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Mergers in Cournot Markets with Environmental Externality and Product Differentiation

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Abstract: Due to the extensive work on why mergers take place our understanding of merger incentives has improved. However, there are not many studies examining how differences in pollution parameters between post and pre-merger markets affect the attractiveness of merger deals. This study examines conditions under which the attractiveness of a merger deal increases in a Cournot market with product differentiation and environmental externality. Our findings suggest that, (*i*) the attractiveness of a deal increases as products become more differentiated, (*ii*) merger deals could result in lower optimal emission tax post-merger, (*iii*) the attractiveness of a deal is more likely to increase if the merged entity is not too pollution-intensive post-merger relative to its pre-merger pollution intensity; and (*iv*) when merged entities modify products to be greener, they are more likely to benefit more from the deal if they are not too pollution-intensive.

Keywords: product differentiation; cleaner technology; mergers and acquisitions; emission tax

JEL Classification: L, Q5, G34

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Highlights

- Mergers could result in lower optimal emission tax post-merger.
- Mergers are more attractive if pollution intensity is smaller post-merger.
- Merger attractiveness depends on greener modification of products post-merger.

Mergers in Cournot Markets with Environmental Externality and Product Differentiation

Abstract

Due to the extensive work on why mergers take place our understanding of merger incentives has improved. However, there are not many studies examining how differences in pollution parameters between post- and pre-merger markets affect the attractiveness of merger deals. This study examines conditions under which the attractiveness of a merger deal increases in a Cournot market with product differentiation and environmental externality. Our findings suggest that, (i) the attractiveness of a deal increases as products become more differentiated, (ii) merger deals could result in lower optimal emission tax post-merger, (iii) the attractiveness of a deal is more likely to increase if the merged entity is not too pollution-intensive post-merger relative to its pre-merger pollution intensity; and (iv) when merged entities modify products to be greener, they are more likely to benefit more from the deal if they are not too pollution-intensive.

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1 Introduction

Since the seminal work of Salant et al. (1983) on horizontal mergers, studies have examined merger profitability in a framework of homogeneous goods market. For instance, Farrell and Shapiro (1990), Levin (1990) and Fauli-Oller (2002) show that profitable mergers result from the acquisition of a high-cost firm by a low-cost firm. Furthermore, synergies may be possible if the cost of the merged entity is much lower than the sum of the costs of constituent firms (Perry and Porter, 1985; McAfee and Williams, 1992; Horn and Persson, 2001). In addition, in a homogeneous good market profitable mergers are shown to be triggered by foreign competition, uncertainty and information asymmetry (Qiu and Zhou, 2006; Banal-Estanol, 2007; Das and Sengupta, 2001).

Since most of the real world mergers are among firms which produce similar but not identical products, horizontal merger models which explicitly incorporate product differentiation are steadily gaining attention among researchers (Deneckere and Davidson, 1985; McElroy, 1993; Lommerud and Sorgard, 1997; Qiu and Zhou, 2006; Kao and Menezes, 2010). For example, Shapiro (1996) argues that the effect of mergers on market variables depends on the extent of competition between merging brands. Recent studies like Ebina and Shimizu (2009) show that profitable mergers are more likely to occur for firms producing closely related products due to the acquisition of a close rival.

Despite the growing interest in merger profitability in markets with product differentiation, there are not many studies extensively examining changes in product types and processes that could occur in post-merger markets. Most studies assume that either pre-merger conditions persist after a merger deal or differences between pre- and post-merger markets are limited to efficiency, output decisions, price, ownership structure and number of firms. For instance, Baker and Bresnahan (1985) rely on pre-merger data to examine a post-merger market in which differentiated firms have merged. Nevo (2000) assumes that the only difference between pre- and post-merger markets is the change in ownership. Werden and Froeb (1994) assume that a merger results in a price change where product characteristics remain the same in the pre- and post-merger markets. Dagen and Richards (2006) use the baby food market to illustrate that the effect of a merger on price and market share significantly depends on post-merger conditions such as whether the merged entity maintains all or some of the brands. Likewise, when cost saving is involved merger profitability may actually depend on post-merger decisions on product types (Norman et al., 2005).

Mergers cause an immediate change in ownership and a subsequent change in operations and practices (Rhodes, 2004). For example, the merged entity may introduce a new brand after the merger deal (Hoberg and Phillips, 2010) or it may invest more on environmentally friendly products and/or processes. Certain choices may be better than others in facilitating integration, aligning different corporate cultures and leading to the success of the organization. Thus when product differentiation is present using pre-merger parameters to evaluate post-merger markets does not provide reliable predictions. The contribution of this study is to examine some conditions under which mergers are more profitable in industries that produce differentiated goods. We extend the discussion to firms producing goods with a negative environmental externality and facing an emission tax.

We explicitly control for pollution parameters and resulting regulation in our model because of two reasons. First, the majority of merger deals take place among firms which contribute to greenhouse gas emissions and pollution. For instance, the value of mergers in pollution-intensive industries identified by Hettige et al. (1995) accounted for about 80% of the value of deals and 81% of the volume of deals in the European manufacturing sector in 2009/2010 (Fikru and Lahiri, 2013; Fikru, 2013). Second, due to changing environmental regulation firms are becoming wearier of environmental liability when they choose merger partners. According to Gillston and Meyer (2013) considering environmental liabilities such as contamination, toxic chemicals in water and pollution should be a vital element of any merger deal. Likewise, Gehsmann and McCeney (2009) argue that companies planning to make a merger deal should assess the effect of environmental policy on those businesses they wish to partner with.

In a Cournot oligopoly model we consider the case where a merged entity, (1) has a different pollution intensity post-merger due to an exogenously imposed change in production technology, and (2) modifies its product (hence contributing to the industry's product differentiation) to be more environmentally-friendly after the merger. For instance, among a sample of 708 food processors which engaged in a merger and acquisition deal during 2001-2012, there was a 17.6% increase in the average number of process modifications targeting reduction of toxic pollutant releases a year after the deal was announced. Similarly, among the same sample there was a 63.1% increase in average number of product modifications two years after the deal with the purpose of reducing release of toxic chemicals (authors' calculation based on Toxic Release Inventory and Thomson Reuter's Analytical data). Another specific example is Land O'Lakes Inc. one of the largest dairy producers in the USA with significant merger and acquisition deals during 2001-2003 (it purchased Farmland Industries Inc. in 2002, Purina Mills Inc. and Philips Morris Inc. in 2001; it also merged with Bongards Creameries in 2003). Starting from 2004 onwards the company reports adoption of some process modification activities to reduce emission of toxic chemicals. In addition, immediately after its merger with Purina Mills Inc. in 2001 it introduced several new brands of butter.[1]

Using the two cases, we study under what conditions the attractiveness of a merger deal increases as products get more and more (or less and less) differentiated. The specific research questions addressed are: (1) What is the effect of mergers on the optimally determined emission tax rate, if any? (2) How does the attractiveness of a merger deal change when the industry's product differentiation changes? (3) How does the effect of product differentiation on the attractiveness of a deal depend on whether the merged entity has modified its technology or product? (4) What is the role of the abatement induced by the emission tax on the attractiveness of a merger deal?

[1]Source: https://www.landolakesinc.com/company/MemberOwnedIdeaDriven/Timeline/default.aspx

Our general finding indicates that a merger deal is more attractive if the merged entity is not too pollution intensive post-merger and if the merged entity differentiates its products to be environmentally conscious post-merger. Some of the specific findings of this study suggest that (*i*) mergers in a differentiated market with environmental externality result in lower optimal emission tax post-merger unless both the pre-merger pollution intensity and abatement induced by tax are relatively very small, (*ii*) the attractiveness of a merger deal among polluting firms increases as products become more differentiated, (*iii*) in the case where the post-merger market's pollution intensity changes due to a change in technology, the attractiveness of a merger deal is more likely to increase with product differentiation when the merged entity's pollution intensity is relatively small, (*iv*) in the case where the merged entity modifies products to be greener, the attractiveness of a merger deal is more likely to increase with product differentiation when the merged entity's pollution intensity is small, and (*v*) abatement induced by emission tax affects merger profitability in such a way that pre- (post-) merger abatement effect decreases (increases) profitability and the net effect depends on the difference in the size of the abatement effects pre- and post-merger.

In section 2 we present the theoretical framework and assumptions. We solve for the profit and welfare maximization problems and compare the pre- and post-merger equilibria. Section 3 and 4 present the two possible post-merger cases and discuss possible outcomes. In section 5 we conclude by forwarding some policy recommendations and questions for future research.

2 The Model

This section spells out the main features of the model. In a formal sense the model is based on Qiu and Zhou (2006) and expanded by introducing pollution parameters discussed in Fujiwara (2009). Consider a Cournot oligopoly model where a fixed number of n firms compete for the production of a differentiated product. Each firm produces one product variety. The production of the good creates environmental externalities. Thus each firm faces an emission tax and employs pollution abatement techniques.

