Environmental Standards and Firms’ Competitiveness: A Theoretical Analysis

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ABSTRACT
This paper provides an additional reason why a win-win situation may emerge within the context of a quality-competition framework. We consider a duopoly model of vertical product differentiation, where single product firms decide whether to supply a high or low quality good \( q_i \) as discrete variable, and then, compete in price à la Bertrand. In this simple setting, we found that the framework of this game can ensue in a typical prisoner’s dilemma as a meaning that, in absence of an environmental policy, both firms choose the low environmental quality of the product although they might be better off shifting together toward the environmentally friendly product. Under this circumstance, an environmental policy (e.g. environmental standards) can improve the environmental quality while simultaneously enhancing firms’ economic performance.

KEYWORDS
Porter Hypothesis; Environmental Quality; Vertical Differentiation, Prisoner’s Dilemma; Environmental Standards

1. Introduction
Neoclassical economic literature emphasized that stricter environmental regulation always entails additional costs which have effects on profitability, demand dynamics, innovation, productivity and investment decisions of the touched firms. Porter [1,2] has challenged this traditional view which asserts just the opposite. The main idea behind Porter reasoning is that firms might be not conscious of certain investment opportunities. In particular, more stringent environmental regulations may generate as “win-win” solution, able to make “dynamic” economic agents capable of exploiting such opportunities for innovation and thus, gaining a long-term profitability and a competitive advantage. This perspective is now generally known as the Porter Hypothesis.

The Porter hypothesis was heavily criticized from scholars on the grounds of conventional economic thinking (see, for instance, Palmer [3]). The idea that firms neglect opportunities of innovation or any other decisions that would allow them to improve the economic performance is irreconcilable with the neoclassical view of the firm as a rational profit maximizer agent.

Lately, other authors provided some new interpretations that would allow the Porter result to arise. Such mechanisms are the consequence of the presence of market failures, at different levels, that provide an opportunity for firms to benefit from environmental regulation. In an economic growth context, Hart [4] finds that an environmental policy intervention might boost R & D investments leading to economic growth. Simpson and Bradford [5] through an international trade model content that a stricter environmental regulation might give rise to a shift of competitiveness from foreign to domestic firms owing to the existence of international externalities. Moreover, there are some studies that look at within-firm mechanisms that would lead to the adoption of green innovations as a result of environmental policy. According to Xepapadeas and de Zeeuw [6], stricter environmental regulation generates positive (downsizing and modernization) effects on firms’ competitiveness. Furthermore, Mohr [7] and Greake [8] illustrate some
Within-firm mechanisms through which a more stringent environmental regulation leads firms to adopt new and eco-friendly technologies that could positively affect competitiveness.

In this paper, it provided an additional explanation why a win-win situation could emerge in a framework of vertical product differentiation and full information. The economic intuition at the basis of our idea is the following: firms sometimes have to choose whether to produce a good with a low environmental quality or, through a sustainability transition, jump to produce an eco-friendly good. Although environmentally friendly products lead to increased production costs for firms, consumers reward this effort by readressing, to some extend, their demand toward them and by being willing to pay a higher price for a greener product (see for instance, [9]). However, a firm might be loath to shift to produce high quality goods since this could make it worse off in competing in prices. The reason is that the producers of low quality variant of the good might take advantage in producing goods due to their lower production costs, get a sizable market share and, accordingly, make the introduction of green products in the market not beneficial enough. Nonetheless, if all firms decide to adopt greener technologies in the production processes by offering high quality products, they might together benefit from the higher willingness to pay of consumers without the risk of being exploited by their competitors. In game theory, this scenario is well represented by prisoner’s dilemma in which the Nash equilibrium of the game is Pareto dominated by a different strategy profile that, however, is not an equilibrium since all the agents would have an individual incentive to deviate from it. In our context, environmental policy instruments might give rise to a win-win situation by bringing firms to translate in a sustainable way toward the production of green products and make economic performance of environment and firm be better off.

