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Summary

This paper considers the environmental policy and welfare implications of a merger between environment firms (i.e., firms managing environmental resources or supplying pollution abatement goods and services). The traditional analysis of mergers in Cournot oligopolies is extended in two ways. First, we show how environmental policy affects the incentives of environment firms to merge. Second, we stress that mergers in the eco-industry impact welfare beyond what is observed in other sectors, due to an extra effect on pollution abatement efforts; this might lead to disagreements between an anti-trust agency seeking to limit market concentration which can be detrimental to consumer surplus and a benevolent regulator who maximizes total welfare.

Keywords: Eco-Industry, Environmental Policy, Horizontal Mergers

JEL Classification: D62, H23, L11

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1 Introduction

Over the past decades, the provision of goods and services to abate pollution or manage environmental resources has by and large become the core business of specialized private firms. This so-called eco-industry is now approaching the aerospace and pharmaceutical sectors in size, with an estimated 2005 global market of US $653 billion that is expected to reach US $776 billion by 2010.[1] Unsurprisingly, government agencies and policy makers are paying extra attention to this sector: not only does it account for a significant number of jobs (1.5 million jobs, or 3.8% of total employment, in the European Union alone in 2002, according to UBA/DIW (2004)), it also constitutes a key ingredient of industrial competitiveness, trade advantage and social stability in a world where the pressure to protect environmental resources is mounting.

Acknowledging this development, the economic literature has lately re-examined optimal environmental policies in the presence of an eco-industry, assuming the economy is either closed (David & Sinclair-Desgagné 2005, Nimubona & Sinclair-Desgagné 2005, Requate 2005, Canton et al. 2008) or open (Fees & Muehlheusser 2002, Copeland 2005, Canton 2007). These articles, however, did not study how environmental regulation affects concentration and mergers in the eco-industry. Investigating such aspects of industry structure seems nevertheless crucial for an understanding of the supply of environmental resources and abatement technologies. In a first attempt to do so, David et al. (2008) just took into account endogenous entry and exit by environment firms in establishing optimal emission taxes. The present paper, on the other hand, will now consider the relationship between emission taxes and mergers of environment firms.

Mergers and acquisitions are quite frequent in the eco-industry. The main firms in the U.S. waste management market, for instance, namely Waste Management Inc., Allied Waste Inc. and Republic Services, secured their growth throughout the 1980s and 1990s via mergers and acquisitions. In the air pollution abatement segment, BASF Catalyst, a division of the German chemical manufacturer BASF, announced in May 2006 it had finally got hold of its U.S. competitor Engelhard, in a hostile takeover that ended up costing more than US $5 billions; this acquisition constitutes BASF's largest such transaction in its 140-year history. In water treatment, Idaho-based Blue Water Technologies Inc. announced in September 2006 it had acquired Applied Process Technology Inc., a Texan

[1] These figures are from Environmental Business International (2006), a private firm which has been collecting and publishing data on the environment industry since 1988.

filter producer. These cases, and many others, seem to corroborate a trend reported earlier by the World Trade Organization (WTO, 1998):

> The available evidence suggests that there is a tendency towards increasing concentration in the environmental industry. A study on mergers and acquisitions in the US in the environmental industry suggests that scale benefits and consumer preferences favour large firms which tend to achieve higher returns than their smaller rivals (European Commission, 1994). [...] As a result of these developments, the number of mergers and acquisitions increased between 1987 and 1991 at an annual rate of 56 per cent to reach 223 transactions in 1991. More recent reports from industry sources suggest that half the private market in the United States is controlled by the top ten companies.

Horizontal mergers have of course been a matter of public policy concern for some time already (see the Clayton Act, 1914 and the Treaty of Rome, Article 81(1), 1957). To inform antitrust authorities, one early branch of the literature looked at the welfare implications of mergers (Williamson 1968, Farrell & Shapiro 1990). On the one hand, mergers may generate scale economies and deliver efficiency gains; on the other hand, they can reduce industry competition and induce losses in consumer surplus. Public authorities will then have to trade-off these positive and negative effects in deciding to approve a merger or not.

Another stream of literature would rather analyze incentives for firms to merge, by comparing profits before and after a merger. Under linear demand and cost functions, Salant et al. (1983) initially showed that the number of firms merging together must account for at least 80% of incumbent firms, in order to make a merger profitable. Extending this model, Fauli-Oller (1997) next emphasized the concavity of demand as the main determinant of profitability: the more concave the demand function, the less lucrative the merger. An important caveat of these analyses is that, with linear costs, firms remained identical after a merger to what they were beforehand. Perry & Porter (1985) first relaxed the linear-cost assumption, thereby introducing synergies through the amount of the industry's total capital stock possessed by incumbent firms - the larger a firm's share of capital, the lower its production costs. Based on this approach, McAfee & Williams (1992) returned to the welfare implications of horizontal mergers, showing that current Mergers Guidelines might at the same time authorize some welfare-reducing mergers and forbid some profitable welfare-enhancing ones.

The merger literature was recently specialized to investigate the relationship between environmental regulation and incentives to merge (Hennessy & Roosen 2002, Benchekroun & Ray-Chaudhuri 2006). Current work deals with polluting sectors, however, not the eco-industry. The latter, to be sure, raises a number of specific issues. First, while incentives to merge are of course also influenced by environmental policy, the relationship holds in a different way: as first pointed out by David and Sinclair-Desgagné (2005), environmental policy affects both the size *and* elasticity of *demand* for environmental goods and services, hence the market power and potential spillovers resulting from a merger. Second, the welfare implications of a given merger go beyond consumer surplus and firm profit. Such a merger influences the supply of environmental goods and services, which then impinges on the quality of the environment; the traditional trade-off between lower production costs and consumer surplus reduction must therefore be properly extended.

This paper's raison d'être is then to consider horizontal mergers in the eco-industry, dealing with the above specificities in a Perry & Porter (1985) and McAfee & Williams (1992) framework where such mergers also entail reductions in production cost. We shall show first that the minimal size for a profitable merger increases with the stringency of environmental regulation; in other words, mergers are less likely to occur as environmental policy tightens up. This result seems empirically testable. It implies, moreover, that putting stronger requirements on polluters might not lower competition in the eco-industry and exacerbate consequently the market power of environment firms. We shall also stress that, since mergers in the eco-industry impact welfare beyond what is observed in other sectors due to their effect on abatement efforts, some disagreements might arise between an anti-trust agency seeking to limit the impact of market concentration on consumer surplus and a benevolent regulator who wants to maximize total welfare.

The paper unfolds as follows. The following section presents our model. Section 3 shows that a higher tax on polluting emissions reduces incentives to merge in the eco-industry. Section 4 explores next the conditions under which a merger in the eco-industry is welfare enhancing. Section 5 then illustrates and discusses when the position of an antitrust agency in this context might differ from the one of a benevolent regulator. Section 6 contains concluding remarks.