Each firm i incurs production and abatement costs where marginal cost of production is assumed to be a constant c. Firms undertake end-of-the-pipe type abatement as in Lahiri and Symeonidis (2007); and in line with Barrett (1994a, b) abatement costs are assumed to be quadratic. Hence, the cost function for each firm i ($i = 1, 2, \ldots, n$) can be written as $C(q_i, e_i) = cq_i + (\delta_i q_i - e_i)^2/2$, where q_i denotes output level of product type i produced by firm i, $\delta_i > 0$ is pollution intensity, $c > 0$ and e_i is net emissions (Lahiri and Symeonidis, 2007). Generalizations using a general cost function $C = C(q_i, e_i)$ as defined in Requate (2006) can be obtained from authors upon request.

Similar to Salant et al. (1983) and Qiu and Zhou (2006) a constant and identical marginal cost of production, c, eliminates any merger incentives associated with efficiency gains and synergy. In this way, we can focus on the role of pollution parameters and product differentiation, a key contribution of this paper. Dropping the i superscript to simplify notation the cost function satisfies (subscripts denote partial derivatives), $C_q = c + \delta(\delta q - e) > 0$, $C_{qq} = \delta^2 > 0$, $C_e = -(\delta q - e) < 0$, $C_{ee} = 1 > 0$ and $C_{qq}C_{ee} - C_{eq}C_{qe} = 0$.

The demand function faced by each firm is adopted from Fujiwara (2009) and Cellini et al. (2004) and derived from preferences such that $p_i = \alpha - (\beta - \gamma)q_i - \gamma \sum_{i=1}^{n} q_i$, satisfying $\beta \geq \gamma \geq 0$, $\alpha > 0 \; \forall i$, where γ represents the degree of product differentiation in the industry. $\gamma = 0$ captures the extreme case where products are not substitutes and hence extremely differentiated. $\gamma = \beta$ represents the extreme case of completely homogeneous goods. If products are completely homogeneous we have the usual market demand $p_i = \alpha - \beta \sum q_i$. If products are completely differentiated, the demand function for product i would be $p_i = \alpha - \beta q_i$.

Each firm pays a per unit emission tax, t, for the level of pollution it fails to abate. Hence the government collects te_i from each firm as tax revenue. The government maximizes the following social welfare function to choose the optimal emission tax:

$$\max_t W = CS(\sum_{i=1}^{n} q_i) + \sum_{i=1}^{n} \pi_i + t \sum_{i=1}^{n} e_i - \varphi(\sum_{i=1}^{n} e_i) \tag{1}$$

$CS(\sum_{i=1}^{n} q_i)$ denotes consumer surplus, π_i is profit of firm i, $\varphi(\sum e_i)$ denotes damages from industry emissions where $d\varphi(\cdot)/de = \varphi' > 0$ denotes the marginal damage from emissions. Welfare is defined as the sum of consumer surplus, profits, revenue collected from emission tax less disutility from industry emissions.

The government and firms play a two-stage game where the government sets policy (i.e., emission tax) via social welfare maximization. Firms then take the policy as given and maximize profits by simultaneously choosing the level of output and emissions in a Cournot-Nash fashion. The assumption of simultaneous decision on output and emissions assumes away the strategic choice of abatement, which has been analyzed elsewhere.[2]

We assume interior solutions and symmetric equilibrium throughout the analysis. Under symmetry we have $q_1 = q_2 = ... = q$ and thus the market demand function can be expressed as $p = \alpha - q(\beta + \gamma(n-1))$. We solve the model by backwards induction, first solving for the firm's problem and then solving for welfare maximization.

2.1 Pre-merger equilibrium

Each firm maximizes profit with respect to output and emission level as follows:

$$\max_{q_i, e_i} \pi_i = (p_i - c)q_i - (\delta_i q_i - e_i)^2/2 - e_i t \tag{2}$$

Assumption 2.1. *$q_i > 0$ for all $i = 1, 2, ..., n$.*

[2]Studies like Montero (2002a, b) and Carlsson (2000) model abatement as a strategic variable where firms first choose abatement (e.g. investment in capital, Research and Development, etc.) and then output level. We assume away this effect in order to focus on the role of product differentiation.

Assumption 2.1 ensures that all firms produce a non-negative quantity (Qiu and Zhou, 2007). The first order conditions are given by:

$$p_i - c - q_i\beta - \delta_i(\delta_i q_i - e_i) = 0 \tag{3}$$

$$\delta_i q_i - e_i - t = 0 \tag{4}$$

Imposing symmetry implies that $p_i = p$, $q_i = q$, $\delta_i = \delta$, and $e_i = e$ and yields $p - c - q\beta - \delta t = 0$ where $p = \alpha - q(\beta + \gamma(n-1))$. This solves for the equilibrium level of output, emission level and profit.

$$q = \frac{\alpha - c - \delta t}{2\beta + \gamma(n-1)} \tag{5}$$

$$e = \frac{\delta(\alpha - c - \delta t)}{2\beta + \gamma(n-1)} - t \tag{6}$$

$$\pi = \beta(q)^2 + t^2/2 \tag{7}$$

where the term $t^2/2$ in the equilibrium profit captures the increase in profit arising from the abatement induced by the tax and the resulting reduction in tax payments (abatement effect). As more abatement takes place due to tax, profit increases due to less tax paid for emissions. Equations (5) and (7) imply that keeping other things constant $\partial q/\partial\gamma < 0$ and $\partial\pi/\partial\gamma < 0$ as in Fujiwara (2009). A higher product differentiation (lower γ) raises market power and profit; and as products become more homogenous market power declines.

Optimal tax is derived by maximizing the welfare function with respect to t. With symmetric equilibrium the welfare function can be rewritten as

$$\max_t W = CS(nq) + n\pi + net - \varphi(ne) \tag{8}$$

Totally differentiating and re-arranging terms yields (please see Appendix A for detailed steps):

$$\frac{dW}{dt} = n\beta q\frac{dq}{dt} + (t - \varphi')n\frac{de}{dt} \tag{9}$$

Setting the above equation equal to zero gives

$$t = \varphi' - \frac{\beta q[dq/dt]}{de/dt} \tag{10}$$

where $dq/dt = -\delta/2\beta + \gamma(n-1) < 0$ and $de/dt = -\delta^2/2\beta + \gamma(n-1) - 1 < 0$. This result is consistent with the literature (Requate, 2006; Fujiwara, 2009; Fikru, 2013; Fikru and Lahiri, 2013). The closed-form solution for optimal tax in the pre-merger market is thus given by

$$t = \frac{\varphi'\left(\frac{\delta^2}{2\beta+\gamma(n-1)} + 1\right) - \frac{\beta\delta(\alpha-c)}{(2\beta+\gamma(n-1))^2}}{\frac{\delta^2(\beta+\gamma(n-1))}{(2\beta+\gamma(n-1))^2} + 1} \tag{11}$$

Assumption 2.2. *Optimal emission tax in the pre-merger market is strictly positive.*

For assumption 2.2 to hold the marginal damage from industry pollution should be higher than a given threshold φ'_0, that is $\varphi' > \varphi'_0$, where $\varphi'_0 = (\alpha-c)\beta\delta/(2\beta+(n-1)\gamma)(2\beta+(n-1)\gamma+\delta^2)$. This holds because absent other policies to control for the oligopoly distortion, the emission tax targets to reduce distortion as well as environmental damages. With $\varphi' > \varphi'_0$ environmental damages are higher than the output distortion and the government uses the positive optimal tax to tackle pollution.

The optimal tax is related to the industry's product differentiation,γ, as follows:

$$\frac{dt}{d\gamma} = \frac{\beta(n-1)\delta(\alpha - c - \delta\varphi')(4\beta + 2n\gamma - 2\gamma + \delta^2)}{[4\beta^2 + \gamma^2(n-1)^2 + \gamma(n-1)\delta^2 + \beta(4\gamma(n-1) + \delta^2)]^2} \tag{12}$$

where $dt/d\gamma < 0$ if $\varphi' > \varphi'_1$ where $\varphi'_1 = (\alpha - c)/\delta > \varphi'_0$. This condition implies that higher product differentiation increases the optimal tax rate. This is consistent with Fujiwara (2009). Intuitively, this is because higher product differentiation leads to higher output ($\partial q/\partial\gamma < 0$) and so higher taxes are required to reduce the resulting environmental externality. In the remainder of the paper we assume $\varphi' > \varphi'_1$ so that $dt/d\gamma < 0$ holds.