In this paper, we analyse a vertically differentiated duopoly under complete information, where single product firms decide simultaneously whether to supply a environmental high- or low-quality good \( q_i \) as discrete variable, and then, compete in price \( \text{à la Bertrand.} \) As in the models of vertical product differentiation developed by Mussa and Rosen [10] and Cremer and Thisse [11], each firm offer a good of environmental quality \( q_i \), which can be high \( (i = H) \) or low \( (i = L) \) and compete in price \( p_i \). Production costs are given by: \( C_i(x) = F_i + c_i x^2 \), where \( x \) indicates the output level and \( F_i, c_i \) are cost-specific parameters.

Let \( p_i \) be the price of the good with quality \( q_i \), then the individual firm’s profit function is:

\[
\Pi_i = (p_i x - C_i(x)), i = H, L.
\]

In the derivation of the demand side we adopt largely the same setup as in Mussa and Rosen [10]: there is a continuum of consumers differing in the environmental concern, and the consumer types are identified by the index \( \theta \), uniformly distributed with density equal to one in the interval \([0,1]\). Parameter \( \theta \) represents the consumers’ marginal willingness to pay for a good produced according to green standards. Each consumer buys at most one unit of variety \( i = H, L \), whereby his/her net utility (or consumer’s surplus) is \( u_i(\theta) = \theta q_i - p_i \) if he/she buys a good of environmental quality \( q_i \) at price \( p_i \) and zero if he/she does not buy any good. Therefore, \( \theta q_i \) represents the willingness to pay for quality \( q_i \), \( p_i \) the price of product \( i \).

3. Price and Quality Competition

We are now in a position to examine our two-stage game. The time structure of the game is as follows:

1) At stage 1 the two firms decide simultaneously the level of the environmental quality for their goods.
2) At stage 2 firms choose their prices \( p_{i}, i \in \{H, L\} \) simultaneously, consumers decide from which firm to buy, and payoffs are realized (see Figure 1).

On the basis of firm’s choices, the market might have three different patterns:
1) Both firms decide to produce the low quality variant of the good;
2) Both firms decide to produce the high quality variant and sell the eco-friendly good;
3) The two firms opt for different quality configurations of the good.

The first two cases entail homogeneous product, while the third results in a market with vertical differentiated products. The construction of the demand system is obtained by computing it for each quality mix. Denoting with \( q_{i} \) and \( q_{j} \) the price set and the demand faced by a firm producing with quality \( q_{i} \) when its rival produces with quality \( q_{j} \) (\( i, j = L, H \)).

Assume first the case where firms supply different quality levels. In this case the options for consumer are:
1) choosing the high environmental quality of the good;
2) choosing the low environmental quality of the good;
3) not buying.

We define the critical willingness to pay \( \theta^{H} \) at which the consumer is indifferent between buying the high and low quality good, and the critical willingness to pay \( \theta^{L} \) at which the consumer is indifferent between purchasing the low quality good or not buying at all. A consumer with environmental awareness \( \theta \) will buy the high environmental quality \( q_{H} \) if and only if \( \theta q_{H} - p_{HL} \geq \theta q_{L} - p_{LH} \), from which we get
\[
\theta^{H} = \frac{p_{HL} - p_{LH}}{q_{H} - q_{L}}.
\]

Similarly, we can obtain
\[
\theta^{L} = \frac{p_{LH}}{q_{L}}.
\]

Since \( \theta \) is uniformly distributed over the interval \([0,1]\), the demand for the high quality variant is given by:
\[
X_{H} = 1 - \theta^{H} = 1 - \frac{p_{HL} - p_{LH}}{q_{H} - q_{L}}.
\]

and the demand for the low quality good is:
\[
X_{L} = \theta^{H} - \theta^{L} = \frac{p_{HL} - p_{LH} - p_{LH}}{q_{H} - q_{L}}.
\]

Secondly, assume that both firms offer the same environmental quality \( q_{i} \). In this context, consumers could either buy one unit of good or not buy.