2 The basic model

Consider a representative price-taking polluting firm that produces one consumption good and sells it on a competitive market at unit price P.[2] The marginal production cost for this good is assumed to be constant and is referred to as c. For an output level x, the firm generates polluting emissions $e(x, A)$, where A represents the firm's abatement effort. Without loss of generality, we take the emission function to be $e(x, A) = \frac{1}{2}(x - A)^2$. This means that $e_x(x, A) > 0$ (more production entails more pollution), $e_A(x, A) < 0$ (more abatement decreases total emissions), $e_{xx}(x, A) > 0$ (emissions from the last unit produced increase with the production level), and $e_{AA}(x, A) > 0$ (abatement effort is subject to diseconomies of scale). Last, we have $e_{xA}(x, A) < 0$ (the higher the abatement, the less the last unit produced generates pollution).[3]

The representative polluting firm is subject to a constant tax t per-unit of emission. However, it can purchase abatement goods and services from a specialized environment industry at a unit price p. It then sets production and abatement efforts in order to maximize the following profits:

$$\max_{x,A} \varphi = Px - cx - pA - te(x, A) \ . \tag{1}$$

Normalizing final consumers' demand as $P(x) = 1 - x$, basic calculations yield the following optimal levels of production and abatement for the polluting firm:

$$x = 1 - c - p \tag{2}$$

$$A = 1 - c - \frac{1 + t}{t} p \ . \tag{3}$$

Let $p(A)$ denote the inverse demand function faced by the environment firms. It is given by the polluters' decision to abate, as captured by equation (3). Rearranging this equation, the inverse demand is then $p(A) = \alpha_1 - \alpha_2 A$, where $\alpha_1 = \frac{(1-c)t}{1+t}$ and $\alpha_2 = \frac{t}{1+t}$. Note that both coefficients - the intercept and the slope - are increasing in t, the environmental tax.

The eco-industry is initially composed of n identical firms competing à la Cournot. Following McAfee & Williams (1992), the total cost of an environment firm i is assumed to be equal to $\frac{a_i^2}{2k_i}$, where a_i is the firm's output and k_i its capital investment. Firms

[2] One could consider an oligopolistic polluting industry without modifying our main results, as long as this industry acts as a price-taker on the market for abatement goods and services.

[3] Compared to David & Sinclair-Desgagné (2005), Nimubona & Sinclair-Desgagné (2005) and Canton et al. (2008), we do not assume that the emission function is additively separable.

are identical and $\sum_{i=1}^{n} k_i = K$. Each firm thus holds an equal share $k_i = k = \frac{K}{n}$ of the industry's global capital. Define

$$\beta_i = \frac{\alpha_2 k_i}{\alpha_2 k_i + 1}$$

and

$$B = \sum_{i=1}^{n} \beta_i \ .$$

One can check that the letter β_i indicates firm i's market share, whereas B renders the overall size of the market.[4]

The following equilibrium quantities and price are now derived for the pre-merger case where all firms are symmetric (see (McAfee & Williams 1992)).[5]

$$a = \frac{\alpha_1}{\alpha_2} \frac{\beta}{1+B}$$

$$A = \frac{\alpha_1}{\alpha_2} \frac{B}{1+B}$$

$$p = \frac{\alpha_1}{1+B} \ .$$

An environment firm's profit is then

$$\pi = pa - \frac{a^2}{2k} \ . \tag{4}$$

3 Horizontal mergers

This section will now consider the incentives of environment firms to merge. The first part studies the minimal size of a profitable merger. The second part examines the impact of environmental policy.

3.1 On merger size and profitability

Suppose that s firms in the eco-industry decide to merge. The total capital of new entity is then sk. Indexing by s the equilibrium values for the merged firm and by o those for

[4] More precisely, the market share of a firm i is $s_i = \frac{\beta_i}{B}$.

[5] In this case, $k_i = k, \forall i$ and $\beta_i = \beta, \forall i$. Therefore $a_i = a, \forall i$.

each of the $(n-s)$ remaining firms (the *outsiders*), we have

$$\beta_s = \frac{\alpha_2 sk}{\alpha_2 sk + 1}$$

$$\beta_o = \beta = \frac{\alpha_2 k}{\alpha_2 k + 1} \ .$$

In this case, B becomes $B_m = \beta_s + (n-s)\beta_o$, so

$$B_m = \frac{s(\alpha_2 k)^2(1+n-s) + n\alpha_2 k}{(s\alpha_2 k + 1)(\alpha_2 k + 1)}$$

and

$$a_s = \frac{\alpha_1}{\alpha_2}.\frac{\beta_s}{1+B_m}$$

$$a_o = \frac{\alpha_1}{\alpha_2}.\frac{\beta_o}{1+B_m} \ .$$

Total output is now

$$A_m = \frac{\alpha_1}{\alpha_2}.\frac{B_m}{1+B_m}$$

and the market price is given by

$$p_m = \frac{\alpha_1}{1+B_m} \ .$$

It can be seen that $B_m < B$ and $p_m > p$, so the size of the market is reduced and the price for abatement is increased with the merger. Moreover, $a_o > a$ and $a_s < a$, meaning that outsiders increase their output and insiders decrease theirs with the merger.

A merger, however, is not always profitable for the involved firms. To be sure, there are two main reasons for firms to merge. First, this reduces production cost. Second, total output will shrink, which increases the market price and the firms' profit (Perry & Porter 1985, Fauli-Oller 2002). Stigler (1950) and others have argued, on the other hand, that firms which do not participate in the merger may actually benefit more than those which merge. They expand output and profit from a higher market price, thereby free-riding on the merger's participants who in turn do not capture all the rent they generate. This may dissuade firms from merging.

Using the methodology of Allain & Souam (2004), one can show that an s-firms merger is profitable for the insiders only if s is superior to a threshold $\hat{s}$ (i.e. if the number of insiders is sufficient high relative to the number of outsiders). The profit of the merged

firm is equal to $\pi_s = p_m a_s - \frac{a_s^2}{2sk}$. Compare now the profit of the merged entity with s times the ex ante individual profit given by equation (4). The sign of the difference is the same as the sign of the following expression (see Appendix 7.1 for a full derivation):

$$\begin{aligned} g(s,n,\alpha_2) &= (\alpha_2 k+1)^2(2s\alpha_2 k+1)[1+(n+1)\alpha_2 k]^2 \\ &\quad -(2\alpha_2 k+1)[s(\alpha_2 k)^2(2+n-s)+\alpha_2 k(n+s+1)+1]^2 \end{aligned} \tag{5}$$

This expression is negative when s is inferior to a unique threshold $\hat{s}$, and positive otherwise. This constitutes our first result.

