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"Green" Managerial Delegation and Environmental Corporate Social Responsibility in Different Market Structures

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Abstract

Purpose: Assuming a duopoly industry with pollution producing processes, the aim of this work is to study the firms' choice to engage in Environmental Corporate Social Responsibility (ECSR) by means of "green" managerial delegation, i.e. hiring managers with preferences for environmental concerns to whom owners delegate both sales and decisions to adopt green technology.

Methodology: Depending on the firms' strategic choices, a two/three-stage game takes place solved by the backward induction method to obtain sub-game perfect Nash equilibria.

Results: When the market structure is a Cournot duopoly, and the environmental sensitivity of "green" managers is extremely low, then the engagement in ECSR is the firms' dominant strategy, regardless of the efficiency level of the available abatement technology. Nonetheless, firms are cast into a prisoner's dilemma. On the other hand, if "green" managers have low-intermediate to intermediate environmental sensitivity, then either no ECSR, multiple symmetric equilibria, or ECSR engagement can emerge as a result in equilibrium. Finally, if managers' environmental sensitivity is adequately high, then firms do not engage in ECSR. When a market entry game is considered with the Stackelberg competition in which the incumbent adopts ECSR while the entrant does not, socially responsible behaviors cause the market to be more contestable. However, the incumbent's owners can use ECSR to secure a dominant position in the market, provided that they hire "green" managers with adequate environmental concerns.

Implications: In the case of entry, non-trivial policy implications arise. Due to increased competition, the welfare of consumers improves (lower prices for the goods). However, the entry of a polluting firm increases emissions. Higher emissions damage consumers and lower the overall social welfare of an environmentally concerned government. Thus, a complete welfare analysis is required prior to the design of a government's regulatory intervention.

Originality/Value: This paper is the first that introduces the figure of the "green" manager who shows, in its utility function, an environmental concern.

Keywords: environmental corporate social responsibility, "green" managerial delegation, duopoly, monopoly, entry deterrence

JEL: L12, L13, L21, M14

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Introduction

In recent decades, companies' adoption of socially responsible behaviors has become a common business practice, particularly the engagement in Environmental Corporate Social Responsibility (ECSR), such as reducing carbon emissions. In fact, KPMG (2015) states that the worldwide rate of carbon reporting of the G250 Fortune Index (the largest global multinationals) is 82%, with rates ranging in the 14 surveyed sectors from 67% (personal and household goods) to 100% (food and beverages). Moreover, on August 19, 2019, more than 180 CEOs of the largest worldwide corporations announced a change of paradigm for big business. In fact, they now believe that firms should serve stakeholders and shareholders in several ways; one of the most relevant is through environment protection (The Economist, 2019). All of those companies are characterized by the separation between ownership and control, which is delegated to managers.

Using a modern game-theoretic approach, Vickers (1985), Fershtman and Judd (1987), and Sklivas (1987) show that the rationale for the separation between ownership and control can be essentially based on strategic reasons: hiring managers instructed to behave more aggressively in the market, forcing rivals to reduce output, and raising market shares and profits. In an oligopoly context, those authors find that the hiring of managers represents a firm's dominant strategy. Nonetheless, profits without managerial delegation would be higher; therefore, firms face a prisoner dilemma situation. However, those authors abstract from the fact that large companies want to follow ECSR.

Maxwell et al. (2000) and Antweiler (2003) affirm that companies spontaneously adopt ECSR to neutralize regulatory threats from governments, which allows companies to circumvent more severe regulations. Lee and Park (2019) are the first authors that introduce an explicit environmental incentive into a managerial compensation contract. In a sequential price competition game, the authors analyze the polluting firms' strategic choice of adopting ECSR, measured by an internal emission price on the damage each firm produces and determined by the owners of the firm. The compensation structure each manager receives is a linear combination of profits and ECSR incentives. In this framework, the key result is that when firms decide to adopt ECSR sequentially, they will adopt ECSR to soften competition when products are a close substitute. However, the late adopter chooses lower ECSR and thus earns a higher profit. In a Cournot duopoly framework with pollution externalities and in the presence of an emissions tax regime, Poyako-Theotoky and Yong (2019) introduce an explicit environmental incentive into a compensation contract that owners offer their managers. The authors show that – depending on the efficiency of the "green" research and deve-

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lopment activity – the explicitly environment-focused contract leads to higher abatement levels than the standard sales compensation contract. Hence, the regulator sets a lower emissions tax, and social welfare increases. Moreover, firm owners earn higher profits when adopting the environmental delegation contract. On the other hand, by using a Stackelberg duopoly model with price competition, in which firms select whether to engage in ECSR, Hirose et al. (2017) show that firms may strategically decide to adopt ECSR because it represents a commitment device. In contrast to the classical second-mover advantage observed in a standard Stackelberg duopoly with price leadership (e.g. Gal-Or, 1985), Hirose et al. (2017) reveal that the first-mover has the advantage: the leader does not engage in ECSR while the follower does, and the profits of both firms in equilibrium increases.

