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NON-TRADEABLE POLLUTION PERMITS AS GREEN R&D INCENTIVES

Non-Tradeable Pollution Permits as Green R&D Incentives*

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Abstract

Acquired wisdom has it that the allocation of pollution rights to firms hinders their willingness to undertake uncertain R&D projects for environmental-friendly technologies. We revisit this issue in a model where firms strategically choose whether to participate in a lottery to attain pollution permits, or instead invest in green R&D, to show that, somewhat counterintuitively, a desirable side effect of the pollution permit is in fact that of fostering environmental R&D in an admissible range of the model parameters.

Keywords: environmental externalities, pollution rights, pollution-reducing innovation

JEL Classification: L13, O31, Q55

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1 Introduction

The regulation of industries producing negative environmental effects is a hot issue in the current literature. Most of the existing contributions in the field of environmental economics examine the existence of Pigouvian taxation aimed at inducing firms to reduce damaging emissions directly[1] or indirectly[2] (for an exhaustive overview, see Bovenberg and Goulder, 2002; and Requate, 2005). Another possibility consists in assigning firms pollution rights, which in turn can be tradable.[3] The latter, in general, is indeed a short run remedy that in principle does not modify the nature of the production technology used by firms, while clearly in the long run it would be best to attain new environmental-friendly technologies.

A comparatively limited number of contributions investigate the link between some forms of environmental regulation and the incentives to generate and adopt green technologies or pollution-abatement measures.[4] In particular, Laffont and Tirole (1996) argue that pollution permits diminish or eliminate altogether firms' incentives towards green R&D because once a firm has acquired the right to pollute then she finds it more convenient to leave aside any uncertain and costly project eventually yielding a green technology. A qualitatively similar conclusion is reached by Damania (1996) in a supergame where quantity-setting firms aims at stabilising collusion while considering the feasibility of green R&D project, being subject to Pigouvian taxation.

Our aim is to nest into this debate by modelling the interplay between the costly acquisition of pollution rights on one side and green innovation incentives on the other, so as to single out the possibility for a public agency aiming at preserving the environment to design the distribution of pollution rights as an instrument to foster environmental R&D. The mechanism yielding this result can be intuitively explained as follows. Instead of modelling an auction for pollution rights, we envisage the possibility that, in order to

[1] See Bergstrom *et al.* (1981), Karp and Livernois (1992, 1994), Benchekroun and Long (1998, 2002), Poyago-Theotoky (2007) and Tsur and Zemel (2008).

[2] To this regard, see Downing and White (1986), Milliman and Prince (1989), Damania (1996), Chiou and Hu (2001), Tsur and Zemel (2002) and Dragone *et al.* (2010).

[3] See von der Fehr (1993), Sartzetakis (1997), Tietenberg (2003) and MacKenzie (2011), *inter alia*. For a modelization of the auction design for the allocation of pollution rights and the resulting R&D incentives to abate pollution in a Cournot duopoly, see Sunnevåg (2003).

[4] See Jung *et al.* (1996); Denicolò (1999); and Scotchmer (2011). Montero (2002) compares the R&D incentives across a number of possible policy instruments, including emission standards and either auctioned or tradeable permits.

acquire them, firms must participate to a lottery controlled by the government. If the outcome of such lottery is the assignment of pollution rights to a limited number of firms (say, one), the losers face two alternatives: the first is to stay out of the market, the other is to enter with a clean technology. In view of this, the regulator may set up the lottery with this in mind, expecting to get two eggs in one basket. That is, awarding, say, monopolistic pollution rights to a single firm may not necessarily force the regulator to accept a suboptimal trade-off between market power (and the associated negative price effect) and pollution abatement, provided that - with some positive probability - losers are going to innovate and enter the market with new clean technologies. To illustrate this perspective, we adopt a simple model involving two firms, that choose whether to participate in the lottery or try their luck in an uncertain R&D project aimed at the attainment of a green technology. We characterise (i) the equilibria of the game between firms, based on expected profit incentives, (ii) the consequences on consumer surplus, and (iii) the social preferences over alternative scenarios. The outcome of our analysis is that there exists a non-empty region of parameters where social and private incentives are indeed aligned, in such a way that at least one firm prefers to invest in R&D, so that it appears that assigning pollution rights via the lottery can be taken - at least indirectly - as a means to drive profit-seeking firms to invest their resources in green technologies even in absence of taxation or subsidization.