Lemma 1 *There exists a unique threshold on the number of insiders (s) from which a merger in the eco-industry becomes profit-enhancing.*

A proof of the existence and unicity of this threshold can be found in Appendix 7.1.

3.2 The impact of environmental policy

Let us now examine how a change in environmental policy can affect incentives to merge in the eco-industry.

Clearly, the level of the emission tax t influences the polluters' abatement decisions and the ensuing inverse demand function $p(A) = \alpha_1 - \alpha_2 A$, where $\alpha_1 = \frac{(1-c)t}{1+t}$ and $\alpha_2 = \frac{t}{1+t}$. Note that a more stringent tax not only increases the market for abatement by raising the intercept α_1; it also modifies the price-elasticity of demand for abatement goods and services by augmenting α_2. The parameter α_1, however, does not appear in $g(s,n,\alpha_2)$. The impact of a change in environmental taxation on merger profitability occurs thus only through the slope coefficient α_2.

To fix ideas, let us first look at the case of a two-firm merger. Such a merger enhances profits if and only if

$$g(2,n,\alpha 2) > 0 \ , \tag{6}$$

where

$$g(2,n,\alpha_2) = 1-2(n-5)\alpha_2 k + [17+(2-3n)n](\alpha_2 k)^2 + 4[1-(n-2)n](\alpha_2 k)^3 \ .$$

This function is studied in Appendix 7.2 and plotted for $n = 4$, $K = 1$ in Figure 1 with respect to α_2. One can see that, as α_2 grows across the interval $[0,1]$, $g(2,n,\alpha_2)$ ends up taking negative values. Hence, as the emission tax t increases (so α_2 goes up as well), the

two-firm merger tends to become unprofitable. In other words, raising the emission tax reduces incentives to form such a merger.

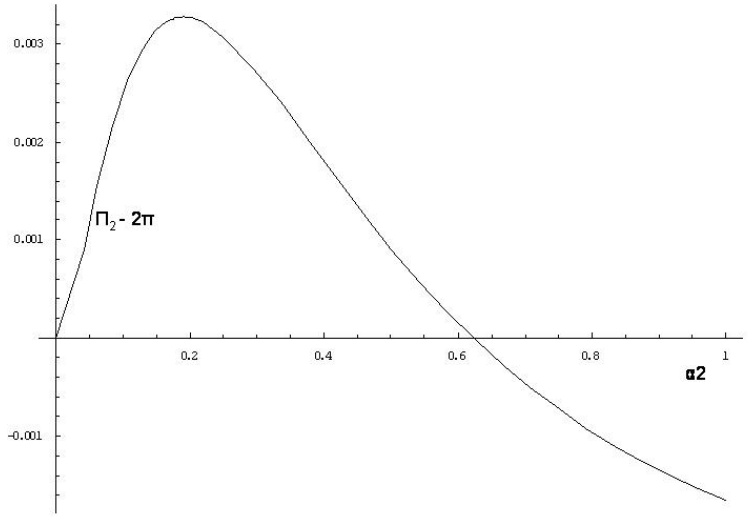

Figure 1: The impact of a change in the environmental policy on a two-firms merger profitability ($n > 2$)

Turning to the general case of an s-firm merger, we found that a similar conclusion held (qualitatively) in numerous simulations: namely, a rise in the emission tax t (so in α_2) makes mergers of a given size less profitable.[6] The threshold $\hat{s}$, moreover, tends to go up with t. This supports our first Proposition.

Proposition 1 *When $n > 2$, making the emission tax more stringent raises the minimal size $\hat{s}$ at which a merger becomes profitable.*[7]

The intuition behind this result is the following. As explained before, incentives to merge come from the opportunity to reduce costs while lowering output and increasing prices. Outsiders, however, will free-ride on the latter, thereby deterring smaller mergers. In the present context, a bigger emission tax will amplify such free-riding, as it makes demand for abatement less price-elastic and allows therefore a given merger to further raise prices.

[6]Such simulations were carried out for $n \in [2, 10^{10}]$ and $K \in [0.01, 10^{10}]$.

[7]Were the eco-industry a duopoly ($n = 2$), $g(2, 2, \alpha_2)$ would always be positive, as the two firms would naturally prefer to merge to form a monopoly. This comes from the absence in this case of free-riding outsiders.

This proposition refines the well-known observation that incentives to merge decrease as B - the size of the market - increases (Fauli-Oller 2002), or equivalently that horizontal mergers generally happen in declining industries (Dutz 1989).[8] In the American waste management market, for instance, the main U.S. firms seem indeed to have secured their growth through mergers and acquisitions when the market was stable (Berg et al. 1998, Diener et al. 2000). Our explanation, however, emphasizes the impact of environmental regulation on the price-elasticity rather than on the size of demand for abatement goods and services.

Let us now investigate the welfare implications of horizontal mergers in the eco-industry.

4 A welfare analysis

Social welfare is defined as the sum of the final consumers' surplus (CS), the polluting industry's profit (φ) and the eco-industry's total profits ($\Pi = \sum_{i=1}^{n} \pi_i$), minus the social damage caused by pollution. Denote as ν the harm inflicted per unit of emission, and by E total pollution damages. Formally,

$$CS = \int_0^x P(u)du - Px$$

$$\varphi = Px - cx - pA - te(x, A)$$

$$\Pi = \sum_{i=1}^{n}(pa_i - \frac{a_i^2}{2k_i}) = pA - \sum_{i=1}^{n}\frac{a_i^2}{2k_i}$$

$$E = \nu e(x, A) \ .$$

As in Barnett (1980), let tax revenues be redistributed in a neutral way. We shall now examine separately the consequences of a merger on each of these functions.

4.1 The eco-industry's profits

Participants to a merger always increase their profits, for they would otherwise choose to remain apart and the merger would not occur. Outsiders are also winners, since their per

[8] Note that $B = \frac{n\alpha_2 k}{\alpha_2 k+1}$ before any merger occurs, which is increasing in α_2.

unit production costs remain unchanged while they can sell at a higher price. Hence, the eco-industry's total profits always goes up after some environment firms merge.

4.2 Pollution damages

Given the polluting firm's optimal production and abatement levels $x = 1 - c - p$ and $A = 1 - c - \frac{1+t}{t}p$, polluting emissions are equal to

$$e(x, A) = \frac{1}{2}(x - A)^2 = \frac{1}{2}(\frac{p}{t})^2 \ . \tag{7}$$

The higher the price p for pollution abatement goods and services, the higher the emission level. Conversely, the higher the tax t, the lower the emissions.

Following a merger in the eco-industry, we have that $p_m > p$, so the price of abatement increases. All things equal, such a merger then induces less abatement effort and favors further depletion of environmental resources.