2.2 Post-merger equilibrium

This sub-section considers the case where two firms, say firm 1 and firm 2, merge. We assume that only one merger deal takes place. The merged entity maintains both plants and two separate product lines. As a result, the Cournot-Nash equilibrium is given by the joint profit maximization of plant 1 and plant 2, and the profit maximization of the rest of the $n-2$ firms or "outsiders" (Salant et al., 1983). The merged entity which now owns two product lines maximizes joint profit according to:

$$\max_{q_1,e_1,q_2,e_2} \pi_1 + \pi_2 = [(p_1 - c)q_1 - (\delta_1 q_1 - e_1)^2/2 - e_1 t] + [(p_2 - c)q_2 - (\delta_2 q_2 - e_2)^2/2 - e_2 t] \quad (13)$$

where subscripts 1 and 2 denote, respectively, plant 1 and plant 2 owned by the merged entity. The first-order profit maximizing conditions are:

$$\frac{\partial(\pi_1 + \pi_2)}{\partial q_1} = p_1 - c - \delta_1(\delta_1 q_1 - e_1) - \beta q_1 - \gamma q_2 = 0 \quad (14)$$

$$\frac{\partial(\pi_1 + \pi_2)}{\partial e_1} = \delta_1 q_1 - e_1 - t = 0 \quad (15)$$

$$\frac{\partial(\pi_1 + \pi_2)}{\partial q_2} = p_2 - c - \delta_2(\delta_2 q_2 - e_2) - \beta q_2 - \gamma q_1 = 0 \quad (16)$$

$$\frac{\partial(\pi_1 + \pi_2)}{\partial e_2} = \delta_2 q_2 - e_2 - t = 0 \quad (17)$$

where these state that marginal revenue equals marginal cost, and the tax is equal to marginal abatement cost. Unlike the pre-merger case, the post-merger first-order conditions indicate that firms 1 and 2 internalize the degree of product differentiation by colluding. This implies that the merged entity accounts for the external effect associated to the demand function to the extent permitted by the level of product differentiation, thereby having the ability to raise profits by restricting output and setting higher prices.

The outsider firms each maximize profit by solving

$$\max_{\tilde{q}_i,\tilde{e}_i} \tilde{\pi}_i = [(\tilde{p}_i - c)\tilde{q}_i - (\delta_i \tilde{q}_i - \tilde{e})^2/2 - \tilde{e}_i t] \text{ where } i = 3, ..., n \quad (18)$$

where $\tilde{\pi}$, $\tilde{q}$ and $\tilde{e}$ denote, respectively, profit, output and emission of outsiders. Symmetry implies that $\delta_1 = \delta_2 = \delta$, and $p_1 = \alpha - \beta q_1 - \gamma q_2 - \gamma(n-2)\tilde{q}$, $p_2 = \alpha - \beta q_2 - \gamma q_1 - \gamma(n-2)\tilde{q}$, and $\tilde{p} = \alpha - \beta\tilde{q} - \gamma(q_1 + q_2) - \gamma(n-3)\tilde{q}$.

The closed-form solutions are given by

$$q_1 = q_2 = \frac{(2\beta - \gamma)(\alpha - c - \delta t)}{2(2\beta^2 + \beta\gamma(n-1) - \gamma^2)} \tag{19}$$

$$\tilde{q} = \frac{\beta(\alpha - c - \delta t)}{2\beta^2 + \beta\gamma(n-1) - \gamma^2} \tag{20}$$

$$\pi_1 + \pi_2 = 2(\beta + \gamma)(q_1)^2 + t^2 \tag{21}$$

where $\pi_1 + \pi_2$ is joint profit for the merged entity. Based on equation (21) an increase in product differentiation (decline in γ) increases the merged entity's profit (for given tax). There are two opposite effects. First, a decline in γ increases the merged entity's profit by increasing its market share and hence market power (Fujiwara, 2009). Second, as γ approaches zero (β), the slope of marginal revenue of the merged entity approaches (becomes twice as steep as) its pre-merger value.[3] Hence, the merged entity's ability to raise profit by restricting output post-merger will decrease (increase).

The merger occurs as long as the joint profit post-merger is higher than the sum of individual profits pre-merger, that is $\pi_1 + \pi_2 - 2\pi > 0$. Furthermore, firms contemplating a merger also take into account the induced change in optimal policy. That is, if the government is not passive it will recalculate optimal policy in the post-merger market by solving

$$\max_t W = CS(q_1 + q_2 + (n-2)\tilde{q}) + \pi_1 + \pi_2 + (n-2)\tilde{\pi} + \\ e_1 t + e_2 t + (n-2)\tilde{e}t - \varphi(e_1 + e_2 + (n-2)\tilde{e}) \tag{22}$$

where $(n-2)\tilde{\pi}$ denotes the sum of profits of the outsider firms, $(n-2)\tilde{q}$ denotes the sum of output of the outsider firms. Additionally, by assumption the damage function is identical

[3] The slope of marginal revenue for the merged entity with respect to output is $-2(\beta + \gamma)$. Pre-merger the slope of marginal revenue for each firm i is -2β. When $\gamma = 0$ the two slopes become identical.

across the pre- and post-merger markets to facilitate comparison across the two markets in section 2.3.

The optimal policy in the post-merger market is given as t_m where (please see Appendix B for detailed steps),

$$t_m = \varphi' - \frac{2q_1(\beta+\gamma)\frac{\partial q_1}{\partial t_m} + (n-2)\beta\tilde{q}\frac{\partial \tilde{q}}{\partial t_m}}{2\delta(\partial q_1/\partial t_m) + (n-2)\delta(\partial \tilde{q}/\partial t_m) - n} \tag{23}$$

where $\partial q_1/\partial t_m = -\delta(2\beta-\gamma)/2(2\beta^2+\beta\gamma(n-1)-\gamma^2) < 0$ and $\partial\tilde{q}/\partial t_m = -\delta\beta/(2\beta^2+\beta\gamma(n-1)-\gamma^2) < 0$. The second term on the right-hand side of equation (23) captures the output distortion arising from the merged entity and outsiders. The closed form solution for the optimal tax post-merger is solved as:

$$t_m = \frac{\eta\varphi' - (\alpha-c)\delta(2\beta^3 n - 3\beta\gamma^2 + \gamma^3)}{\eta - \delta^2(2\beta^3 n - 3\beta\gamma^2 + \gamma^3)} \text{ where } \eta > 0 \tag{24}$$

where $\eta = 2[2\beta^2 + (n-1)\beta\gamma - \gamma^2][2n\beta^2 + n\beta(\gamma(n-1)+\delta^2) - \gamma(n\gamma+\delta^2)]$. For any given $n > 2$, $t_m > 0$ if $\varphi' > \varphi_2'$ where $\varphi_2' = \delta(\alpha-c)(2n\beta^3 - 3\beta\gamma^2 + \gamma^3)/\eta$. We find that $\varphi_1' > \varphi_2'$ which implies that as long as $\varphi' > \varphi_1'$ the post-merger optimal policy is positive.

We perform the following comparative analysis using the post-merger policy

$$\frac{dt_m}{d\gamma} = 2\delta(\alpha - c - \delta\varphi')\frac{J}{D^2} \tag{25}$$

where for any given n, $J > 0$.[4] Thus, $dt_m/d\gamma < 0$ under the given assumption of positive tax. Similar to the pre-merger case, a higher product differentiation leads to a higher tax required to reduce the environmental externality resulting from more output. In addition, the following will prove helpful in subsequent sections:

$$\frac{dt_m}{d\delta} = \frac{(\alpha-c)a_0 + \varphi'\delta a_1}{(a_2)^2} \tag{26}$$

[4] $J = 8\beta^6 n^2(n-1) + n\gamma^6 - 4\beta^4 n\gamma(6\gamma - 6n\gamma + 3\gamma n^2 + 2\delta^2(n-2)) + \beta^3\gamma^2(8n\gamma - 6\delta^2 - 3n\delta^2 + 3n^2\delta^2) + 2n\beta^5(n-2)(-6\gamma + 2\gamma n^2 + \delta^2(n+1)) + 2\beta\gamma^4(-2\delta^2 - 3\gamma n + n\delta^2) + \beta^2\gamma^3(-\gamma n^3 + 4\delta^2 + 8\gamma n^2 - 2\delta^2 n^2 - 3\gamma n + 2n\delta^2)$ and $D = 8\beta^3 n(\beta + \gamma(n-1)) + \delta^2[2\beta^3 n + \gamma^3 - \beta\gamma^2(4n-5) - 2\beta^2\gamma(n+1)(n-2)] + \gamma^2 n[2\beta^2(n+1)(n+3) - 4\beta\gamma(n-1) + 2\gamma^2]$.

where $a_1 = 4n(2\beta^2+\beta\gamma(n-1)-\gamma^2)^2(2\beta^3 n-3\beta\gamma^2+\gamma^3) > 0$ and $a_0 = -(2\beta^3 n-3\beta\gamma^2+\gamma^3)(a_2)$.[5] Under the given assumptions (i.e. $\varphi' > \varphi'_1$ and $t_m > 0$) we find $dt_m/d\delta > 0$. This is intuitive since a higher pollution intensity triggers a larger tax rate than a lower pollution intensity.