The remainder of the paper is structured as follows. Section 2 illustrates the setup. Section 3 briefly outlines the problem from the consumers' viewpoint. In section 4, the firms' equilibrium behaviour is illustrated. Section 5 assesses the social welfare consequences of market equilibria. An example based on the Cournot model is contained in section 6. Section 7 concludes the paper.

2 The setup

Consider a one-shot non cooperative game played by two single-product firms, indexed by $i = 1, 2$, supplying a homogeneous good with the same marginal cost. Initially, they share the same brown technology, whereby the production of the final output creates a negative externality in the form of polluting emissions. We suppose that, to mitigate the environmental implications of this technology, the government introduces a regulation according to which if a firm wants to produce she must not pollute the environment or she has to buy the pollution right which is sold by the government only to one firm. Therefore, at the outset, each firm faces the following perspective:

- she can take part in a lottery for emission rights. The exogenous individual probability of winning the lottery is $p = 1/2$, and the winner must pay a fixed fee F to the government in order to acquire the emission permit. Since we may suppose that F is redistributed among consumers as windfall money, the total effect of these costs on welfare is nought. The loser incurs a fixed cost Γ to shut down and quit the market. Alternatively,

- the firm may invest a given amount, K, to attain a green technology which comes out of the R&D division with probability $\alpha \in [0, 1]$. If so, she has the right to produce as her technology is now clean. If, instead, the R&D project yields no results, the firm, besides K, incurs a fixed cost Γ to quit the market. The innovation is patentable; in case both firms innovate, the authority allows both of them to patent the new technology and a symmetric green duopoly obtains.

In line with this setting, we have three cases: (i) both firms participate in the lottery for pollution rights; (ii) both invest in R&D looking for a green technology; (iii) one buys the pollution rights while the other invests in search of the green technology. In all cases, the marginal cost of production remains the same, the only difference between the two technologies being that one is clean and the other is not.

Therefore, denoting the participation in the lottery as L and the search for a green technology as G, we have the 2×2 game shown in matrix 1.

		2: L	2: G
1	L	$E\pi^{LL}, E\pi^{LL}$	$E\pi^{LG}, E\pi^{GL}$
1	G	$E\pi^{GL}, E\pi^{LG}$	$E\pi^{GG}, E\pi^{GG}$

Matrix 1

Here, $E\pi^{GG}$, $E\pi^{GL}$, $E\pi^{LG}$ and $E\pi^{LL}$ are firms' expected profits when both invest in green technology, one of them invests in green technology and the other buys the pollution permit, or both take part in the lottery, respectively.

Consider first the scenario where both firms are participating in the lottery. In this case, the winner becomes a monopolist and makes monopoly profits, while the loser gets no revenues and also incurs a fixed cost Γ. Therefore, the individual expected profits in this case are

$$E\pi^{LL} = \frac{\pi_M - F - \Gamma}{2}, \tag{1}$$

where π_M is gross monopoly profit. The non-negativity of $E\pi^{LL}$ requires $\pi_M > F + \Gamma$.

Alternatively, when both firms invest in R&D for a green technology, the expected profits for each firm are

$$E\pi^{GG} = -K + \alpha\left[(1-\alpha)\pi_M + \alpha\pi_D\right] - (1-\alpha)\,\Gamma. \tag{2}$$

Expression (2) consists of the R&D cost and the sum of (i) monopoly profits if the firm succeeds in innovating before the other and get the exclusive patent, and (ii) gross duopoly profits, $\pi_D < \pi_M$, if both firms show up simultaneously at the patent office with the green technology to get it patented on parallel, as it is rational for a smart government to have a totally green duopoly combining environmental friendly production with the equally desirable of output expansion on market price and therefore on consumer surplus.