Consider now the net difference between post-merger and pre-merger pollution damages, which is given by

$$\Delta E = \nu(\frac{p_m^2 - p^2}{2t^2}) \ . \tag{8}$$

When t increases, the denominator in (8) grows, which tends to lessen the pollution induced by a merger of environment firms. On the other hand, t also affects the numerator in (8) in a way which is described in the following Lemma.[9]

Lemma 2 *(i) The higher t (resp. n), the higher (resp. lower) the initial abatement price p. (ii) The higher the initial price, the higher the difference between post and pre-merger prices.*

It follows that a higher tax augments the numerator in (8). Setting a larger emission tax thus has an ambiguous effect on the variation in pollution after some environment firms merge.

According to our simulations, a higher tax (particularly at already low taxation levels) might actually bring about a higher variation in environmental quality after a merger occurs. This fact and its rationale constitute the next proposition.

Proposition 2 *Variation in pollution damages following a horizontal merger in the eco-industry are magnified under higher emission taxes, when the indirect negative impact of*

[9]See Appendix 7.3 for the proof.

a merger on environmental quality — through the difference between post and pre-merger abatement prices — exceeds the direct positive impact of the tax.

Note that an increase in the number of environment firms n will alleviate this problem by reducing the gap between p_m and p (see Lemma 2).[10]

4.3 Polluters' profits

The overall effect of a merger on polluters' profits seems ambiguous. Recall that the representative polluter's profit is $\varphi = Px - cx - pA - te(x, A)$. The price P of the final good being positively correlated with the price for abatement (since $P = c + p$), it thus increases after some environment firms merge. Under those circumstances, polluters also produce less, which lowers total production costs. The variation of pA, on the other hand, is unclear, since p increases but A goes down. Moreover, polluting emissions are higher after a merger, so the tax payment is increased.

Let us now substitute the optimal levels of output and abatement effort by polluting firms ($x = 1 - c - p$ and $A = 1 - c - \frac{1+t}{t}p$) in their profit function. The difference between post- and pre-merger polluters' profits is then equal to

$$\Delta\varphi = \frac{p_m^2 - p^2}{2t} > 0 \ . \tag{9}$$

In the present model, a horizontal merger in the eco-industry therefore increases polluters' profits. This (perhaps surprising) result comes from the fact that the higher equilibrium price P more than compensates for higher abatement costs and tax payment.

4.4 Consumer surplus

Following a merger in the eco-industry, polluting firms produce less and the price of the final good increases. Consumer surplus then shrinks.

To see more precisely what happens, use the equilibrium levels of P and x to write the difference between post- and pre-merger consumer surplus as

$$\Delta CS = (1 + c)(p - p_m) \ . \tag{10}$$

[10] According to the previous section, moreover, higher emission taxes tend to deter merging activities per se. The overall effect on pollution of imposing more stringent emission taxes is therefore difficult to characterize in general.

This entity is necessarily negative, since $p_m > p$. As the environmental tax increases, the gap between p_m and p grows bigger so the incurred loss worsens. From the previous section, however, we know this impact is reduced when there are more competing environment firms or the price of abatement goods and services is low.

4.5 Total welfare

In sum, a merger of environment firms has opposite effects on welfare: it decreases environmental quality and consumer surplus but increases the eco-industry and the polluting sector's profits.

To examine the overall outcome, note that total welfare is given by

$$W = \int_0^x P(u)du - cx - \sum_{i=1}^{n} \frac{a_i^2}{2k_i} - \nu e(x, A) \ . \tag{11}$$

At the equilibrium levels of x and A, the latter transforms into

$$W = 1/2 - \frac{c(2-c)}{2} - \frac{\alpha_1^2}{2(1+B)^2}[1 + \frac{B}{t}(1+t)(1-B.h) + \frac{\nu}{t^2}] \ , \tag{12}$$

where $h = \sum_{i=1}^{n} (\frac{a_i}{A})^2 = \sum_{i=1}^{n} (\frac{\beta_i}{B})^2$ is the Herfindahl index of the eco-industry.[11] Only the last term of the latter expression is modified by the occurrence of a merger. Hence, a horizontal merger in the eco-industry is welfare-enhancing if and only if

$$\frac{\alpha_1^2}{2(1+B_m)^2}\left[1 + \frac{B_m}{t}(1+t)(1-B_m.h_m) + \frac{\nu}{t^2}\right] < \frac{\alpha_1^2}{2(1+B)^2}\left[1 + \frac{B}{t}(1+t)(1-B.h) + \frac{\nu}{t^2}\right],$$

where h_m is the eco-industry's Herfindhal index after the merger. Rearranging this inequality yields the following proposition.

Proposition 3 *A horizontal merger in the eco-industry is welfare-enhancing if and only if*

$$\frac{B(1-B.h)(1+B_m)^2 - B_m(1-B_m.h_m)(1+B)^2}{(1+B)^2 - (1+B_m)^2} > \frac{\nu + t^2}{t(1+t)} \ . \tag{13}$$

This result gives rise to several interesting interpretations. First, as ν increases, a merger in the eco-industry is less likely to be welfare-increasing (for the right-hand-side of (13) increases in ν). This is not surprising since such a merger induces less abatement

[11] The algebra that lead to this expression can be found in Appendix 7.4.

efforts to curb emissions; were pollution inflicting more damage on society, having some environment firms merge would then be less desirable.

Appendix 7.5 considers the impact on (13) of the number of environment firms n. This number affects only the left-hand-side of (13), where it has an ambiguous effect. First, a higher n reduces the negative consequences of a merger on the environment and on downstream users, while raising the potential cost economies one could get through a merger. On the other hand, when n increases for a given s, the proportion of insiders decreases, thereby reducing the cost economies this particular merger would yield.[12] No clear-cut conclusion therefore exists concerning the impact of an increase in n on condition (13). When $K = 1$, however, it can be shown that a larger n always makes a merger more likely to be welfare enhancing.

The emission tax t shows up on the right-hand-side of expression (13), which increases in t if t is not too low. It is also implicit on the left-hand-side, through α_2 which enlarges B and B_m but diminishes h_m.[13] Overall, the effect of t on condition (13) is therefore uncertain (see Appendix 7.5 for additional details).

Finally, note that the denominator of the left-hand-side of (13) is positive, since B_m is always smaller than B. The right-hand-side of (13) is also always positive. The following corollary is thus at hand.

Corollary 1 *A necessary condition for a merger to be welfare-enhancing is*

$$\frac{B(1-Bh)}{B_m(1-B_m h_m)} > \left(\frac{1+B}{1+B_m}\right)^2 . \tag{14}$$

This inequality means that total production costs in the eco-industry decrease with the merger.