Let us assume first that both firms opt for producing goods with high environmental quality \( q_{H} \). For a consumer of type \( \theta \) it is optimal to purchase one unit of the product if and only if \( \theta q_{i} - p_{i} \geq 0 \), being \( p_{H} \) in this case the lowest available price in the market. Hence the market demand of a good with high environmental quality is given by the mass of consumers with \( \theta \geq \frac{p_{i}}{q_{i}} \), i.e.,
\[
X_{H} = \max \left\{ 1 - \frac{p_{i}}{q_{i}}, 0 \right\}.
\]

3.1. Price Competition Game

We solve the game backwards starting from the second stage, the price game. Firms choose prices subject to their previous choices for the environmental quality. When firms offer different environmental qualities and compete in prices, they choose \( p_{HL} \) and \( p_{LH} \) in order to maximize the following function:
\[
\max_{p_{HL}} \pi_{HL} = \left( p_{HL} - c_{H} \right) \left( 1 - \frac{p_{HL} - p_{LH}}{q_{H} - q_{L}} \right) - F_{H}
\]

and
\[
\max_{p_{LH}} \pi_{LH} = \left( p_{LH} - c_{L} \right) \left( \frac{p_{HL} - p_{LH}}{q_{H} - q_{L}} - \frac{p_{LH}}{q_{L}} \right) - F_{L}
\]

From the First Order Condition (FOC) we obtain the following reaction functions:
\[
\frac{\partial \pi_{HL}}{\partial p_{HL}} = \frac{\left(q_{H} - q_{L}\right)^{2} + 2p_{LH} \left(q_{H} - q_{L}\right) + 2c_{H} \left(q_{H} - q_{L}\right)}{2 \left(q_{H} - q_{L}\right)^{2}}
\]

\[
\frac{\partial \pi_{LH}}{\partial p_{LH}} = \frac{q_{H}^{2} \left(q_{H} - q_{L}\right) p_{HL} + 2c_{L} q_{H} q_{L} p_{HL}}{2q_{H} q_{L} \left(q_{H} - q_{L}\right) + 2c_{L} q_{H}^{2}}
\]

From the above system of equations it is possible to

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**Figure 1.** Time structure of the model.
derive the prices at equilibrium, from them the quantities and finally the profits.

With regard to the firm producing low quality good we obtain:

\[ p^*_L = \frac{q_L (q_L - q_L) + 2c_L q_H) (q_H - q_L + 2c_H)}{\psi^*} \]

\[ x^*_L = \frac{q_L q_H (q_H - q_L + 2c_H)}{\psi^*} \]

\[ \pi^*_L = \left( \frac{q_L q_H (q_H - q_L + 2c_H)}{\psi} \right)^2 \times q_L (q_L - q_H + c_L q_H) - F_L \]

while for the firm producing the environmental friendly good we obtain:

\[ p^*_H = \frac{2q_H (q_L (q_H - q_L) + c_L q_H) (q_H - q_L + 2c_H)}{\psi^*} \]

\[ x^*_H = \frac{2q_H (q_L (q_H - q_L) + c_L q_H)}{\psi^*} \]

\[ \pi^*_H = \left( \frac{2q_H (q_L (q_H - q_L) + c_L q_H)}{\psi} \right)^2 \times (q_H - q_L + 2c_H) - F_H \]

with

\[ \psi = 4q_H (q_L (q_H - q_L) + q_L c_H + q_H c_L + c_L c_H) \]

\[ - q_L (q_L (q_H - q_L) + 2q_L c_H + 2q_H c_L) \]

When both firms offer the same environmental quality \( q_a \), the market structure is given by two symmetric firms competing in prices that sell a homogeneous good. Let \( \Pi^a \left(p^a_u, p^a_b \right) = \pi^a_x x^a - c_i \left(x^a \left(p^a_u, p^a_b \right) \right) \) denote the profits of firm \( a \) in this symmetric quality game when it sets price \( p^a_u \) and its competitor sets price \( p^a_b \).