In the third case, in which one invests to attain a clean technology and one participates in the lottery, since the firm which takes part in the lottery is the only potential buyer, she will obtain the pollution permit for sure and her expected payoff is

$$E\pi^{LG} = -F + (1-\alpha)\pi_M + \alpha\pi_D, \tag{3}$$

which depends on whether the rival succeeds in innovating or not. Accordingly, the maximum willingness to pay for the emission right cannot exceed $(1-\alpha)\pi_M + \alpha\pi_D$. In this scenario, the expected payoff for the firm activating the R&D project is

$$E\pi^{GL} = -K + \alpha\pi_D - (1-\alpha)\,\Gamma. \tag{4}$$

Hence, the game has a two-stage structure, where the first stage describes the firms' choice between taking part in the lottery or investing in green R&D, and the second models market behaviour. Moves are simultaneous in both stages, with complete, symmetric and imperfect information in each, while strategies taken at the first stage are observable to firms prior to playing the second stage. The solution concept is subgame perfection by backward induction.

3 The consumers' view point

We shall now have a look at the level of consumer surplus generated by consumption (and therefore gross of the redistribution of F) in the three different perspectives:

(G,G) In this case, the expected surplus for consumers is the aggregate amount of the monopolistic consumer surplus if one firm innovates and the other one does not, and the duopolistic consumer surplus if both firms attain the innovation:

$$ECS^{GG} = 2\alpha(1-\alpha)CS_M + \alpha^2 CS_D, \tag{5}$$

where CS_M and CS_D are the levels of consumer surplus in monopoly and duopoly, respectively.

(L,G) or (G,L) If one firm buys the pollution permit and the other invests in R&D, the expected consumer surplus becomes

$$ECS^{LG} = ECS^{GL} = (1-\alpha)CS_M + \alpha CS_D - (1-\alpha)E_M - \alpha E_D, \tag{6}$$

illustrating the fact that depending on the probability of innovation, consumers incur some amount of negative externality either in monopoly, E_M, or in the asymmetric duopoly where only one of the two firms creates a negative externality, $E_D (< E_M)$.

(L,L) If both firms participate in the lottery, one of them wins it and becomes a monopolist with the existing brown technology, which obviously entails a negative externality for consumers:

$$ECS^{LL} = CS_M - E_M. \tag{7}$$

By comparing these functions, we have

$$\Delta_{cs}^{gl,ll} \equiv ECS^{GL} - ECS^{LL} = \alpha\left[CS_D - CS_M + E_M - E_D\right], \tag{8}$$

$$\Delta_{cs}^{gg,gl} \equiv ECS^{GG} - ECS^{GL} = (1-\alpha)\left[(2\alpha-1)\,CS_M - \alpha CS_D + E_M - E_D\right] + E_D, \tag{9}$$

$$\Delta_{cs}^{gg,ll} \equiv ECS^{GG} - ECS^{LL} = (2\alpha(1-\alpha)-1)\,CS_M + \alpha^2 CS_D - E_M. \tag{10}$$

Since we know that $CS_D > CS_M$ and $E_M > E_D$, it is easily shown that $\Delta_{cs}^{gl,ll} > 0$ which means that consumers prefer the perspective in which one firm goes for the green technology rather than that in which both take part in the lottery. For the other two expressions, (9) and (10), we find that as α increases $\Delta_{cs}^{gg,gl}$ and $\Delta_{cs}^{gg,ll}$ increase monotonically and, for sufficiently large values of α, they become positive. Therefore, while from the consumers' standpoint having one firm investing in green technologies and the other buying pollution rights is more desirable than having both involved in the lottery for the pollution rights, consumers dislike the idea that both firms may disregard pollution permits and to invest symmetrically in clean technologies unless the probability of successful innovation be sufficiently high.

Having characterised consumer preferences concerning the strategi behaviour of firms, there remains to assess the pivotal role of the R&D cost K in determining whether there exists a parameter range wherein social and private incentives are indeed reciprocally aligned.

4 Equilibrium analysis

Here, we characterise the subgame perfect equilibrium solution of the non cooperative game between the two firms, based on the examination of matrix 1. The shape of firms' strategic behaviour is essentially determined by probability α as well as the relative size of costs F and K.