The latter assertion is demonstrated in Appendix 7.4. Before any merger, firms are identical and the eco-industry's total production costs are

$$\eta = \frac{na^2}{2k} .$$

After s firms in the eco-industry have merged, on the other hand, the eco-industry's total costs become

$$\eta_m = \frac{a_s^2}{2sk} + (n-s)\frac{a_o^2}{2k} .$$

[12] Recall that the outsiders' production costs always increase after a merger.

[13] In our model, since pre-merger firms are symmetric, $h = 1/n$ so h does not depend on t.

Appendix 7.6 shows that the sign of the difference $\eta_m - \eta$ between post-merger and pre-merger total costs is in fact given by the following polynomial

$$\psi = -(\alpha_2 k)^3[ns^2 - s(n^2+n-1) + (n+1)^2] - 2(\alpha_2 k)^2(s+2n+2) - \alpha_2 k(s+2n+5) - 2.$$

If the term $[ns^2 - s(n^2+n-1) + (n+1)^2])$ is positive, then the whole expression is necessarily negative (so total costs would be reduced with the merger). Otherwise, ψ may either be positive or negative. The following proposition finally covers the two cases.

Proposition 4 *There are circumstances when a merger may increase total production costs in the eco-industry. This only happens in an industry with at least five firms and when the number of merging firms (s) is small compared to the total number of incumbent firms (n).*

Proof: See Appendix 7.6.

5 Conflicts within government

The previous section showed that horizontal mergers in the eco-industry have oftentimes conflicting or ambiguous impacts on various components of social welfare. In practice, this feature could generate conflicts within government, since the mission to safeguard specific components of social welfare often fall on different public agencies. This situation will now be examined.

5.1 Profits vs. welfare

We just studied the conditions under which a merger in the eco-industry is welfare-enhancing. However, this merger may or may not occur, depending on whether it benefits or not its initiators.

An s-firms merger is profit-enhancing if and only if $\pi_s > s\pi$, i.e.

$$\frac{(1+B)^2}{(1+B_m)^2} > \frac{(s\alpha_2 k+1)^2(2\alpha_2 k+1)}{(\alpha_2 k+1)^2(2s\alpha_2 k+1)} \tag{15}$$

On the other hand, by Corollary 1, a merger increases social welfare only if $\frac{B(1-Bh)}{B_m(1-B_m h_m)} > \frac{(1+B)^2}{(1+B_m)^2}$, i.e. if it reduces the eco-industry's production costs. If condition (15) is verified but the latter is not, then an s-firms merger will occur while it is not socially desirable.

Conversely, if the condition of Corollary 1 is verified but (15) is not, then the s-firms merger will not occur whereas it might have been welfare-improving.

The different possible scenarios can be seen in the following graph, which depicts the differences in profitability $\Pi_s - s\pi$ and production costs $\Delta c(A)$ of a merger with respect to the number s of environment firms involved.

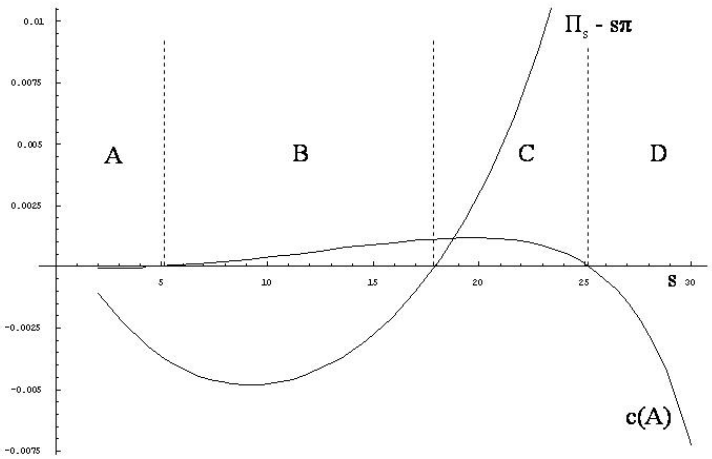

Figure 2: Production costs and profits according to the size of the merger

Part A corresponds to the case where a merger reduces production costs but is not profitable. In Part B, a merger would neither be profitable nor increase welfare. In Part C, a merger would be profitable but would harm welfare. Part D, finally, is the most desirable scenario where a profitable merger reduces total production costs and might enhance welfare. Note that the latter occurs when a significant proportion of incumbent firms participate in the merger.

5.2 The anti-trust agency and the benevolent regulator

Nowadays, any significant merger has to gain approval from local antitrust authorities. The latter increasingly invoke standard criteria and data, such as industry concentration and barriers to entry (see Khemani & Shapiro (1993) and Bergman et al. (2005) for discussions on this). A merger might then be challenged unless it is expected to deliver such important cost-savings that it will also benefit consumers. Disagreements between local authorities (such as the U.S. Antitrust Agency and the Competition Authority of the

European Union, for example) finally come from the different relative weights respectively given to producers and consumers (Fridolsson 2007).

One must certainly acknowledge, however, that the environmental impact of a merger has not yet become a relevant criterion for antitrust authorities. Consider therefore the effect of a horizontal merger in the eco-industry on polluters, environment firms and consumers only. It is given by

$$\begin{aligned} S &= CS + \varphi + \Pi \\ &= 1/2 - \frac{c(2-c)}{2} - \frac{\alpha_1^2}{2(1+B)^2}[1 + \frac{B}{t}(1+t)(1-Bh)] \ , \end{aligned}$$

so an antitrust authority would currently approve a merger if and only if

$$\frac{B(1-Bh)(1+B_m)^2 - B_m(1-B_m h_m)(1+B)^2}{(1+B)^2 - (1+B_m)^2} > \frac{t}{t+1} \ . \tag{16}$$

Clearly, $\frac{\nu+t^2}{t(1+t)} > \frac{t}{t+1}$, so the condition in Proposition 3 is stricter than condition (16). This implies that the antitrust agency might actually accept a merger which is welfare-decreasing.

Proposition 5 *When the following inequalities are verified, an antitrust agency might approve a welfare-reducing horizontal merger in the eco-industry:*

$$\frac{t}{t+1} < \frac{B(1-Bh)(1+B_m)^2 - B_m(1-B_m h_m)(1+B)^2}{(1+B)^2 - (1+B_m)^2} < \frac{v+t^2}{t(1+t)} \ .$$

One may conclude from this that both antitrust and environmental protection agencies should collaborate when contemplating a merger of environment firms (in a way similar to what happens when horizontal mergers occur in the energy or defense sectors).

5.3 An illustration

Figure 3 now illustrate this point for a two-firm merger ($s = 2$), given an emission tax t and the number n of environment firms.

