

$$\Delta \frac{\partial q^f}{\partial t^f} = -s^f \beta^2 (n+1) < 0$$

$$\Delta \frac{\partial q^f}{\partial k} = \beta q^f (\beta^2(n+1) - n\gamma^2)(m-k) + \beta\gamma^2 n(q^f - \tilde{q}^f) < 0$$

where $q^f < \tilde{q}^f$. Next, we make use of $kq^f = \tilde{q}^f$ (from first-order conditions), whence $\partial \tilde{q}^f/\partial t^h > 0$, $\partial \tilde{q}^f/\partial t^f < 0$, $\partial \tilde{q}^f/\partial k = k(\partial q^f/\partial k) + q^f$, $\partial q^f/\partial t^h - \partial \tilde{q}^f/\partial t^h < 0$, and

$$\begin{aligned} \frac{\partial^2 \tilde{q}^f}{\partial t^h \partial k} &= \frac{\partial q^f}{\partial t^h} > 0 \\ \frac{\partial^2 \tilde{q}^f}{\partial t^f \partial k} &= \frac{\partial q^f}{\partial t^f} < 0 \end{aligned}$$

Appendix B

The following expressions are obtained when welfare is evaluated at the Nash equilibriurm:

$$\begin{aligned} \Delta \frac{\partial^2 q^h}{\partial t^h \partial k} &= -s^h \beta^2 (m - 2k + 2) < 0 \\ \Delta \frac{\partial^2 q^h}{\partial t^f \partial k} &= -s^f \beta \gamma (m - 2k + 1) < 0 \\ \Delta \frac{\partial^2 q^f}{\partial t^h \partial k} &= 0 \\ \Delta \frac{\partial^2 q^f}{\partial t^f \partial k} &= 0 \end{aligned}$$

Next, using $E^h = ne^h = n(s^h q^h - t^h)$, $E^f = ke^f + (m-k)\tilde{e}^f = k(s^f q^f - t^f) + (m-k)(s^f \tilde{q}^f - t^f)$ and $kq^f = \tilde{q}^f$ we obtain the following when welfare is evaluated at the Nash equilibriurm:

$$\begin{aligned} \Delta \frac{\partial^2 E^f}{\partial t^h \partial k} &= \frac{\partial e^f}{\partial t^h} - \frac{\partial \tilde{e}^f}{\partial t^h} + k \frac{\partial^2 e^f}{\partial t^h \partial k} + (m-k) \frac{\partial^2 \tilde{e}^f}{\partial t^h \partial k} \\ &= \frac{\partial e^f}{\partial t^h} - \frac{\partial \tilde{e}^f}{\partial t^h} + (m-k) \frac{\partial^2 \tilde{e}^f}{\partial t^h \partial k} \\ &= \frac{\partial e^f}{\partial t^h} (m - 2k + 1) > 0 \\ \Delta \frac{\partial^2 E^h}{\partial t^h \partial k} &= s^h n \frac{\partial^2 q^h}{\partial t^h \partial k} < 0 \end{aligned}$$

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