These contributions may help to explain the recent trend of ECSR adoption. However, the current article takes a different route. First, by introducing the figure of the "green" manager (Wright et al., 2012; Riillo, 2017) with environmental concerns in a given Cournot duopoly, this paper shows that ECSR can arise in equilibrium due to firms' strategic interactions in the product market. Second, all the above contributions abstract from the strategic nature of a market entry game and, therefore, the role played by ECSR as a barrier to entry, which is another key subject of the current paper.

Salop (1979) distinguishes between structural ("innocent") and strategic entry barriers. Structural barriers are characteristic of a market that protects the market power of incumbents by making entry unprofitable. On the other hand, strategic barriers are incumbents' behaviors undertaken so that their actions influence the choice of entry; e.g. inflicting losses to entrants (for a comprehensive discussion of the various definitions of "barriers to entry" in economics, see McAfee et al., 2003; 2004). In his groundbreaking contribution, Spence (1977) investigates the incumbent firm's strategic choice of capacity in the presence of a potential entrant in an industry with standard goods, by making an explicit distinction between capacity and output produced. The capacity the incumbent invests in the first period acts as a constraint on the quantity produced. If the size of entry costs is adequately small for the entrant, the incumbent accommodates the entry. In the event of a threat of entry, the incumbent can prepare a sufficiently large capacity and, ultimately, expand the output level to lessen the price, therefore deterring the competitor's potential entry. However, if an entry does not occur due to high costs, this capacity remains underutilized. Dixit (1980) further studies the role of an irreversible investment commitment as an entry-deterrence instrument to change the initial conditions of the post-entry game to the benefit of the incumbent. In contrast to Spence (1977), Dixit (1980) finds that – if firms agree to play the post-entry game along the lines of Nash rules – the incumbent does not choose to install additional capacity that could remain idle in the pre-entry phase. Using a game-theoretic approach and underlying the crucial role played by asymmetric information, Milgrom and Roberts (1985) suggest that – if a firm is threatened by potential entrants – predatory practices can be rational against early entrants, even if those are costly, because they lead to a reputation that deters other entrants.

The main results of this paper are the following. In a given Cournot duopoly market structure, if the environmental sensitivity of “green” managers is particularly low, then engagement in ECSR represents a firm’s dominant strategy, irrespective of the efficiency of the available abatement technology. However, firms are cast into a prisoner’s dilemma. If the “green” manager shows a low-intermediate/intermediate environmental sensitivity, then in equilibrium emerges no ECSR or multiple symmetric equilibria or an engagement in ECSR. Finally, if managers’ environmental sensitivity is sufficiently high, firms do not engage in ECSR irrespective of the efficiency level of the abatement technology. On the other hand, in a market entry game à la Dixit-Spence with post-entry Stackelberg competition, the incumbent’s ECSR increases the fixed cost thresholds that block and deter the potential competitor’s market entry. In other words, entry is “less blockaded” and “less deterred” than in an industry without social responsibility, while the more efficient the abatement technology, the more contestable the market. Thus, ECSR affects incumbent owners’ strategic choices and, consequently, the endogenous market structure that arises in equilibrium.

The rest of this paper is organized as follows. Section “The Model and Results” introduces the setup for the analysis, while section “Conclusion” concludes our findings and outlines future research.

The Model and Results

Let us consider a duopoly industry in which Firm 1 and Firm 2 compete in quantities (Cournot competition). Firms produce homogeneous goods for the market, and each unit of the goods produced causes k unit of pollution. Firms exhibit a constant return to scale technology with linear, constant marginal costs c. We assume that a cleaning technology is available. However, following Asproudis and Gil-Moltó (2015), we assume the absence of a technology that can completely eliminate emissions, that is $k > 0$. With regard to the assumption of the abatement cost function, the pollution abatement cost *(CA)* is $CA = z(1-k)^2$, in which the parameter $z > 0$ may also be interpreted as an exogenous technical progress index. For example, a reduction in z can represent an exogenous technical shock as the arrival of a new, cost-effective technology. The adoption of the cleaner technology requires fixed costs with decreasing returns to investment; i.e. the emission's abatement always entails some costs. One can think of an environmental technology that is not directly connected to production levels, such as the number of filters in a refinery's pipe to cut CO2 emissions or 'scrubbers' to get rid of SO2 from a gas – or coal-fired electric plant. Therefore, given that k is the pollution per unit of production, a reduction (resp. an increase) of k is related to a more (resp. less) efficient abatement technology: an identical level of polluting emission can be abated in a less (resp. more) expensive manner. The parameter z scales up/down the total abatement cost; therefore, it represents a measure of the abatement technology's efficiency. In other words, this approach of applying the firms' pollution abatements demonstrates the Environmental Corporate Social Responsibility (ECSR); i.e. a reason for profit-oriented firms to engage in socially responsible activities. Moreover, "green" management whose goal is to reduce production inputs can also lessen operational costs and raise the firms' profitability. However, to implement the ECSR, firms hire a "green" manager (see Wright et al., 2012; Riillo, 2017) with an environmental sensibility to whom owners delegate both the choice of the output and emission levels. In other words, to hire a "green" manager represents the firm's commitment to engage in ECSR.