Each curve represents the pairs (n, t) where differences in profits, the above surplus S and total welfare are equal to zero. Above the iso-profit curve, a two-firm merger decreases profits for insiders; conversely, below this curve, it is in the interest of the two firms to merge. Within the brackets of the welfare curve, a merger is welfare-increasing; outside

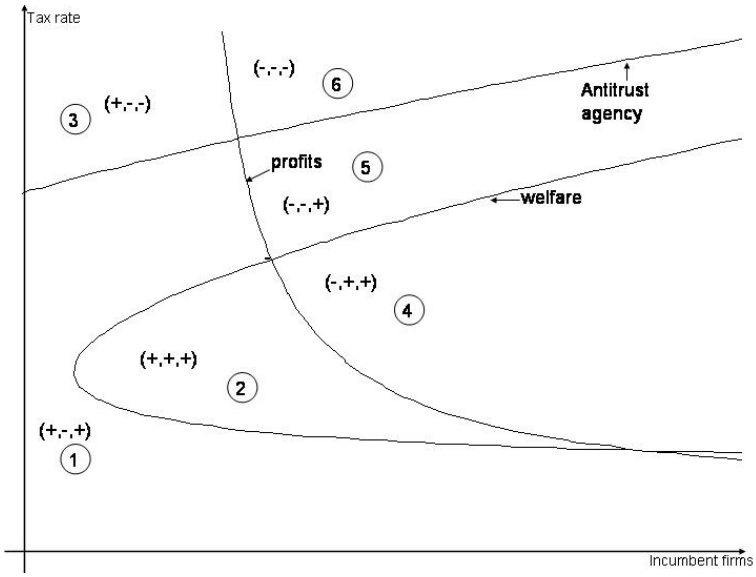

Figure 3: Welfares and profits according to the number of firms and pollution tax rates

those brackets, it is welfare-reducing. Above (below) the surplus curve, finally, profits and consumer surplus are reduced (increased) by a two-firm merger. The signs put in the figure represent these relationships, with the first, second and third component standing for profits, welfare and surplus respectively. The curves are of course drawn using specific values for ν, c and K. A change in c has no impact, however, while ν and K affect the size of the areas between curves but not their qualitative shapes.

The figure shows that a two-firm merger is profit-enhancing at low levels of n and t. This is consistent with our previous result that a tighter environmental policy reduces incentives to merge. It appears, moreover, that a two-firm merger is welfare-increasing when the initial number of firms is above a certain threshold and the emission tax takes intermediate values. Unsurprisingly, an anti-trust agency which considers only the surplus S approves a merger more often than a benevolent regulator who maximizes total welfare.

The figure finally exhibits six disjoint areas corresponding to as many possible cases:

1. In area 1, a two-firm merger is profitable but welfare-reducing, even though the antitrust agency would approve it.

2. This is the most desirable scenario: when the initial number of incumbent firms is relatively low and the emission tax takes intermediate values, a two-firm merger increases profits, surplus and total welfare.

3. Under high emission taxes and a small number of environment firms, profits increase

but welfare and total surplus go down following a merger. Neither a benevolent regulator nor the antitrust agency would thus approve it.

4. At intermediate values of t and n, a merger would increase both welfare and surplus, but it would not happen because insiders find no extra benefits in it.

5. When the number of firms and the emission tax are relatively high, a two-firm merger will not occur although an antitrust authority would approve it. Such a merger would be unprofitable and welfare-decreasing.

6. When both n and t take high values, a two-firm merger hurts profits, surplus and total welfare altogether.

Conflicts between environment firms and different regulating agencies would clearly arise in situations 1, 3 and 4. In the latter case, since both surplus and welfare are enhanced by a two-firm merger but environment firms are reluctant to come together, it might actually be worthwhile to consider subsidizing mergers.

6 Concluding remarks

This paper investigated the rationale and welfare consequences of horizontal mergers in the eco-industry. We assumed that such a merger creates a new entity with lower production costs (because of synergies between previously separate firms), while increasing concentration in the eco-industry and therefore raising the price of pollution abatement goods and services.

In terms of welfare, it appears that mergers involving environment firms are not desirable if the social cost of pollution is large. When pollution generates major damages, however, it is reasonable to expect that the regulator will adopt a more stringent environmental policy, putting for example higher taxes on polluting emissions. Section 3 established that such a measure actually hampers incentives to merge in the eco-industry (a merger would have to include a larger number of firms in order to raise these firms' profits). This key result seems empirically testable. Its underlying intuition runs as follows: a more stringent tax will decrease the price-elasticity of demand for environmental goods and services, thereby allowing outsiders to a merger to benefit even more from the larger residual demand.

Sections 4 and 5 also emphasized that environmental costs should supplement conventional welfare analyses of mergers when dealing with horizontal mergers in the eco-industry.

Some possible extensions of the present work might be worth mentioning at this point. Other (more realistic) market structures should certainly be considered, such as asymmetric oligopolies and oligopolies with a competitive fringe. It would also be instructive and useful, moreover, to study the optimal emission tax in this context; to be sure, the proposed policy would now have to internalize its effect on the structure of the eco-industry.

7 Appendix

7.1 Proof of Lemma 1

The profit of the merged entity is

$$\pi_s = \frac{\alpha_1^2 sk(\alpha_2 k+1)^2(2s\alpha_2 k+1)}{2[s(\alpha_2 k)^2(2+n-s)+\alpha_2 k(n+s+1)+1]^2} \ . \tag{17}$$

Profit before the merger, on the other hand, is

$$\pi = \frac{\alpha_1^2 k(2\alpha_2 k+1)}{2(1+B)^2(\alpha_2 k+1)^2} \ . \tag{18}$$

After some simplifications, we obtain that the difference $\pi_s - s\pi$ has the same sign as the following expression

$$\frac{(\alpha_2 k+1)^2(2s\alpha_2 k+1)}{(s(\alpha_2 k)^2(2+n-s)+\alpha_2 k(n+s+1)+1)^2} - \frac{(2\alpha_2 k+1)}{(1+(n+1)\alpha_2 k)^2} \ ,$$

which in turn has the same sign as

$$g(s,n,\alpha_2) = (\alpha_2 k+1)^2(2s\alpha_2 k+1)[1+(n+1)\alpha_2 k]^2 - (2\alpha_2 k+1)[s(\alpha_2 k)^2(2+n-s)+\alpha_2 k(n+s+1)+1]^2$$

We shall now prove the existence and unicity of a threshold $\hat{s}$ from which g is positive using Allain & Souam (2004)'s methodology. Since g is a 4th degree polynomial in s, it admits four roots. It is decreasing and equal to zero if $s = 1$, $\forall n > 1$. When $s = n$, its value is always strictly positive. Consequently, there is at least one number $\hat{s} \in]1, n[$ for which it is equal to zero. Furthermore, $\lim_{s\to-\infty} g(n,s,\alpha_2) = -\infty$, i.e. there is a

root included between $-\infty$ and 1. As $\lim_{s\to+\infty} g(s,n,\alpha_2) = -\infty$, there is another root included between n and $+\infty$. Therefore, the root $\hat{s}$ belonging to $[1,n]$ is unique. When $s \in]1,\hat{s}]$, g is negative; when $s \in [\hat{s},n]$, g is positive.