2.3 Comparing pre- and post-merger outcomes

In making comparisons between the pre-merger and post-merger markets, we accommodate for a potential exogenous change in pollution intensity in the post-merger market. The potential change in pollution intensity, if it takes place post-merger, occurs after the deal has been established. This is because specific integration plans are usually solidified after the deal closes (Pwc, 2011). So, the potential difference across δ is imposed after the equilibrium in each scenario (i.e., pre-merger and post-merger) is calculated. This enables us to examine under which conditions merged entities benefit better from the proposed deal. Let δ represent pollution intensity in the pre-merger market as before; and δ_m represents pollution intensity in the post-merger market. Expressions for output levels are re-written here for completeness:

$$q_1 = q_2 = \frac{(2\beta-\gamma)(\alpha-c-\delta_m t_m)}{2(2\beta^2+\beta\gamma(n-1)-\gamma^2)} \tag{27}$$

$$\tilde{q} = \frac{\beta(\alpha-c-\delta_m t_m)}{2\beta^2+\beta\gamma(n-1)-\gamma^2} \tag{28}$$

$$q = \frac{\alpha-c-\delta t}{2\beta+\gamma(n-1)} \tag{29}$$

Hence, for $\beta > \gamma > 0$ (i) $q_1 < \tilde{q}$, (ii) if $t_m \leq t$ and $\delta_m \leq \delta$ then $\tilde{q} > q$ and (iii) if $t_m = t$ and $\delta_m = \delta$ we find that $q_1 < q$ which is consistent with Qiu and Zhou (2006). In words, the outsiders produce more than one of the plants of the merged entity and also more than their pre-merger output levels. A single plant of the merged entity produces less than it used to in the pre-merger market. The reduction in output post-merger by the merged entity reflects output coordination in order to push the market price upwards.

[5] $a_2 = 2\beta^3 n(4\beta+1)[4(n-1)\gamma+\delta^2] + \gamma^3(2n\gamma+\delta^2) + \beta\gamma^2(5\delta^2-4n^2\gamma+4n\gamma-4n\delta^2) + 2\beta^2\gamma(n+1)[n^2\gamma-2\delta^2-3n\gamma+n\delta^2] > 0$

Industry output in the pre- and post-merger markets are, respectively, given by

$$qn = \frac{(\alpha - c - \delta t)n}{2\beta + \gamma(n-1)} \tag{30}$$

$$q_1 + q_2 + (n-2)\tilde{q} = \frac{(\beta n - \gamma)(\alpha - c - \delta_m t_m)}{2\beta^2 + \beta\gamma(n-1) - \gamma^2} \tag{31}$$

If $t_m = t$ and $\delta_m = \delta$, we find that the industry output pre-merger is higher than the industry output post-merger. Thus, a merger reduces industry output and increases price which is the usual market power motive for merger (Trautwein, 1990).

In order to compare the pre- and post-merger optimal policies, we find the sign of equation (9) evaluated at t_m. To do this we substitute the expression of $t_m - \varphi'$ from equation (23) into equation (9). Based on equation (23) $t_m - \varphi' < 0$. We assume that the welfare function is strictly concave. A positive (negative) sign of (9) indicates $t_m < t$ ($t_m > t$). In particular, from (9) we obtain

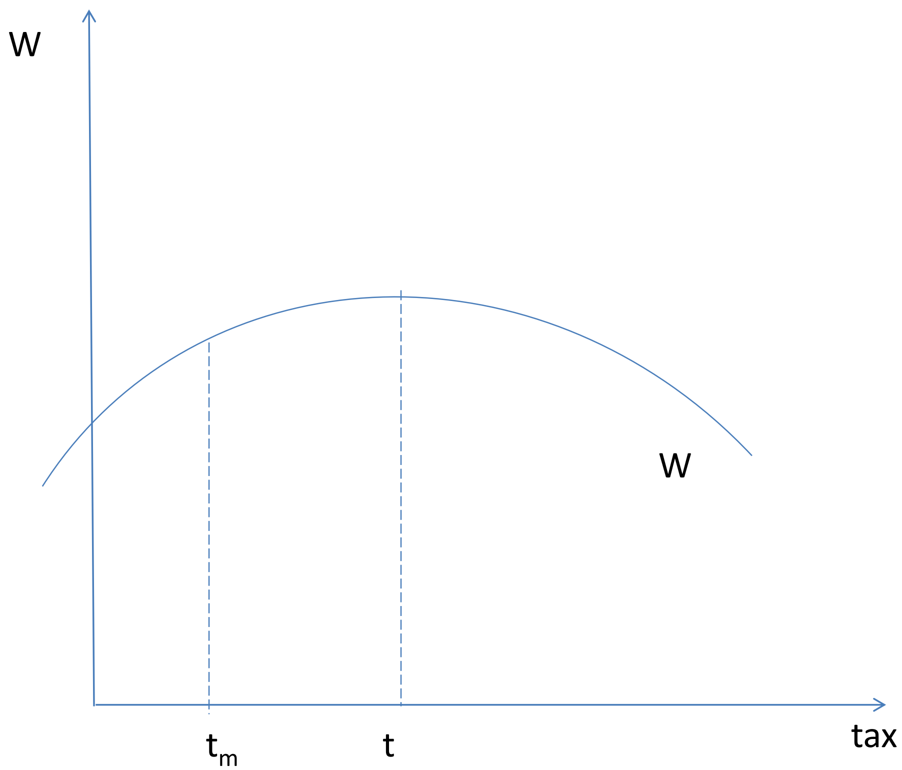
$$\left.\frac{\partial W}{\partial t}\right|_{t_m} = n\beta q \frac{\partial q}{\partial t} - \left(\frac{2q_1(\beta+\gamma)\frac{\partial q_1}{\partial t_m} + (n-2)\beta\tilde{q}\frac{\partial \tilde{q}}{\partial t_m}}{2\delta_m(\partial q_1/\partial t_m) + (n-2)\delta_m(\partial \tilde{q}/\partial t_m) - n} \right) n \frac{\partial e}{\partial t} \tag{32}$$

where $2\delta_m(\partial q_1/\partial t_m) + (n-2)\delta_m(\partial \tilde{q}/\partial t_m) - n < 0$ and $\partial e/\partial t = \delta(\partial q/\partial t) - 1 < 0$. Multiplying both sides by $-[2\delta_m(\partial q_1/\partial t_m) + (n-2)\delta_m(\partial \tilde{q}/\partial t_m) - n]$ and collecting terms gives

$$\begin{aligned} -\psi \left.\frac{\partial W}{\partial t}\right|_{t_m} &= 2n \frac{\partial q}{\partial t}\frac{\partial q_1}{\partial t_m}\left[\delta q_1(\beta+\gamma) - \delta_m \beta q\right] \\ &\quad + n(n-2)\delta\beta \frac{\partial q}{\partial t}\frac{\partial \tilde{q}}{\partial t_m}\left[\tilde{q}\delta - q\delta_m\right] \\ &\quad - n\left[2(\beta+\gamma)q_1 \frac{\partial q_1}{\partial t_m} + (n-2)\beta\tilde{q}\frac{\partial \tilde{q}}{\partial t_m} - n\beta q \frac{\partial q}{\partial t}\right] \end{aligned} \tag{33}$$

where $\psi = -(2\delta_m(\partial q_1/\partial t_m) + (n-2)\delta_m(\partial \tilde{q}/\partial t_m) - n) < 0$. The first two terms capture the effect of damages from pollution and the extent to which the post-merger tax should be less or greater than the pre-merger tax. The third term represents the abatement induced by the tax.

Figure 1: Pre- and post-merger emission tax



If the pre-merger pollution intensity is relatively large (i.e., $\delta > \delta_m$) and if $\beta q \partial q/\partial t$ in the last term of equation (33) is small, then the expression in (33) is positive implying that $t_m < t$, $\forall \gamma \in [0, \beta]$. This is because a sufficiently large pollution intensity in the pre-merger market, along with the abatement induced by the tax (third term in equation (33)), results in a higher pre-merger tax. Even if $\delta < \delta_m$, then $t_m < t$ holds if the third term in equation (33) and the second term in equation (33) are large enough. Figure 1 illustrates this result.

The only case where equation (33) turns negative is if δ is sufficiently small and the third term in equation (33) is sufficiently small. In this case $t_m > t$ since a sufficiently small pollution intensity in the pre-merger market, along with small abatement induced by the tax in the post-merger market (third term in equation (33)) induces the government to set a relatively higher tax in the post-merger market.

Proposition 2.3 addresses the first research question of what the effect of mergers could be on the optimally set emission tax under the given model framework.