The characterization of the equilibrium price in the symmetric case departs from the classic Bertrand paradox with price equal to marginal cost (which is the unique Nash equilibrium when firms have constant marginal costs), due to the existence of strictly convex costs. In fact, Dastidar [12] proved that in a Bertrand model with symmetric firms and strictly convex costs the Nash equilibria are necessarily non-unique. Specifically, a pure strategy Nash equilibrium is characterized by both firms setting the same price \( p^*_u \), which is bounded by two thresholds: \( p_L \leq p^*_u \leq p_H \), where \( p_L \) and \( p_H \) are defined by the following condition:

\[ \Pi^a \left(p^*_u = p^*_L, p^*_b = p^*_L \right) = -F_i \]

\[ \Pi^a \left(p^*_u = p^*_H, p^*_b = p^*_H \right) = p^*_L X_i \left( p^*_H \right) - c_i \left( X_i \left( p^*_H \right) \right) \]

In words, \( p_L \) is the lowest price compatible with an equilibrium and it is defined as the price that equals average variable costs, making firms indifferent between producing at \( p_L \) and not producing. While \( p_H \) is the highest price compatible with a Nash equilibrium and it is defined as the price such that every firm is indifferent between setting the equilibrium price \( p_L \) (and hence splitting the demand evenly) and cutting marginally the price in order to exclude its rival and serve the whole demand.

For each game, the location of the equilibrium price in the interval \([p_L, p_H] \) can be interpreted as the degree of strength of price competition. The situation with \( p^*_u = p_L \) can be seen as the one with the toughest competition and \( p^*_u = p_H \) as the one with the mildest competition. Following Dastidar [12], and depending on the degree of price competition, the price \( p^*_u = p^*_L = p^*_H \), the demand faced by each firm \( x^*_u = x^*_L = x^*_H \) and firm profits \( \Pi^*_u = \Pi^*_L = \Pi^*_H \) in equilibrium can be parameterized in the following way:

\[ p^*_u = \frac{c_i q_L}{c_i + (2 - \Phi) q_L} x^*_u = \frac{q_L (2 - \Phi)}{2 \left( c_i + (2 - \Phi) q_L \right)} \]

\[ \Pi^*_u = p^*_u x^*_u - c_i \left( x^*_u \right) = \frac{c_i q_L (2 - \Phi)}{4 (c_i + (2 - \Phi) q_L)^2} - F_i \]

where \( \Phi \) represents the (inverse of the) intensity in the price competition and it can assume values in the interval \([0, 4/3] \). In particular \( \Phi = 0 \) corresponds to the case \( p^*_u = p_L \), while \( \Phi = 4/3 \) corresponds to \( p^*_u = p_H \) and \( \Phi = 1 \) corresponds to the Bertrand reference case of price equal to marginal cost.

### 3.2. Quality Choice Game

As we said before, firms at first stage decide the environmental quality of the good they are willing to produce: \( q_H \) or \( q_L \) by focusing on the consequences of their choice for the second stage. It is possible to describe the environmental quality game of the firms as a simultaneous game in classical form as follows:

| FIRM 2 | \( q_u \) | \( q_L \) |
|--------|---------|---------|
| FIRM 1 | \( q_a \) | \( (x^u_a, x^u_a) \) | \( (x^u_a, x^u_a) \) |
|        | \( q_L \) | \( (x^u_L, x^u_L) \) | \( (x^u_L, x^u_L) \) |

In game theory, the Nash equilibrium is a solution concept of a non-cooperative game involving two or
more players, in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only their own strategy unilaterally. If each player has chosen a strategy and no player can benefit by changing strategies while the other players keep theirs unchanged, then the current set of strategy choices and the corresponding payoffs constitute a Nash equilibrium. Therefore, the prevailing quality mix of the firms will be the Nash equilibrium of this game.