Considering (1), (2), (3) and (4), we have

$$\Delta_{\pi}^{gl,ll} \equiv E\pi^{GL} - E\pi^{LL} = \frac{1}{2}(F - \pi_M) + \alpha\pi_D - \left(\frac{1}{2} - \alpha\right)\Gamma - K, \tag{11}$$

$$\Delta_{\pi}^{gg,lg} \equiv E\pi^{GG} - E\pi^{LG} = F - (1-\alpha)^2\pi_M - \alpha(1-\alpha)\pi_D - (1-\alpha)\Gamma - K, \tag{12}$$

$$\Delta_{\pi}^{gg,ll} \equiv E\pi^{GG} - E\pi^{LL} = \frac{1}{2}F - \left(\frac{1}{2} - \alpha(1-\alpha)\right)\pi_M + \alpha^2\pi_D - \left(\frac{1}{2} - \alpha\right)\Gamma - K. \tag{13}$$

If the right hand sides of (11)-(13) are simultaneously positive, investing in search of the green technology is a dominant strategy for both firms and (G, G) emerges as the unique and Pareto-efficient equilibrium of the game. The game is instead a prisoners' dilemma with (G, G) as the unique but Pareto-inefficient equilibrium if the RHS of (11-12) is positive while (13) is negative. Independently of the nature of the resulting equilibriium, we may compare $\Delta_\pi^{gl,ll}$, $\Delta_\pi^{gg,lg}$ and $\Delta_\pi^{gg,ll}$, which results in:

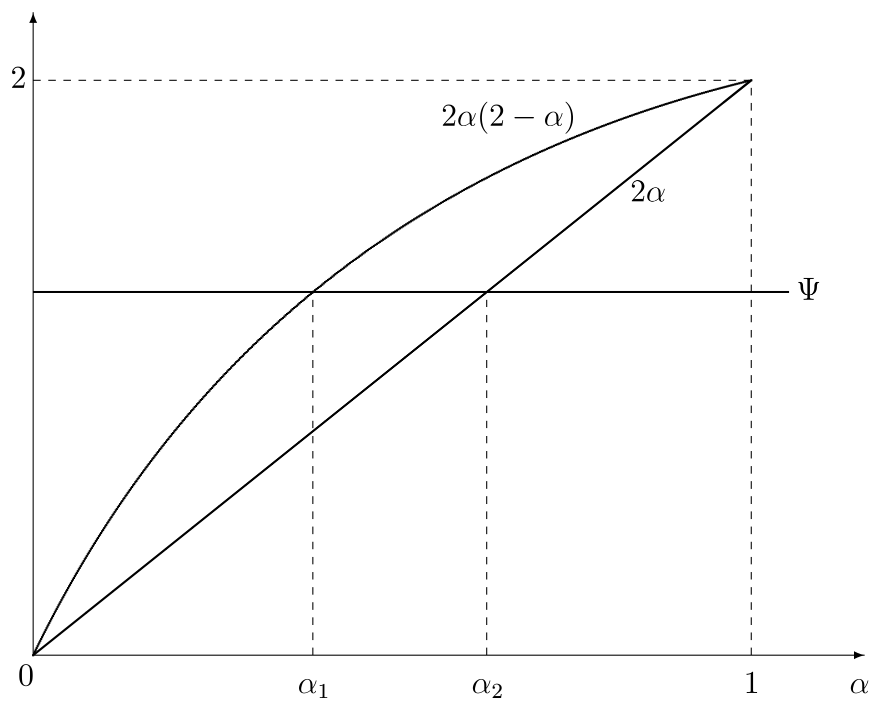
$$\Delta_\pi^{gg,lg} \gtrless \Delta_\pi^{gl,ll} \, \forall \, 2\alpha\,(2-\alpha) \gtrless \frac{\pi_M - F + \Gamma}{\pi_M - \pi_D} \equiv \Psi > 1, \tag{14}$$

$$\Delta_\pi^{gg,lg} \gtrless \Delta_\pi^{gg,ll} \, \forall \, 2\alpha \gtrless \frac{\pi_M - F + \Gamma}{\pi_M - \pi_D} \equiv \Psi > 1, \tag{15}$$

$$\Delta_\pi^{gg,ll} > \Delta_\pi^{gl,ll} \text{ always.} \tag{16}$$

The fact that inequality (16) is met over the entire admissible parameter space means that if a firm finds that the case where she invests in R&D and her rival buys the pollution right is more profitable than the case in which both take part in the lottery for pollution rights, certainly she prefers the symmetric green R&D outcome rather than the symmetric lottery; therefore, $E\pi^{GG} > E\pi^{GL}$. In order to assess the sign of the other two inequalities, in figure 1 we plot the two curves $2\alpha\,(2-\alpha)$ and 2α and the straight line Ψ. Depending on the value of α, we have three domains where the sign of the inequalities changes: $(0,\alpha_1)$, (α_1,α_2) and $(\alpha_2, 1)$.