Proposition 2.3. *Mergers result in lower optimal emission tax post-merger (i.e., $t_m < t$) as long as the post-merger pollution intensity, δ_m, is sufficiently small and/or abatement induced by the post-merger tax is sufficiently large and positive.*

2.4 Profitability of merger

We define $\Delta = \pi_1 + \pi_2 - 2\pi$ as the *profitability of the merger*; the merger occurs as long as $\Delta > 0$. Gelves (2014) defines Δ as the incentive to merge in a differentiated market. An increase in Δ represents a more attractive merger deal whereas a decline in Δ represents a less attractive merger deal. In particular,

$$\begin{aligned}\Delta &= 2(\beta+\gamma)(q_1)^2 + (t_m)^2 - 2\beta q^2 - t^2 \\ &= 2(\beta+\gamma)\left(\frac{(2\beta-\gamma)(\alpha-c-\delta_m t_m)}{2(2\beta^2+\beta\gamma(n-1)-\gamma^2)}\right)^2 + {t_m}^2 - 2\beta\left(\frac{\alpha-c-\delta t}{2\beta+\gamma(n-1)}\right)^2 - t^2 \qquad (34)\end{aligned}$$

It is noteworthy that in general the sign of (34) is ambiguous; whether $\Delta < 0$ or $\Delta > 0$ depends upon parameter values $\beta \geq \gamma \geq 0$, differences in tax payments, δt and $\delta_m t_m$, and differences in abatement effects between the pre- and post-merger markets, t^2 and t_m^2. If we assume away these differences in taxes, pollution intensities, and abatement effects our results would be similar to Qiu and Zhou (2006), thereby motivating the analysis of the role of taxes and pollution intensities in explaining conditions which yield positive profitability.

In order to address the second and third research questions we consider two cases both of which imply an exogenous change in pollution intensity in the post-merger market. First, a change in pollution intensity of the post-merger market is caused by modification of production technology or process. The post-merger pollution intensity is represented by a constant δ_m, whereas the pre-merger pollution intensity is δ. The implication of cases like, $\delta = \delta_m$, $\delta < \delta_m$ and $\delta > \delta_m$ will be examined in section 3 because they have a crucial impact on profits. For example, for a given level of tax, a relatively large pollution intensity leads to lower output and hence lower profit.

Second, a change in pollution intensity of the post-merger market is caused by modification of products to be more environmentally friendly. Firms can modify product content, characteristics or packaging to minimize environmental impact. For instance, a disinfectant manufacturer could modify products by excluding the use of toxic reactants which would significantly reduce the manufacturer's pollution intensity (EPA Website, 2015). In this case, the pollution intensity will no longer be a constant, but rather a function of γ. In particular, $\delta(\gamma)$ denotes pollution intensity in the pre-merger market where $d\delta(\gamma)/d\gamma = 0$; and $\delta_m(\gamma)$ is pollution intensity in the post-merger market where $d\delta_m(\gamma)/d\gamma = \delta'_m \geq 0$. If $\delta'_m > 0$, the merged entity becomes cleaner (environmentally conscious) post-merger by differentiating its product. The exogenous change in γ can be thought of as a change in the type of market; specifically, a market which becomes more differentiated as firms become environmentally conscious. It is noteworthy that because we are considering two different sets of firms (i.e., firms in the pre- and post-merger markets) the change in market conditions may affect firms across the two sets differently. This set-up allows us to focus on the analysis of product differentiation and merger profitability via the environmentally conscious (merged) firm, but also to account for the potential impact of product differentiation via optimal policy as market conditions change.

With these two cases in mind, we present the following general functional forms to study the effect of an exogenous change in γ on the profitability of a merger (Gelves, 2014): $\delta_m(\gamma)$, $t_m(\gamma, \delta_m(\gamma))$, $q_1(\gamma, \delta_m(\gamma), t_m(\gamma, \delta_m(\gamma))$, $t(\gamma)$ and $q(\gamma, t(\gamma))$. Differentiation of Δ with respect to γ gives

$$\frac{d\Delta}{d\gamma} = 2(q_1)^2 + 4(\beta + \gamma)q_1\frac{dq_1}{d\gamma} - 4\beta q\frac{dq}{d\gamma} + 2t_m\frac{dt_m}{d\gamma} - 2t\frac{dt}{d\gamma} \quad (35)$$

where

$$\frac{dq_1}{d\gamma} = \frac{\partial q_1}{\partial t_m}\frac{dt_m}{d\gamma} + \frac{\partial q_1}{\partial \gamma} + \frac{\partial q_1}{\partial \delta_m}\delta'_m \tag{36}$$

$$\frac{dq}{d\gamma} = \frac{\partial q}{\partial t}\frac{dt}{d\gamma} + \frac{\partial q}{\partial \gamma} \tag{37}$$

and where $\partial q_1/\partial\gamma < 0$, $\partial q/\partial\gamma < 0$, $\partial q_1/\partial t_m < 0$, $\partial q_1/\partial\delta_m < 0$, $\partial q/\partial t < 0$, $\partial t_m/\partial\gamma < 0$, $\partial t_m/\partial\delta_m > 0$ and $dt/d\gamma < 0$ have been shown before. We also have,

$$\frac{dt_m}{d\gamma} = \frac{\partial t_m}{\partial \gamma} + \frac{\partial t_m}{\partial \delta_m}\delta'_m \tag{38}$$

We assume that parameters β, n, α and c remain fixed. The effect of market size (β and α), number of firms and efficiency (c) have been studied elsewhere (Fikru and Lahiri, 2014; Fauli-Oller, 2002; Huck et al., 2004). Despite the growing number of studies on the effect of product differentiation on mergers (e.g., Qiu and Zhu, 2006; Gelves, 2014) none have accounted for a possible change in product, process and policy in the post-merger market.

There are four major channels through which a change in γ affects profitability, Δ. First, given taxes and pollution intensity (i.e., $dt/d\gamma = 0, dt_m/d\gamma = 0, \delta'_m(\gamma) = 0$), a decrease in γ (higher degree of product differentiation) increases market power, which in turn increases profits both in the pre- and post-merger markets. A decrease in γ also limits the merged entity's ability to coordinate output in order to raise post-merger profit (please see equation (21)). The net effect on Δ is ambiguous and is analyzed in section 3. This channel is presented as a benchmark model and results are consistent with Qiu and Zhou (2006).

Second, with given taxes (i.e., $dt/d\gamma = 0, dt_m/d\gamma = 0$) and $\delta'_m(\gamma) > 0$ a decrease in γ decreases $\delta_m(\gamma)$. A decrease in the post-merger pollution intensity, $\delta_m(\gamma)$, affects the merged entity's profit in two ways. First, a decline in $\delta_m(\gamma)$ increases post-merger production and hence post-merger profit. This is presented in section 4.1 and the net effect on Δ is discussed. Second, a decrease in $\delta_m(\gamma)$ decreases t_m. A decline in t_m affects the merged entity's post-merger profit in two opposite ways: decreases profit through the abatement effect and increases profit through lower tax payments. This second case is discussed in section 4.2.

Third, with a constant pollution intensity post-merger (i.e., $\delta_m'(\gamma) = 0$), a decrease in γ leads to an increase in optimal taxes pre- and post-merger (i.e., $dt/d\gamma < 0$ and $dt_m/d\gamma < 0$). An increase in optimal taxes has two opposite effects on pre- and post-merger profits: profits increase through the abatement effect and decrease through tax payments. The net effect on Δ via this channel is investigated in section 4.3.

Fourth, the case where all channels are operating at the same time is examined. This general case is presented in section 4.4. Because of the intricacy of the model it is hard to find clear-cut conditions in which product differntiation increases or decreases the profitability of the proposed merger. Hence, one has to isolate reasonable cases which involve different combinations of the pollution intensity parameters (δ and δ_m), optimal tax rates (t and t_m) and abatement effects (t^2 and t_m^2) in the pre- and post-merger markets.

3 Merged Entity and Cleaner Technology

In this section we examine how differences between the pre- and post-merger pollution intensity potentially affect merger profitability. Throughout this section we assume that $\delta_m'(\gamma) = 0$, $dt_m/d\gamma = 0$ and $dt/d\gamma = 0$. Even though there are a myriad of cases, we present a few while keeping in mind that the post-merger tax is relatively smaller, i.e., $t_m < t$.

Rewriting equation (35) by assuming $\delta_m'(\gamma) = 0$, $dt_m/d\gamma = 0$ and $dt/d\gamma = 0$ we get:

$$\begin{aligned} \frac{d\Delta}{d\gamma} &= \left[2(q_1)^2 + 4(\beta+\gamma)q_1\frac{dq_1}{d\gamma}\right] - 4\beta q\frac{dq}{d\gamma} \\ &= \left[-2(q_1)^2\lambda\right] + \frac{4\beta q^2(n-1)}{2\beta+\gamma(n-1)} \end{aligned} \tag{39}$$

whence,

$$\lambda = \frac{3\gamma(2\beta^2 + \beta\gamma(n-1) - \gamma^2) + 2(\beta+\gamma)(2\beta-\gamma)(\beta(n-1) - 2\gamma)}{(2\beta-\gamma)(2\beta^2 + \beta\gamma(n-1) - \gamma^2)} > 0 \tag{40}$$

$$\frac{dq_1}{d\gamma} = \frac{-q_1[2\beta^2 + \beta\gamma(n-1) - \gamma^2 + (2\beta-\gamma)(\beta(n-1) - 2\gamma)]}{(2\beta-\gamma)(2\beta^2 + \beta\gamma(n-1) - \gamma^2)} < 0 \tag{41}$$

$$\frac{dq}{d\gamma} = \frac{-q(n-1)}{2\beta + \gamma(n-1)} < 0 \tag{42}$$

Equations (40)-(42) imply that higher product differentiation increases pre- and post-merger profit, thereby making the sign of (39) ambiguous. This is because pre-merger profit rises with a decrease in γ, thereby lowering profitability because $-4\beta q dq/d\gamma > 0$ (Fujiwara, 2009). Analogously, a decline in γ raises the merged entity's profit, thereby raising profitability. There are two opposite effects at play here: the merged entity's profit rises due to more market power (i.e., $4(\beta+\gamma)q_1 dq_1/d\gamma < 0$) and declines due to its inability to raise profit by restricting output post-merger (i.e., $2q_1^2 > 0$); this latter effect is because the slope of marginal revenue aligns with the pre-merger value (see footnote 3).