4. Environmental Standards and the Porter Hypothesis

The aim of this study is to try to answer the following questions: is it possible that both firms be explicitly better off as a result of an intervention of environmental policy? And if it is possible, which are the economic instruments that allow this result? Let us assume that the government implements a new policy designed to promote the use of more environmentally friendly technologies in order to discourage the production of the standard (low quality) variants of a given good.

In order to simplify the exposition we concentrate on a simple instrument such as an environmental quality standard that forces firm that produce the low quality variant of the good to adopt a new and greener technology. For a given amount of investments necessary to comply with an environmental standard (S), the regulated environmental quality decision can be viewed a simultaneous game in normal form as follows:

\[
\begin{array}{c|cc}
 & q_H & q_L \\
\hline
q_H & (\pi_{HH}, \pi_{HL}) & (\pi_{HH} - S, \pi_{HL}) \\
q_L & (\pi_{HL} - S, \pi_{HL}) & (\pi_{HL} - S, \pi_{HL} - S) \\
\end{array}
\]

From the above game matrix is possible to perceive the intuition behind our model of vertical product differentiation and show how it could essentially yield a win-win outcome and, as a consequence, provide additional support for the Porter’s hypothesis. The economic idea at the basis of this result can be explicated as follows. If firms in our model are trapped at an equilibrium that is not Pareto efficient \((q_H, q_L)\), then a proactive and new environmental policy (i.e. environmental standard) might make both firms better off allowing them to exploit a greater willingness to pay of consumers for high environmental quality products. To better understand, let us think about a situation where firms are producing a good with a low environmental quality \((q_L)\) and there is a more environmentally friendly alternative available \((q_H)\). In this circumstance, even if both firms would enjoy an higher profit from a concerted choice to adopt the higher quality good, it would be quite unlikely to do so individually because such decision could virtually expose it to the opportunistic behaviour of the rival that might place on the market the low quality good at a lower price, getting a large share of the market and thus, an higher payoff. In this scenario, environmental standard might lead a win-win situation by motivating one or both firms to shift on a more sustainable and profitable production. Briefly, this idea can be summarized in the following proposition:

**Proposition 1:** An environmental standard will give rise to a win-win situation if the Nash equilibrium of the game observable in a context of a public intervention generates higher payoffs for both firms than those gained by a Nash equilibrium of the quality game in absence of an environmental policy.

Generally, the win-win situation is achievable with any equilibrium pattern that ensures higher payoff for firms on one hand, and a reduced environmental damage on the other hand. However, the idea we emphasised before suggests that this result arises when the equilibrium of the game moves from \((q_H, q_L)\) in the absence of environmental policy to \((q_H^*, q_L^*)\) when standards have been set. We start with two examples through which our model of vertical differentiation can actually replicate this theoretical possibility in order to better understand the necessary and sufficient conditions under which a win-win situation can emerge.

**Example 1**

Let us imagine that producers of plastic bags in a given market have to decide either to continue using regular plastic \((q_L)\) or to start producing plastic bags using bio-plastic derived from bio-waste valorisation \((q_H)\). Those firms that decide to make their product eco-friendly would not have to buy new equipment or other tools in order to shift their modes of production, but we suppose that they would sustain only higher input costs (for example, they would have to buy bio-plastic derived from bio-waste at an higher price). Namely, the quality shift would generate an increase only in marginal costs of production. Moreover, let us assume that this market is a duopoly described by the following parameter configuration:

\[q_{L, 0} \quad q_{H, 0}\]

1All of the relevant results are compatible with other environmental policy instruments. The simplest and most straightforward alternative to this strategy would be to impose a penalty or a lump-sum tax on those firms that produce the low environmental quality of the good. This lump-sum tax could be interpreted as a license that must be purchased by any firm wishing to produce goods of quality \(q_L\).