Figure 1 :



For $\alpha \in (0,\alpha_1)$,[5] we have $\Delta_\pi^{gg,lg} < \Delta_\pi^{gl,ll}$ and $\Delta_\pi^{gg,lg} < \Delta_\pi^{gg,ll}$. Thus, if $F-K$ is high

[5]It is worth mentioning that since $\Psi > 1$, this region always exists. In the cases $\Gamma > \pi_M - 2\pi_D + F$ or $\pi_D \gg F$, Ψ could become higher than 2 and, therefore, $\alpha_1 = 1$.

enough (i.e. the cost of R&D is sufficiently lower than the cost of pollution rights) such that $\Delta_{\pi}^{gg,lg} > 0$, both firms find it profitable to invest in green technologies and (G, G) is the Pareto efficient equilibrium of matrix 1. If instead $F - K$ is sufficiently low such that $\Delta_{\pi}^{gl,ll} < 0$, the equilibrium of the game is (L, L). The remaining situation is where $\Delta_{\pi}^{gg,lg} < 0$ and $\Delta_{\pi}^{gl,ll} > 0$. In this case, as it is discussed in Proposition 1, we have asymmetric equilibria along the secondary diagonal in chicken game where one firm buys the pollution right while the other invests in green technology.

In the region $(\alpha_1, 1)$, we have $\Delta_{\pi}^{gg,lg} > \Delta_{\pi}^{gl,ll}$. Therefore, if $\Delta_{\pi}^{gl,ll} > 0$, the unique and Pareto efficient equilibrium is (G, G). Where instead $\Delta_{\pi}^{gg,lg} < 0$, the equilibrium is (L, L) and in (α_1, α_2) this is a Pareto inefficient equilibrium of a prisoner's dilemma game. In the other cases (i.e. $\Delta_{\pi}^{gl,ll} < 0$ and $\Delta_{\pi}^{gg,lg} > 0$), the matrix becomes a coordination game with the two equilibria on the main diagonal of matrix 1, i.e., either both firms participate in the lottery or both invest in search of the green technology. In such a coordination game and in the region $(\alpha_2, 1)$, we have $E\pi^{GG} > E\pi^{LL}$.

The above discussion yields the following result:

Proposition 1 *A chicken game, with $E\pi^{GL} > E\pi^{LL}$ and $E\pi^{LG} > E\pi^{GG}$ and therefore (G, L) and (L, G) are Nash equilibria, may arise provided that Γ and α are sufficiently large. Otherwise, only symmetric equilibria are observed.*

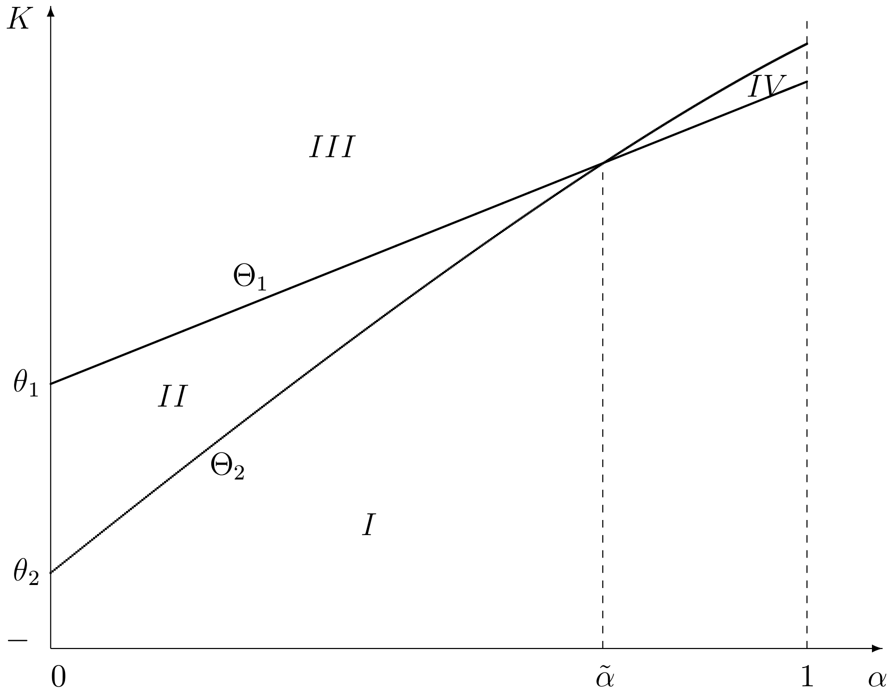
Proof. Considering (11) and (12), we have