We examine the ambiguity of (39) by evaluating profitability at $\gamma = 0$ and, also, without any loss of generality at $\gamma = \beta = 1$:

$$\Delta|_{\gamma=0} = (q+q_1)(\delta t - \delta_m t_m) + t_m^2 - t^2 = \delta q t - t^2 - \delta_m q_1 t_m + t_m^2 + q_1\delta t - q\delta_m t_m \tag{43}$$

$$\left.\frac{d\Delta}{d\gamma}\right|_{\gamma=0} = (n-1)(q+q_1)(-\delta t + \delta_m t_m)/\beta \tag{44}$$

$$\Delta|_{\gamma=\beta} = \frac{(n+1)^2(\alpha - c - \delta_m t_m)^2 - 2n^2(\alpha - c - \delta t)^2}{n^2(n+1)^2} + t_m^2 - t^2; \quad 2n^2 > (n+1)^2 \tag{45}$$

$$\left.\frac{d\Delta}{d\gamma}\right|_{\gamma=\beta} = \frac{4n^3(n-1)(\alpha - c - \delta t)^2 - (n+1)(n-2)(\alpha - c - \delta_m t_m)^2}{n^3(n+1)}; \frac{4n^3(n-1)}{(n+1)(n-2)} > 1 \tag{46}$$

where the terms t^2 and t_m^2 in (43) and (45) denote, respectively, the abatement effect in the pre- and post-merger equilibrium. t^2 and t_m^2 enter negatively and positively into the Δ function, respectively. The terms δt and $\delta_m t_m$ denote the level of tax payments under the pre- and post-merger equilibrium, respectively.

Using expressions (43) through (45) as the backbone for the analysis we consider two cases. In section 3.1 we present the case where $\delta_m \leq \delta$ and section 3.2 discusses the possibility where $\delta_m > \delta$. Using these two cases we illustrate how the net effect of product differentiation on the profitability of a merger depends on the merged entity's post-merger adoption of cleaner technology. We also show how results depend upon differences in the pre- and post-merger markets in terms of abatement effects, relative size of the pollution intensity and tax levels. In both sections 3.1 and 3.2 we assume $dt_m/d\gamma = 0$, $dt/d\gamma = 0$, $\delta'_m(\gamma) = 0$, and $t_m < t$.

As a general remark we first state that for $\gamma \in [0, \beta]$ profitability, Δ, is more likely to be positive if the abatement effect of the merged firm, t_m^2, is sufficiently large and its pollution intensity, δ_m, sufficiently small. This is because a large t_m^2 and small δ_m raise profit of the merged entity in relation to pre-merger profits. This is apparent by inspection of (43), (45) and (34).

Remark 3.1. *For any degree of product differentiation $\gamma \in [0, \beta]$ profitability is positive for sufficiently small post-merger pollution intensity, δ_m, and sufficiently large abatement effect post-merger.*

3.1 Pollution intensity is not higher post-merger, $\delta_m \leq \delta$

Consider the case where $\delta_m = \delta$ and (i) $\Delta|_{\gamma=0} > 0, \quad if \quad t_m^2 - t^2 \quad small$; (ii) $\Delta|_{\gamma=\beta=1} < 0, \quad if \quad t_m < t \quad small$; and (iii) evaluated at $\gamma = 0$, $d\Delta/d\gamma < 0$. As a result, there is a $0 < \hat{\gamma} < \beta = 1$ such that $\Delta = 0$. This means there is a range of γ for which profitability, Δ, may be positive or negative. The key aspect driving this result is twofold. First, since the difference in the abatement effect is negligible, where $t_m^2 - t^2$ is small, and because pollution intensities are assumed to be identical, differences in profits pre- and post-merger, and therefore profitability, arise from different taxes paid as stated in (ii). In particular, the merged entity pays a lower tax post-merger which increases its profit post-merger. Second, differences in profits pre- and post-merger also depend on the degree of product differentiation.

In very differentiated markets (i.e., $\gamma \simeq 0$) both pre- and post-merger profits rise due to market power, but the merger deal is profitable (i.e., post-merger profit exceeds pre-merger profits) because the net effect on the merged entity's profit is higher due to the smaller tax, t_m. Markets with very differentiated products allow for relatively more market power and higher profits for the merged entity. If goods are almost completely homogeneous ($\beta \simeq \gamma$), then both pre- and post-merger firms enjoy less market power and lower profits. Even if the merged entity's marginal revenue is steeper, the net effect on its profit is less since the merged entity pays a lower tax. As a result consistent with Qiu and Zhou (2006) the merger deal is less profitable for homogenous goods.

If the abatement effect in the pre-merger equilibrium is sufficiently large (i.e., in contrast to (i) the difference $t_m^2 - t^2 < 0$ is large), then profitability, Δ, is non-positive in very differentiated markets (also, keep in mind that since pollution intensities are identical in this case their role is negligible). Formally, the expression in (43) is negative and the expression in (44) is negative. This is because a relatively large abatement effect in the pre-merger market renders pre-merger profit higher than post-merger profit. In this case, a smaller post-merger pollution intensity, δ_m, is crucial to raise profitability for very differentiated markets.

Another case of interest where a smaller post-merger pollution intensity, δ_m, is crucial to raise profitability is where tax rates are similar to each other ($t_m \simeq t$). In this case the difference in pre- and post-merger abatement effect induced by differences in taxes is negligible (e.g., the last term in (43) and (45) is negligible). As a result, chances of a profitable merger deal in very differentiated markets become small unless differences in pollution intensity between the pre- and post-merger markets are present where δ_m is sufficiently small.

When $\delta_m < \delta$, the possibility of positive profitability in very differentiated markets is enhanced because a smaller δ_m means that tax payments increase to a lesser extent for the merged entity. This is particularly the case if differences in abatement effect are small (i.e., $t_m^2 - t^2$ is small). If so, and if the difference between δ_m and δ is large then merger profitability arises mainly from the difference in tax payments between the pre- and post-merger markets. In contrast, if the difference in abatement effect is large (i.e., $t_m^2 - t^2 < 0$ is large), then profitability is likely to be non-positive, thereby suggesting an important role for a smaller δ_m in order to raise profitability.

3.2 Pollution intensity is higher post-merger, $\delta_m > \delta$

If pollution intensity post-merger, δ_m, is sufficiently large, then profitability becomes negative for very differentiated products. This is because (a) tax payments of the merged entity rise relatively more and (b) pre-merger profits are larger due to a relatively higher abatement effect, i.e., $t_m^2 < t^2$. Thus, with a sufficiently large δ_m, profitability declines via higher tax payments post-merger and higher abatement effect pre-merger as γ becomes smaller.

We summarize the result obtained from this section as a proposition.

Proposition 3.2. *The attractiveness of a merger deal increases with the increase in product differentiation when the merged entity is relatively less pollution-intensive post-merger than pre-merger.*

4 Merged Entity and Modified Product

In this section we examine the potential role an environmentally conscious firm in the post-merger equilibrium may have on profitability. This is captured by assuming a function $\delta_m = \delta_m(\gamma)$, where $d\delta_m/d\gamma = \delta_m'(\gamma) > 0$; the properties of the $\delta_m(\cdot)$ function are discussed in section 2.4. We re-write (35) along with (36)-(38):

$$
\begin{aligned}
\frac{1}{2}\frac{d\Delta}{d\gamma} &= (q_1)^2 + 2(\beta+\gamma)q_1\partial q_1/\partial\gamma - 2\beta q\partial q/\partial\gamma \\
&+ \frac{\partial t_m}{\partial\gamma}\left[2(\beta+\gamma)q_1\frac{\partial q_1}{\partial t_m} + t_m\right] - \frac{\partial t}{\partial\gamma}\left[2\beta q\frac{\partial q}{\partial t} + t\right] \\
&+ \delta_m'\left[2(\beta+\gamma)q_1\frac{\partial q_1}{\partial\delta_m} + \frac{\partial t_m}{\partial\delta_m}\left(2(\beta+\gamma)q_1\frac{\partial q_1}{\partial t_m} + t_m\right)\right] \qquad (47)
\end{aligned}
$$

The first line of equation (47) captures the effect discussed in the benchmark model presented in Section 3. The second line of equation (47) captures the effect of γ on Δ via changes in the taxes. The third line of equation (47) captures the effect of γ on Δ via reduction in the pollution intensity of the merged entity as products become more differentiated. In the remainder of this section we maintain $t_m < t$.