2We assume the existence of a well-established technological alternative to the current one.
Now, through some straightforward computations the related payoff matrix for environmental quality decision game result to be:

|        | FIRM 1 | FIRM 2 |
|--------|--------|--------|
|        | $q_u$  | $q_l$  | $q_u$  | $q_l$  |
| FIRM 1 | (6.48, 6.48) | (6.15, 5.42) |
|        | (5.42, 6.15) | (6.24, 6.24) |

It is worth to mention that the above game has the structure of a typical prisoner’s dilemma paradigm in which the unique Nash equilibrium, $(q_l, q_l)$, is not efficient from the perspective of firms because both producers of plastic bags would be better off if they were able to set an agreement to use only bio-plastic derived from bio-waste. However, the second outcome is not a Nash equilibrium, since each firm has incentives to deviate from it.

Now assume that the government set an environmental standard S to be complied with on any producer that continues to use regular plastic. The new pay off matrix of the quality choice game is now the following:

|        | FIRM 2 |
|--------|--------|
|        | $q_u$  | $q_l$  |
| FIRM 1 | (6.48, 6.48) | (6.15 – S, 5.42) |
|        | (5.42, 6.15 – S) | (6.24 – S, 6.24 – S) |

The new payoff matrix shows that the environmental standard forces low quality producers to adopt a greener technology, giving rise to compliance costs, in such a way as to reduce the payoffs of some of them who would like to behave opportunistically without increasing those of others producers. At first sight, the policy would seem to be totally detrimental to the whole industry. However, it is easy to understand that, for any environmental standard S that implies higher production costs ($S > 7.70$), the Nash equilibrium of the game shifts to $(q_l, q_l)$. As a result, if we look at the previous and subsequent equilibrium payoff and compare them, we will find that the profits of both plastic bags producers increase when a sufficiently high environmental standard is set. The economic intuition at basis of this result is that in the original quality choice game, both producers would be better off if they would have shifted together from $q_l$ to $q_H$. However, this does not occur since the firm that choose to produce the eco-friendly good would be worse off given the opportunistic behaviour of its rival. In particular, by producing the low quality good (i.e. plastic bag using regular plastic) the producer would sustain a lower cost, thus charging a lower price and, as a consequence, gains a large share of the market. Therefore, the environmental standard is able to suppress this opportunistic behaviour and, consequently, solve the coordination failure in the industry.

**Example 2**

Now let us think about an industrial market in which the producers of a certain good make use of engines fuelled with a very polluting fossil fuel $(q_l)$. These firms could decide to shift to a cleaner fuel $(q_H)$ that entails the same unit cost and that generates the same heat power, if compared with the polluting one. Therefore, the only requirement is the installation of new engines. In this case, the better environmental quality of a product does not affect its variable costs, but rather it implies a fixed cost of adoption (i.e. buying a new engine). Moreover, let us assume that this market is still a duopoly described by the following parameter configuration:

$$(q_{H}, q_{L}, F_{H}, F_{L}, c_{H}, c_{L}, \Phi) = (110, 100, 0.7, 0, 200, 200, 1.3)$$

through some straightforward computations, the related payoff matrix for environmental quality decision game results to be:

Differently from the previous example the structure of this game is no longer consistent with a prisoner’s dilemma since both $(q_{L}, q_{L})$ and $(q_{H}, q_{H})$ are Nash equilibria considering that all other quality choice combinations $(q_{L}, q_{H})$ and $(q_{H}, q_{H})$ entail smaller payoffs for duopolists. Moreover, the fact that the high quality equilibrium $(q_{H}, q_{H})$ dominates the low quality one $(q_{L}, q_{L})$ from the firms’ perspective provides possibility for a win-win situation to appear. To this end, let us assume now that the government set an environmental standard S to be complied with on any producer that continues to use regular engines fuelled with fossil fuel in order to drastically reduce polluting emissions. The new pay off matrix of the quality choice game is now the following:

Still, the above payoff matrix shows as an environmental standard, by discouraging the production of low quality variant of the good, solves the coordination failure between producers. In particular, in this case, the environmental policy eliminates the multiplicity of equilibria and makes the most efficient equilibrium $(q_{H}, q_{H})$ prevailing. To this end, it is suffices to set an environmental standard S causing compliance costs greater than 0.09 on those firms opting for low quality variant of the good for having a unique Nash equilibrium of the game $(q_{H}, q_{H})$. Consequently, if we look at the previous Nash equilibria and at the subsequent ones, we will find that
the profits of producers increase as a result of an environmental policy.