7.2 Change in the tax and merger profitability

$g(2,n,\alpha_2)$ is a polynomial function of α_2 of degree 3. It then has at most three roots. $g(2,n,0) = 1$ and $g(2,n,1) < 0$ when $n \geq 3$. Therefore, there is at least one root lying between 0 and 1. Note that $g(2,n,-1)$ is negative and $\lim_{\alpha_2\to-\infty} g(2,n,\alpha_2) = +\infty$. Thus, the two other roots are necessarily negative. In sum, a two-firm merger is profitable as long as the environmental tax leads to an α_2 lower than a threshold $\hat{\alpha_2}$. If $n = 2$, then $g(2,n,1) > 0$ and $g(2,n,\alpha 2)$ is positive for all α_2 included in [0,1].

Figure 1 represents $g(2,n,\alpha 2)$ as a function of α_2, when $n = 4$ and $K = 1$. As shown in this figure, $g(2,n,\alpha 2)$ becomes negative as α_2 increases. In other words, when the tax is increased, the merger is less likely to be profit-enhancing. As shown in Figure 4, when $n = 2$ the function $g(2,n,\alpha 2)$ is always positive, so the variation of α_2 does not affect the incentives to merge.

Our result is confirmed in the general case of a s-firms merger through a wide range of simulations. A rise in α_2 (i.e. a rise in t) increases the level $\hat{s}$ from which a merger becomes profitable. In other words, as the environmental tax becomes stricter, less mergers in the eco- industry are profitable.

7.3 The effect of a change in t or n on the difference $p_m^2 - p^2$

(i) The variation in t:

The variation of $p_m^2 - p^2$ with t is given by the sign of its derivative, i.e. $2\left(\frac{\partial p_m}{\partial t}p_m - \frac{\partial p}{\partial t}p\right)$.

We have

$$p = \frac{\alpha_1}{1+B}$$

$$p_m = \frac{\alpha_1}{1+B_m}$$

and

$$B = \frac{n\alpha_2 k}{\alpha_2 k + 1}$$

$$B_m = \frac{\alpha_2 sk}{\alpha_2 sk + 1} + (n-s)\frac{\alpha_2 k}{\alpha_2 k + 1}$$

Recall that $B_m < B$ and $p_m > p$.

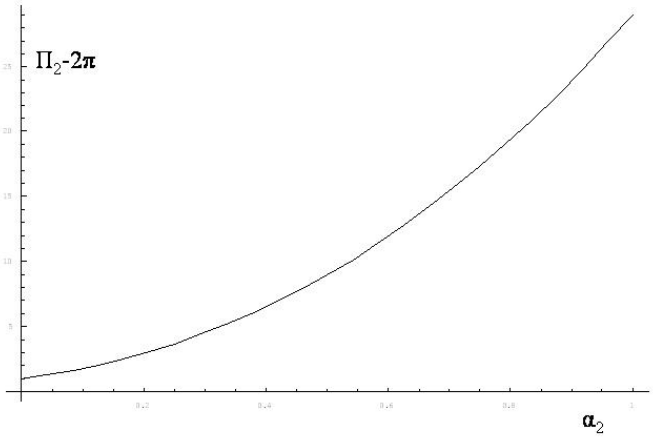

Figure 4: The impact of a change in the environmental policy on a two-firms merger profitability in a duopoly case

Note now that when the environmental tax increases, both the price before merger and the price after merger increase, i.e. $\frac{\partial p}{\partial t} > 0$ and $\frac{\partial p_m}{\partial t} > 0$. Furthermore, considering the fraction $\frac{p_m}{p} = \frac{1+B}{1+B_m}$, we can show that it always increases in t (via the increase in α_2). Therefore, $\frac{\partial p_m}{\partial t} p - p_m \frac{\partial p}{\partial t} > 0$, which entails $\frac{\frac{\partial p_m}{\partial t}}{\frac{\partial p}{\partial t}} > \frac{p_m}{p}$.

As a result, $\frac{\partial p_m}{\partial t} > \frac{\partial p}{\partial t}$ so $\frac{\partial p_m}{\partial t} p_m - \frac{\partial p}{\partial t} p > 0$. And the difference $p_m^2 - p^2$ grows in t.

(ii) The variation in n:

The variation of $p_m^2 - p^2$ with n is given by the sign of its derivative, i.e. $2\left(\frac{\partial p_m}{\partial n} p_m - \frac{\partial p}{\partial n} p\right)$.

First, the price after merger is always higher than the price before merger, i.e. $p_m > p$. Second, we know that when the number of incumbent firms increases, both the price before merger and the price after merger decrease, i.e. $\frac{\partial p}{\partial n} < 0$ and $\frac{\partial p_m}{\partial n} < 0$.

Furthermore, studying the fraction $\frac{p_m}{p} = \frac{1+B}{1+B_m}$, we can show that it always decreases in n. Therefore, $\frac{\partial p_m}{\partial n} p - p_m \frac{\partial p}{\partial n} < 0$, which yields $\frac{\frac{\partial p_m}{\partial n}}{\frac{\partial p}{\partial n}} > \frac{p_m}{p}$ (recall that both prices decrease in n). We can deduce that $\frac{\partial p_m}{\partial n} < \frac{\partial p}{\partial n}$. As a result, $\frac{\partial p_m}{\partial n} p_m - \frac{\partial p}{\partial n} p < 0$ and the difference $(p_m^2 - p^2)$ decreases in n.

7.4 The expression for net welfare

Following McAfee & Williams (1992) and the fact that an equilibrium a_i must satisfy the first order-condition for profit maximization, we have that

$$p = \alpha_1 - \alpha_2 A = (\alpha_2 + k_i^{-1})a_i \ .$$

We then obtain the following expression for the eco-industry's total profits:

$$\Pi = \frac{\alpha_1^2 B(1+Bh)}{2\alpha_2(1+B)^2} \ ,$$

where $h = \sum_{i=1}^{n}(\frac{a_i}{A})^2 = \sum_{i=1}^{n}(\frac{\beta_i}{B})^2$ is the Herfindahl index of the sector.