4.1 Case 1: $\partial t_m/\partial\gamma = 0$, $\partial t_m/\partial\delta_m = 0$, $\partial t/\partial\gamma = 0$ and $\delta_m'(\gamma) > 0$

In this case we can re-write equation (47) as follows:

$$
\begin{aligned}
\frac{d\Delta}{d\gamma} &= -2(q_1)^2\left[\frac{3\gamma(2\beta^2+\beta\gamma(n-1)-\gamma^2) + 2(\beta+\gamma)(2\beta-\gamma)(\beta(n-1)-2\gamma)}{(2\beta-\gamma)(2\beta^2+\beta\gamma(n-1)-\gamma^2)}\right] \\
&+ \frac{4\beta q^2(n-1)}{2\beta+\gamma(n-1)} - \frac{2(2\beta^2+\beta\gamma-\gamma^2)q_1 t_m}{2\beta^2+\beta\gamma(n-1)-\gamma^2}\delta_m' \qquad (48)
\end{aligned}
$$

where the last term is the effect on profitability via the effect of the environmentally conscious, merged entity. This expression is similar to (39) where $\partial t/\partial\gamma = 0$, $\partial t/\partial\delta_m = 0$ and $\partial t_m/\partial\gamma = 0$, except for the last term which is negative. This implies that post-merger profits rise because of the reduction in tax payments as a result of a smaller pollution intensity. Thus, relative to the analysis in section 3, $d\Delta/d\gamma$ tends to be more negative because of δ_m'. For example if $\delta_m = \delta$ then $d\triangle/d\gamma = (n-1)(q_1+q)(\delta_m t_m - t\delta)/\beta - q_1 t_m\delta_m'/\beta$ when $\gamma = 0$. The key difference between the current case and section 3 is that $d\triangle/d\gamma$ evaluated at $\gamma = 0$ and indeed at any γ yields a more negative item. The implication is that when the merged entity is environmentally conscious by changing product type, the effect of a unit decrease in γ on increasing the profitability of the merger is now much higher. This is because when the industry's product differentiation increases, the merged entity decreases its pollution intensity, δ_m, thereby getting more output and more profit post-merger. If $\delta_m \neq \delta$ then we also get results similar to those presented in section 3. As a policy implication, it is noteworthy that with sufficiently small δ_m becoming environmentally friendly by modifying products can make the merger deal more profitable in very differentiated markets.

4.2 Case 2: $\partial t_m/\partial\gamma = 0$, $\partial t_m/\partial\delta_m > 0$, $\partial t/\partial\gamma = 0$ and $\delta'_m(\gamma) > 0$

We refer to the last term, third line, in equation (47). The additional effect introduced in this case is the fall in post-merger tax when δ_m decreases with a decrease in γ. This is because a reduction in δ_m (due to a reduction in γ) results, on the one hand, in an increase in output and emissions and, on the other, in a reduction in emissions for a given level of output. With a small δ_m the former effect is smaller and thus tax falls with δ_m (i.e., $\partial t_m/\partial\delta_m > 0$). As long as the abatement effect on profits is small (the term $t_m(\partial t_m/\partial\delta_m) > 0$ in (47) is small), profitability rises with more product differentiation.

4.3 Case 3: $\partial t_m/\partial\gamma < 0$, $\partial t_m/\partial\delta_m = 0$, $\partial t/\partial\gamma < 0$ and $\delta'_m(\gamma) = 0$

The additional effect introduced in this case is the second line from equation (47). When $\delta'_m = 0$ and $\delta_m \neq \delta$, profitability rises with more differentiated products via the tax change if $t_m\partial t_m/\partial\gamma - t\partial t/\partial\gamma < 0$ is relatively large and δ_m is relatively small so that $-\delta_m(\partial t_m/\partial\gamma)(\beta+\gamma)2q_1/2(2\beta^2+\beta\gamma(n-1)-\gamma^2) < -\delta(\partial t/\partial\gamma)\beta 2q/(2\beta+\gamma(n-1))$. This is because a relatively large abatement via t_m and a relatively small δ_m raise profit of the merged entity. The relatively higher tax change resulting from product differentiation in the post-merger market works in favor of the profitability of the merger when δ_m is small enough (see proposition 3.2). In this case the increase in the merged entity's profit, due to product differentiation, is relatively larger since it takes place via the tax and the effect discussed in the benchmark model. As a policy implication, it is worth mentioning that profitability may be enhanced via policy.

The other possibility in which profitability rises with more differentiated products is if δ_m is small so that $2(\beta+\gamma)q_1\partial q_1/\partial t_m + t_m > 0$. Intuitively this is because the effect of a tax increase (due to lower γ) on the merged entity's tax payments is small with a small δ_m. Profitability can also rise with more differentiated products when δ is large so that $2\beta q\partial q/\partial t + t < 0$. Intuitively, this is because the effect of a tax increase (due to lower γ) on the tax payment of pre-merger firms is large (due to a large δ) hence reducing profits pre-merger.

Suppose the tax change is equal (i.e., $\partial t_m/\partial\gamma = \partial t/\partial\gamma = \mu < 0$), $\partial t_m/\partial\delta_m = 0$ and $\delta_m' = 0$. Equation (47) becomes

$$\Psi + \mu\left[2(\beta+\gamma)q_1\frac{\partial q_1}{\partial t_m} + t_m - 2\beta q\frac{\partial q}{\partial t} - t\right] \tag{49}$$

where $\mu < 0$ and $\Psi = (q_1)^2 + 2(\beta+\gamma)q_1\partial q_1/\partial\gamma - 2\beta q\partial q/\partial\gamma$ is the effect discussed in the benchmark model presented in section 3. As before, the sign of the term in squared brackets depends upon how pollution intensities and abatement effects compare. For example, if δ_m is relatively small and abatement induced by the tax across the two regimes is small, then the term in brackets is positive and so profitability rises via the proportional increase in the tax as products become more differentiated.

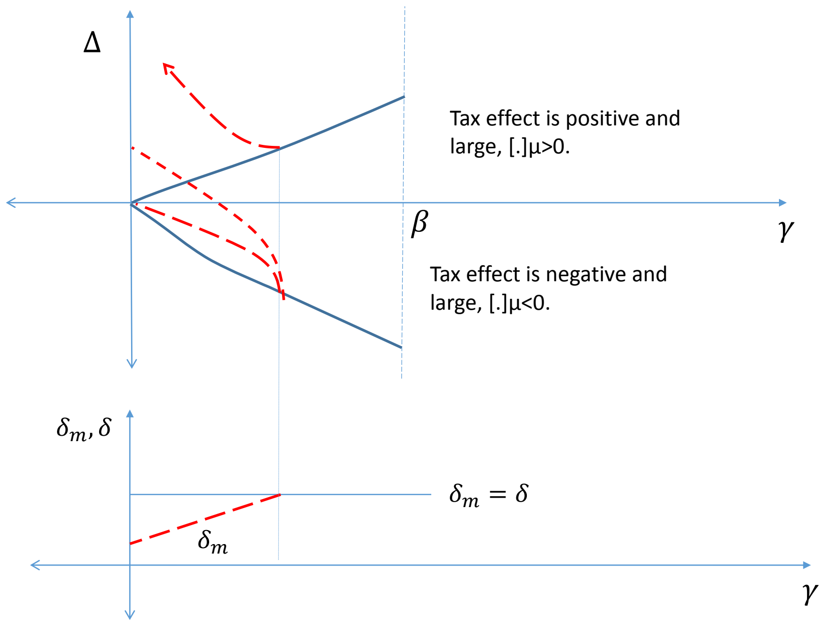
To analyze (49) more fully let's assume that differences in taxes, pollution intensities and abatement effects across the pre- and post-merger markets are negligible. That is, $\delta_m = \delta$, and (i) $(t_m)^2 - t^2$ small so that differences in abatement effect across the two markets is small, (ii) $t_m < t$ as shown before (iii) $t_m \simeq t$ which implies that even though t_m is less than t, the difference between the tax in the pre- and post-merger markets is small. Under (i)-(iii), at $\gamma \simeq 0$ we get $\Delta \simeq 0$ and (49) is close to $\Psi < 0$ since the term in squared brackets becomes very small, which is analogous to section 3.1. The reason the term in brackets $\mu[\cdot]$ becomes very small is threefold. First, very differentiated markets ($\gamma \simeq 0$)

reduce the ability of the merged entity to increase profits by restricting output (i.e., slope of marginal revenue pre- and post-merger is the same) and, as result, the effect of a tax increase on pre- and post-merger output and profit is similar since pollution intensities are identical (i.e., $2(\beta+\gamma)q_1(\partial q_1/\partial t_m) - 2\beta q(\partial q/\partial t) = 0$). Second, any difference in the pre- and post-merger abatement effect is negligible by (ii) and therefore t_m^2 and t^2 are trivial. Figure 2 shows that given $\delta_m = \delta$, as illustrated by the solid line in the lower plane, at $\gamma \simeq 0$ we have $\Delta \simeq 0$ and $d\Delta/d\gamma < 0$ in the upper plane. In this case the impact of a policy change does not seem to play a key role in increasing profitability when markets are very differentiated.