The above examples show, at first glance, that a win-win result can theoretically emerge irrespective of the nature of the cost increases generated by any given quality improvement of the products. Moreover, such a result is directly dependent on the occurrence of certain conditions. In the next section, we will formalize the necessary and sufficient condition in order to obtain an improvement either on the firms' economic performance than on environmental point of view as a result of an environmental policy.

5. Deriving the Win-Win Equilibria Conditions

As discussed above, we are considering a model of vertical product differentiation where two firms simultaneously choose the environmental quality of the good they produce - which can either be high \((q_H)\) or low \((q_L)\) - and subsequently compete on price à la Bertrand. We are now in a position to formalize what does it mean to achieve a win-win configuration in this framework and what conditions need to be met.

Firstly, an environmental policy (characterised, for example, by an environmental standard enforced on those firms which produce the low quality variant of the good) will give rise to a win-win configuration if the Nash equilibrium of the game resulting from such policy provides higher payoffs for both firms than those achieved with a Nash equilibrium of the game in absence of an environmental public policy (unregulated game). Taking into account the original definition of a win-win configuration, we know from the Porter’s contributions [1,2] that it is compatible with any equilibrium outcome. However, the previous specification suggests that such configuration arises when the equilibrium of the game moves from \((q_L, q_L)\) in the absence of environmental regulation to \((q_H, q_H)\) once regulation have been implemented and such shift implies higher payoffs for both firms.

Secondly, an environmental policy (i.e. environmental standard imposed on those firms which produce the low quality variant of the good) will lead to a win-win configuration only if \((q_L, q_L)\) is a Nash equilibrium of the unregulated quality choice game and \((q_H, q_H)\) is the unique Nash equilibrium of the game resulting from such environmental policy. Namely, in order to achieve a win-win outcome, the early equilibrium of the game needs to be different from the one resulted from regulation. If not, the establishment of an environmental standard would not have effect on firms’ payoffs. Moreover, a win-win situation will never arise if the environmental regulation brings only one firm to modify its production strategy. This is a simple characterization of revealed preference and, as emphasized by Echenique et al. [13], it has a straightforward understanding since a possible unilateral strategy change was already available in the unregulated game and no firm find it optimal to alter its strategy. Therefore, the necessity of a simultaneous strategy change, and the fact that the firms are symmetric, ensures that a win-win result can be obtained only if environmental regulations lead firms to shift from the initial equilibrium \((q_L, q_L)\) to the final and unique equilibrium \((q_H, q_H)\).

From the above propositions it is immediate to obtain the following result, which provides us the necessary and sufficient conditions under which environmental regulation can yield an increase in firm payoffs in terms of profits.

**Necessary and Sufficient Conditions:** Environmental regulation can provide a win-win configuration if and only if the resulting conditions are met:

\[
S > \max\left\{\pi_{LL} - \pi_{HH}, \pi_{LL} - \pi_{HH}^*\right\} \quad (1)
\]

\[
\pi_{HL}^* < \pi_{LL} < \pi_{HH}^* \quad (2)
\]

1) Condition 1 entails that the implementation of an environmental standard \(S\) is able to make the configuration \((q_H, q_H)\) the unique Nash equilibrium of the environmental quality decision game after policy intervention. In this context, \(S > \pi_{LL}^* - \pi_{HH}^*\) is required to switch on the desired equilibrium configuration (in the first example, \(S > \pi_{LL}^* - \pi_{HH}^* = 16.49 - 8.79 = 7.70\) was the condition able to eliminate any opportunistic behaviour of firms), and \(S > \pi_{LL}^* - \pi_{HH}^*\) is similarly required to avoid \((q_L, q_L)\) from being an equilibrium and allow thus, \((q_H, q_H)\) to be the unique Nash equilibrium of the game.