The overall turnover of the eco-industry is

$$T = \frac{\alpha_1^2 B}{\alpha_2(1+B)^2} \ .$$

The difference between turnover and profits then yields the following expression for total production costs:

$$CT = \frac{\alpha_1^2 B}{\alpha_2(1+B)^2}\frac{1-Bh}{2} \ . \tag{19}$$

This in turn leads to the welfare function

$$W = \frac{1}{2}\left(1-(c+\frac{\alpha_1}{1+B})^2\right) - c\left((1-c)-\frac{\alpha_1}{1+B}\right) - \frac{\alpha_1^2 B}{\alpha_2(1+B)^2}\frac{1-Bh}{2} - \frac{\nu}{2t^2}\frac{\alpha_1^2}{(1+B)^2}$$

After some simplifications, the latter expression becomes equation (12).

7.5 The impact of n and t on welfare

Recall that

$$B = \frac{n\alpha_2 k}{\alpha_2 k+1},\ B_m = \frac{s(\alpha_2 k)^2(1+n-s)+n\alpha_2 k}{(s\alpha_2 k+1)(\alpha_2 k+1)}$$

$$h = \frac{1}{n},\ h_m = \sum_{i=1}^{n-s+1}\left(\frac{\beta_i}{B_m}\right)^2 = (n-s)\left(\frac{s\alpha_2 k+1}{s\alpha_2 k(1+n-s)+n}\right)^2 + \left(\frac{s(\alpha_2 k+1)}{s\alpha_2 k(1+n-s)+n}\right)^2 .$$

We can use these equations to simplify expression (13). Note that

$$B(1-Bh) = \frac{n\alpha_2 k}{(\alpha_2 k+1)^2} \text{ and}$$

$$B_m(1-B_m h_m) = B(1-Bh) - \frac{s(s-1)(\alpha_2 k)^2(2+\alpha_2 k(s+1))}{(1+\alpha_2 k)^2(1+s\alpha_2 k)^2} \ .$$

This allows to rewrite expression (13) so that

$$-\frac{n\alpha_2 k}{(\alpha_2 k+1)^2} + \Psi\frac{(1+B)^2}{(1+B)^2-(1+B_m)^2} > \frac{\nu+t^2}{t(1+t)} \tag{20}$$

where $\Psi = \frac{s(s-1)(\alpha_2 k)^2(2+\alpha_2 k(s+1))}{(1+\alpha_2 k)^2(1+s\alpha_2 k)^2}$ does not depend on n.

- First, consider now the consequence of a change in n on the welfare-increasing condition. The first term on the left-hand-side of equation (20) is decreasing in n. On the other hand, $\frac{(1+B)^2}{(1+B)^2-(1+B_m)^2}$ increases in n if and only if

  $$\frac{\partial B}{\partial n}(1+B_m) - \frac{\partial B_m}{\partial n}(1+B) < 0 \ ,$$

  which is actually the case since $\frac{\partial B_m}{\partial n} > \frac{\partial B}{\partial n}$ and $B_m < B$. The effect on Ψ of a change in n, moreover, is ambiguous. It follows that the overall impact of a modification of n on the left-hand-side of (13) is unsure.

  One can show, however, that for a two-firm merger, if K is not too high, then an increase in n always augments the likelihood that a merger will be welfare-enhancing. For consequences on polluters are always softened and potential cost economies are increased with a bigger n.

- Second, assume now that t increases. The first term on the left-hand-side of equation (20) then increases if $\alpha_2 < 1/k$. On the other hand, $\frac{(1+B)^2}{(1+B)^2-(1+B_m)^2}$ decreases in t if and only if

  $$\frac{\partial B}{\partial t}(1+B_m) - \frac{\partial B_m}{\partial t}(1+B) > 0 \ ,$$

  which holds according to Appendix 7.3. The term Ψ, furthermore, is necessarily increasing in t. The variation of the second term of the left-hand-side of expression (20) is thus also ambiguous, while the right-hand-side grows with t if $t > \frac{2\nu+2\sqrt{\nu(\nu+1)}}{2}$. The overall impact of a change in t therefore remains uncertain.

All we can show, in fact, is that a more stringent environmental policy induces a less concentrated post-merger market, for

$$\frac{\partial h_m}{\partial \alpha_2} = -\frac{2(n-s)(s-1)^2 s}{(n+s\alpha_2 k(1+n-s))^3} < 0 \ .$$

7.6 On post-merger cost economies in the eco-industry

Using the expressions for a, a_s and a_o that were derived in section 2, the difference in production costs is equal to

$$\eta_m - \eta = -\frac{\alpha_1^2 k}{2}[\frac{n}{[\alpha_2 k(n+1)+1]^2} - \frac{s(\alpha_2 k+1)^2 + (n-s)(s\alpha_2 k+1)^2}{[s(\alpha_2 k)^2(n-s+2)+\alpha_2 k(n+s+1)+1]^2}],$$

which can be rewritten as

$$\eta_m - \eta = \frac{\alpha_1^2 \alpha_2 k^2 s(s-1)}{2} . \frac{\psi}{[\alpha_2 k(n+1)+1]^2[s(\alpha_2 k)^2(n-s+2)+\alpha_2 k(n+s+1)+1]^2}$$

with

$$\psi = -(\alpha_2 k)^3[ns^2 - s(n^2+n-1) + (n+1)^2] - 2(\alpha_2 k)^2(s+2n+2) - \alpha_2 k(s+2n+5) - 2$$

One can see that $\eta_m - \eta$ has the same sign as ψ. Let us now study the sign of the first term in ψ, in order identify the circumstances when a merger increases production costs. Consider the sign of

$$\Delta = ns^2 - s(n^2+n-1) + (n+1)^2 \ . \tag{21}$$

The discriminant of this second degree polynomial function of s is

$$\Theta = n^4 - 2n^3 - 9n^2 - 6n + 1 \ .$$

The latter has four roots among which three are excluded from the analysis for being inferior to 1. The fourth root is approximately equal to 4.36. That is, for all n inferior or equal to 4, Θ is negative and thus Δ is positive for all values on s. In other words, in an eco-industry initially composed of strictly less than five firms, a merger will always reduce total production costs.

For n superior or equal to 5, (21) is negative when s belongs to the interval $[s_1, s_2]$

where

$$s_1 = \frac{n^2 + n - 1 - \sqrt{n^4 - 2n^3 - 9n^2 - 6n + 1}}{2n}$$

and

$$s_2 = \frac{n^2 + n - 1 + \sqrt{n^4 - 2n^3 - 9n^2 - 6n + 1}}{2n} \ .$$

Observe that $1 < s_1 < s_2 < n$ and $s_1 < 2$ when $n \geq 5$. This root is thus excluded from our analysis as the number of firms merging cannot be inferior to two. Hence, the polynomial (21) is negative when the number of firms is inferior to s_2 and positive when it is superior to s_2. Total production costs in the eco-industry may increase with the merger only if the polynomial (21) is negative, that is, only if n is superior or equal to 5 and s is rather small compared to n.

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