In the case where $\beta > \gamma > 0$ (and still under conditions *i-iii*), the term in squared brackets in (49) is positive *if and only if* $(\beta+\gamma)(2\beta-\gamma)^2(2\beta+\gamma(n-1))^2 < 4\beta(2\beta^2 + \beta\gamma(n-1) - \gamma^2)^2$; that is, if pre-merger profit falls sufficiently with a tax increase compared to the effect on the merged entity's profit. So, for given $\mu < 0$, profitability rises with more differentiated products if the effect via the tax is large: as products become more differentiated the government raises the tax to address higher levels of pollution and this increase in the tax has a relatively large profit-reducing effect pre-merger (i.e., the term $2\beta q(\partial q/\partial t) + t$ is negative and relatively large), thereby raising profitability. Analogously, if the effect on pre-merger profit via the tax is relatively small then the term in brackets is negative and, therefore, profitability falls with more differentiated products.

Now, at the other extreme case where $\beta \simeq \gamma$, as in section 3.1 we get $\Delta < 0$, $\Psi > 0$, and the term in squared brackets is positive. Thus, the expression in (49) is negative if the tax effect is sufficiently large, that is $\mu[\cdot] < 0$ and large. Figure 2 illustrates this by showing that when γ is close to β, $\Delta < 0$ and $d\Delta/d\gamma < 0$ if the tax effect is large. This indicates that profitability rises with more differentiated products. The intuition is as follows. First, when goods are homogeneous profitability is negative ($\Delta < 0$) as explained in section 2.4. Second, pre-merger profit falls sufficiently more with a tax increase compared to the effect on the merged entity's profit (and so the term in squared brackets is positive). This is because when goods are homogeneous the merged entity exhibits a relatively steeper marginal revenue and,

Figure 2: $dt/d\gamma < 0$ and $dt_m/d\gamma < 0$; profitability and changes in profitability



as a result, an increase in tax has a smaller effect on its output and profits. In this case the role of a policy change is important in increasing profitability, particularly in markets where goods are homogeneous.

4.4 Case 4: $\partial t_m/\partial\gamma < 0$, $\partial t_m/\partial\delta_m > 0$, $\partial t/\partial\gamma < 0$ and $\delta_m'(\gamma) > 0$

This sub-section presents the most general case where a change in γ changes t_m, t, and δ_m; a change in δ_m also changes t_m as shown by equation (47). Combining these effects, profitability is more likely to rise in the case where δ_m is small as a long as the tax adjustment via δ_m is small i.e., $\partial t_m/\partial\delta_m > 0$ small. This is because a tax increase is more likely to raise the merged entity's profits through a large abatement effect and so profitability rises via $\partial t_m/\partial\gamma$ and $\partial t/\partial\gamma$. If $\partial t_m/\partial\delta_m > 0$ is small when δ_m is small, the merged entity's profit will not be hurt too much. Furthermore, from equation (47) one can see that profitability is more likely to rise with increasing product differentiation as long as the abatement induced by tax is positive and large (i.e., $4(\beta+\gamma)q_1\partial q_1/\partial t_m + t_m > 0$), and the pre-merger abatement via tax, t, is small, i.e.,$-2\beta q\partial q/\partial t - t > 0$. The role of $\delta'_m > 0$ is illustrated in Figure 2 where the dashed lines on the upper plane indicate the Δ function when $\delta'_m > 0$.

We summarize results from this section in the following proposition.

Proposition 4.1. *In markets where firms are differentiating products to be environmentally conscious, the attractiveness of a merger deal increases with product differentiation if the pollution intensity of the merged entity is smaller post-merger than pre-merger.*

5 Conclusion and Policy Implication

Mergers are important for creating value and maximizing sustainable competitive advantage. Due to the extensive work on why mergers take place our understanding of merger incentives has improved. However, there are not many studies examining how differences in pollution parameters between post- and pre-merger markets affect the attractiveness of merger deals. We explicitly account for post-merger markets where firms adopt proactive environmental strategies. In such markets we examine conditions under which the attractiveness of a merger deal increases with the increase in product differentiation. Our findings suggest that, (*i*) merger deals could result in lower optimal emission tax post-merger, (*ii*) the attractiveness of a deal increases as products become more differentiated, (*iii*) the attractiveness of a deal is more likely to increase if the merged entity is not too pollution-intensive post-merger; and (*iv*) when merged entities modify products to be greener, they are more likely to benefit more from the deal if they are not too pollution intensive post-merger.

The results of this study have important policy implications. First, the model suggests that there is an incentive for merged entities to pollute less post-merger and predicts that mergers induce pollution reductions, including in markets where differentiation is taking place. Hence, current market-share and concentration criteria may not be sufficient when accepting or rejecting merger proposals. Anti-trust agencies may benefit from adjusting merger control policies by including some sustainability indicators. For instance, anti-trust agencies may require firms contemplating to merge to present post-merger environmental protection plans. Second, the findings of this study suggest that merger deals can lead to a need for revising the current environmental policy framework. It may be optimal to reduce penalty for pollution post-merger. This finding introduces the potential role of environmental agencies in altering the attractiveness of merger and acquisition deals among pollution-intensive firms. Even though the primary target of environmental policy is to achieve an efficient level of emissions, it is possible that when such policies are always optimally chosen, they affect conditions under which mergers become attractive. This also implies that when anti-trust agencies accept merger proposals, thereby allowing a merger to occur, they should study the possible effect of mergers on environmental policies. This requires that anti-trust agencies work in harmony with environmental regulators. Therefore, we recommend that a communication bridge between environmental policy makers and anti-trust agencies may facilitate informed policy making.

There are several dimensions in which an extension of this current study would benefit merger models and policy making. Research could benefit from an in-depth examination of the effect of mergers among polluting firms on upstream and downstream industries. For example, for polluting firms which out-source abatement services, merger deals may have an implication on the market for abatement goods and services (Canton et al., 2012). In addition, welfare implications of such mergers may provide additional insight for policy-making.

Moreover, the current study can be extended to reflect actual market structures such as markets with free entry and exit, markets where more than one merger deal takes places at a time, and when there are more than two merger participants. Finally, it may be interesting to empirically test the main results of this study in order to identify sectors whose environmental strategies have wider impacts.

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Appendix

A Pre-merger welfare maximization

The pre-merger welfare is given as:

$$\max_{t} W = CS(nq) + n\pi + net - \varphi(ne) \tag{A.1}$$

Total differentiation gives

$$dW = -nqdp + nd\pi + ntde + nedt - n\varphi' de \tag{A.2}$$

Moreover, differentiation of profit gives $nd\pi = \beta qdq + nqdp - nedt$. Therefore,

$$dW = n\beta qdq + (t - \varphi')nde \tag{A.3}$$

To find the expression for optimal tax we use

$$\frac{dW}{dt} = n\beta q\frac{dq}{dt} + (t - \varphi')n\frac{de}{dt} \tag{A.4}$$

Setting the above equation equal to zero gives

$$t = \varphi' - \frac{\beta q[dq/dt]}{de/dt} \tag{A.5}$$

B Post-merger welfare maximization

Total differentiation of the welfare function post-merger gives

$$\begin{aligned} dW = &-q_1dp_1 - q_2dp_2 - (n-2)\tilde{q}d\tilde{q} + d\pi_1 + d\pi_2 + (n-2)d\tilde{\pi} \\ &+ (e_1 + e_2 + (n-2)\tilde{e})dt + (de_1 + de_2 + (n-2)d\tilde{e})t \\ &- \varphi'(de_1 + de_2 + (n-2)d\tilde{e}) \end{aligned} \tag{B.1}$$

where

$$d\pi_1 = (p_1 - c - \delta t)dq_1 + q_1 dp_1 - \delta q_1 dt + tdt \tag{B.2}$$

$$d\pi_2 = (p_2 - c - \delta t)dq_2 + q_2 dp_2 - \delta q_2 dt + tdt \tag{B.3}$$

$$d\tilde{\pi} = (\tilde{p} - c - \delta t)d\tilde{q} + \tilde{q}d\tilde{p} - \delta\tilde{q}dt + tdt \tag{B.4}$$

Hence, equation (B.1) can be re-written as:

$$dW = 2(\beta + \gamma)q_1 dq_1 + (n-2)\beta\tilde{q}d\tilde{q} + (t - \varphi')[2\delta dq_1 + \delta(n-2)d\tilde{q} - ndt] \tag{B.5}$$

Using (B.5) the optimal policy in the post-merger market is given by (we use the subscript m to denote optimal policy post-merger):

$$t_m = \varphi' - \frac{2q_1(\beta + \gamma)\frac{\partial q_1}{\partial t_m} + (n-2)\beta\tilde{q}\frac{\partial \tilde{q}}{\partial t_m}}{2\delta(\partial q_1/\partial t_m) + (n-2)\delta(\partial\tilde{q}/\partial t_m) - n} \tag{B.6}$$