2) Condition 2 is twofold. The first inequality \(\pi_{LL}^* < \pi_{HH}^*\) allows us to understand that \((q_L, q_L)\) is an equilibrium configuration of the quality choice game in absence of environmental regulation. The second inequality \(\pi_{LL}^* < \pi_{HH}^*\) is crucial since ensures that both firms would benefit if they concurrently shift from the early equilibrium outcome \((q_L, q_L)\) to the high quality variant equilibrium of the game \((q_H, q_H)\).

It is easy to check that the first condition \(S > \max\left\{\pi_{LL} - \pi_{HH}, \pi_{LL} - \pi_{HH}^*\right\}\), given a value of \(S\) sufficiently high, is always met. What is really relevant for a win-win situation to arise is the fulfilment of the second condition. Moreover, looking at the above conditions, two particular scenarios could emerge if we consider the further fulfilment of slightly different conditions. On the one side, considering that first condition always holds let us assume that not only the second condition is met but additionally the inequality \(\pi_{HH} > \pi_{LL}^*\) result to be true in the first stage of the quality choice game. As it was shown in the first example, the fulfilment of this
condition makes \((q_L, q_H)\) the only possible Nash Equilibrium of the game. This configuration corresponds to a classical prisoner’s dilemma paradigm in which the new environmental regulation succeeds in shifting firm interests away from a not optimal equilibrium outcome. On the other side, we may assume just the opposite, that is \((\pi^*_{LH} < \pi^*_{HH})\). In this scenario, the structure of the quality choice game is no longer consistent with a prisoner’s dilemma paradigm since both \((q_L, q_L)\) and \((q_H, q_H)\) are Nash equilibria – considering that all other quality choice combinations \((q_L, q_H)\) and \((q_H, q_L)\) entail smaller payoffs for firms – and the environmental regulation serves to dissuade the production of low quality goods in order to eliminate the multiplicity of equilibria and to guarantee the occurrence of a “desired” equilibrium in which both economic and environmental performance are achieved.

The examples presented in the previous section provided an exemplification of such possible scenarios allowing our model of vertical product differentiation to answer the research questions objective of this study.

6. Concluding Remarks

In this paper, we analysed a vertically differentiated duopoly under complete information, where single product firms decide whether to supply a high or low quality good \((q)\) as discrete variable, and then, compete in price \(à la\) Bertrand. We found that the framework of this game could ensue in a typical prisoner’s dilemma as a meaning that, in absence of an environmental policy, firms choose the low environmental quality of the product although they might be better off shifting together toward the environmentally friendly product. Under this circumstance, an environmental policy could improve the environmental quality while simultaneously enhancing firms’ economic performance. In order to obtain our results, we concentrated on a particular environmental policy instrument: an environmental standard that forces firms to produce the high quality variant of the product. This instrument was able to determine a shifting toward a new profit-enhancing configuration by solving a coordination failure.

This coordination effect might be carried out to involve further forms of the environmental regulation. A concrete alternative could be to set a lump-sum tax on those firms producing the low quality goods. Analogous effects could also appear applying a Pigouvian tax that makes low quality variant of the good more costly for firms with respect to the high quality variant.

It is opportune to stress the fact that, among our model’s assumption, environmental quality of the product has been thought as a discrete decision for firms results to be central in order to derive our findings. First of all, because this assumption permits having equilibria in which firms opt for the same quality variants. Second, the opportunity to achieve a win-win situation rests strongly on the restricted possibility of choosing on quality levels for firms.

Finally, it is worth stating that our findings provide a theoretical basis for the Porter hypothesis. It focuses on a pure market mechanism rather than on any market failure that offers a field for environmental regulation to benefit firms.

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