$$\Delta_{\pi}^{gl,ll} > 0 ... \forall .. K < -\frac{1}{2}\pi_M + \alpha\pi_D - \left(\frac{1}{2} - \alpha\right)\Gamma + \frac{1}{2}F \equiv \Theta_1, \tag{17}$$

$$\Delta_{\pi}^{gg,lg} < 0 ... \forall .. K > -(1-\alpha)^2\pi_M - \alpha(1-\alpha)\pi_D - (1-\alpha)\Gamma + F \equiv \Theta_2. \tag{18}$$

It is obvious that both Θ_1 and Θ_2 are upward sloping with respect to α. In figure 2, we plot the two curves Θ_1 and Θ_2 against α.

Figure 2 :



In this figure, as it can be checked from (17) and (18), at $\alpha = 0$, we have $\theta_2 \left(= F - \pi_M - \Gamma\right) < \theta_1 \left(= \frac{1}{2}\left(F - \pi_M - \Gamma\right)\right) < 0$. There could be an intersection, $\tilde{\alpha}$, between the curves provided that $\Gamma < \pi_M - 2\pi_D + F$, otherwise, $\tilde{\alpha} = 1$. This yields $\Theta_1 > \Theta_2$ in the region $(0, \tilde{\alpha})$. Therefore, there exists a viable range of parameters between the two curves, region II, where matrix 1 becomes a chicken game with asymmetric equilibria along the secondary diagonal of the 2×2 game where one firm buys the pollution right and the other goes for the green technology. However, in the vicinity of $\alpha \rightsquigarrow 0$, in order to have at least one firm investing in green technologies K should be negative, which is economically inadmissible. Thus the probability of successful innovation must be high enough so as for the firms to have an incentive to invest in R&D. Finally, in regions I, III and IV we observe a pure coordination game along the main diagonal, as both (G, G) and (L, L) are Nash equilibria.

■

5 Social optimum

We are now in a position to put together consumers' likings and firms' incentives so as to evaluate social preferences according to the expected welfare levels arising in the three possible cases.

Since the pollution permit fees are going to be redistributed across consumers, the social planner decides only on the basis of K (and not F). Then, the expected amount of social welfare in each case is as follows:

$$ESW^{GG} = -2K + 2\alpha(1-\alpha)SW_M + \alpha^2 SW_D - 2(1-\alpha)\Gamma, \tag{19}$$

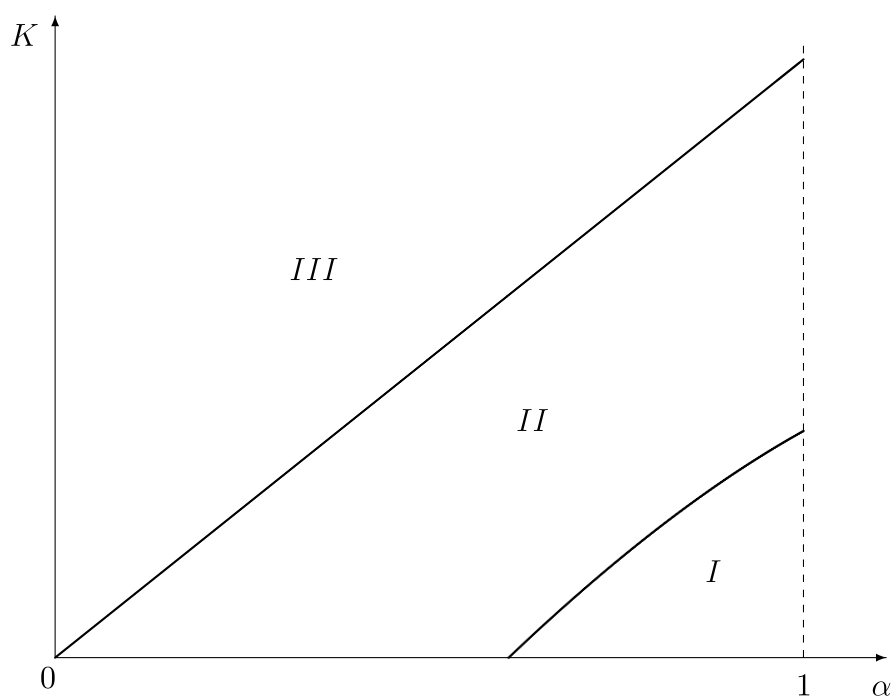
$$ESW^{LG} = ESW^{GL} = -K + (1-\alpha)SW_M + \alpha SW_D - (1-\alpha)E_M - \alpha E_D - (1-\alpha)\Gamma, \tag{20}$$

$$ESW^{LL} = SW_M - E_M - \Gamma. \tag{21}$$

in which SW_M and SW_D are the social welfare levels (gross of external effects) in monopoly and duopoly, respectively.

By comparing (19), (20), (21) and knowing that $SW_D > SW_M$ and $E_D < E_M$, we can characterise social preferences in the space (α, K) as in figure 3.

Figure 3: The upper and lower solid curves, respectively, characterise the points where expect



This figure shows that social welfare is highest in GG, LG (or GL) and LL if (α, K) are such that the industry allocation falls in region I, II and III, respectively.

Now, we have to ascertain whether the regions in figure 3 overlap, at least to some extent, with the corresponding regions in figure 2. More precisely, we are looking for conditions ensuring that the two regions labelled as II in figures 2 and 3 do overlap.

Proposition 2 *Provided firms incur a sufficiently large cost to quit the market, there exists a range of parameters wherein profit incentives yield asymmetric equilibria generated by a chicken game where $E\pi^{GL} > E\pi^{LL}$ and $E\pi^{LG} > E\pi^{GG}$ and such equilibria are also socially efficient.*

Proof. In order to prove the validity of this claim, it suffices to observe that there are infinitely many admissible values of F such that the curves delimiting region II in figure 2 intersect the horizontal axis in figure 3 between the origin and the curve dividing regions I and II in figure 3. ■

For illustrative purposes, in the next section we lay out an example based on the linear Cournot model.

6 Example

Consider a market where 2 symmetric firms producing the same homogeneous good with zero marginal cost $c = 0$. The inverse demand function is defined as $p = A - Q$, where $Q = \sum q_i$, $i = 1, 2$ and $q_i \geq 0$ is the individual output of firm i. If firm i wins the lottery or succeeds in her innovation, q_i is strictly positive; otherwise she is not allowed to operate in the market. Accordingly, the industry can be either a monopoly or a duopoly. Therefore, the optimal level of output as well as the corresponding profits are either $q_M = A/2$, $\pi_M = A^2/4$ or $q_D = A/3$ and $\pi_D = A^2/9$, and the resulting social welfare levels (gross of negative externalities) are $SW_M = 3A^2/8$ and $SW_D = 4A^2/9$. To model pollution, we assume that the negative externality is a quadratic function of output, $E = bQ^2/2$. Hence, externalities in the two cases are $E_M = bA^2/8$ and $E_D = bA^2/18$.

Then, plugging profits, social welfare levels and externalities in inequalities (12), (11) and (13), we get

$$E\pi^{GG} > E\pi^{LG} \quad \text{if} \quad k < f - \frac{(1-\alpha)(9-5\alpha)}{36} - (1-\alpha)\gamma, \tag{22}$$

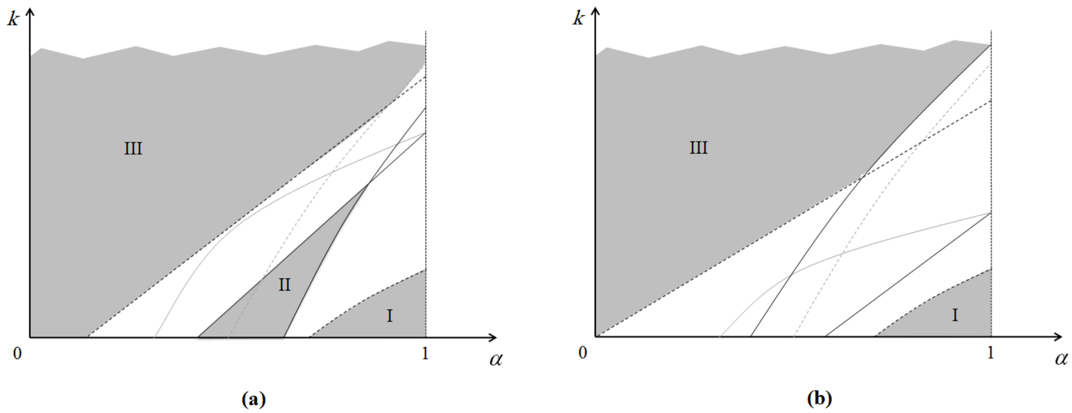


Figure 1: The gray aresa represent the regions where firms' strategic incentives and social incentives are reciprovally aligned. In (a) Γ is strictly positive, in (b) $\Gamma \sim 0$.

$$E\pi^{GL} > E\pi^{LL} \quad \text{if} \quad k < \frac{f}{2} - \frac{(9-8\alpha)}{72} - \left(\frac{1}{2} - \alpha\right)\gamma, \tag{23}$$

$$E\pi^{GG} > E\pi^{LL} \quad \text{if} \quad k < \frac{f}{2} - \frac{(10\alpha^2 - 18\alpha + 9)}{72} - \left(\frac{1}{2} - \alpha\right)\gamma, \tag{24}$$

where $k = K/A^2$, $f = F/A^2$ and $\gamma = \Gamma/A^2$.

Note that, in order for firms to have an incentive to take part in the lottery, F must not be greater than π_D, i.e. $f \leq 1/9$, as the firm participating in the lottery may expect the other firm to come up with new technology.

By comparing (19), (20) and (21) we find

$$ESW^{GG} > ESW^{LG} \text{ if } k < \frac{b(9-5\alpha) - (1-\alpha)(27-22\alpha)}{72} - (1-\alpha)^2\gamma, \tag{25}$$

$$ESW^{GL} > ESW^{LL} \text{ if } k < \frac{5\alpha\,(1+b)}{72} - (\frac{1}{2} - \alpha)\gamma, \tag{26}$$

$$ESW^{GG} > ESW^{LL} \text{ if } k < \frac{9b + 54\alpha - 22\alpha^2 - 27}{72} - \left((1-\alpha)^2 + (\frac{1}{2} - \alpha)\right)\gamma. \tag{27}$$

Now, we can perform a numerical simulations by normalizing all but two parameters. For instance, taking plausible values $b = 1/5$, $f = 1/10$ and $\gamma = 1/10$, we can plot k against α to assess inequalities (22), (23), (24), (25), (26) and (27). The outcome is illustrated in figure 4.

In regions I, II and III, firms and the social planner alike prefer GG, LG (GL) and LL, respectively. Therefore, it can be seen that, when Γ is not close to zero, there indeed exists a viable range of parameters (area II) where we have a chicken game whose equilibria are also welcome from the planner's viewpoint. This confirms our main point that using the instrument of assigning pollution right through the simple lottery we have modelled here may indeed serve the purpose of creating a side incentive for firms losing the lottery in the first place or deciding not to participate in it to take the alternative root which is to finance R&D efforts for green technologies.

7 Concluding Remarks

There are two main lines of research in modelling the abatement of polluting emissions: the optimal assignment of pollution rights and the introduction of corrective taxes or subsidies to internalize the externality and provide firms with R&D incentives that otherwise would not arise spontaneously.

We have taken an alternative route to highlight the possibility that a mechanism for the costly acquisition of pollution rights might actually turn the losers into green innovators. According to our analysis, it seems indeed that controlling pollution rights may exert - somewhat unexpectedly - some positive long-run impacts on the environmental performance of industries by virtue of indirect innovation incentives that can be considered as the side-effect of the allocation of pollution rights.

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