In the next subsections, we first present the case of a monopoly with ECSR as a benchmark. Then, the analysis focuses on a given Cournot duopoly market structure, in which firms decide whether to engage in ECSR. Finally, a market entry game model following Dixit-Spence is considered to examine the impact of ECSR on the endogenous market structure.

Benchmark: Monopoly Outcomes

We first analyze the monopoly market structure. The (inverse) linear demand for goods is $p = a - q_1$, in which p denotes the market price (the slope of the demand parameters is normalized to 1) while q_1 marks the monopolist output.

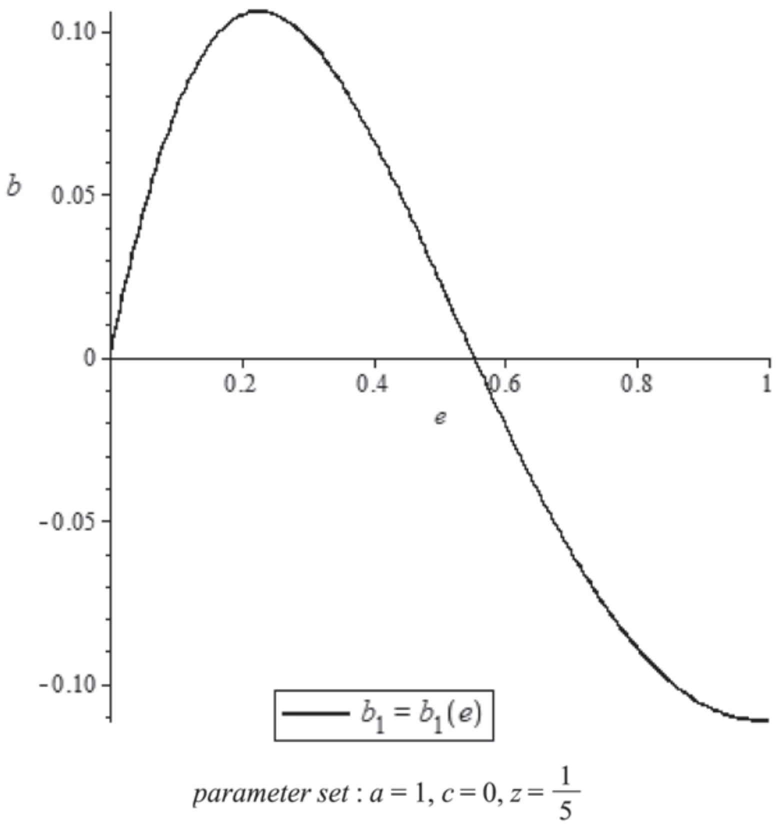
First, let us consider the case of a non-environmentally concerned monopolist ($k = 1$). The profits are $\pi_1 = (a - q_1 - c)q_1$, whose maximization yields $q_1^{MS} = (a-c)/2$, which is the optimal output for the monopolist. Substitution of the optimal output into the profits' function leads to the monopolist's profits, $\pi_1^{MS} = (a-c)^2/4$ (upper script *MS* stands for "monopoly standard"). Let us now consider the case of ECSR adoption ($k \in (0,1)$). The monopolist's profit function is

$$\pi_1 = (a - q_1 - c)q_1 - z(1-k)^2 . \tag{1}$$

To implement ECSR, the owners hire a "green" manager to whom they offer a public observed contract whose remuneration is formulated as $R = A + BU \geq 0$, in which $A \geq 0$ is the fixed salary component of the manager's compensation, $B \geq 0$ is a constant parameter, and U is the manager's utility. Therefore, by offering the "green" manager a contract, the firm commits to ECSR. Without loss of generality, the fixed salary component is set equal to zero and B equal to one. The monopolist manager's utility takes the following form (see Vickers, 1985; Jansen et al., 2007, 2009; Fanti and Meccheri, 2013):

$$U_1 = \pi_1 + (b_1 - ek)q_1,\ i = 1, 2, \tag{2}$$

Figure 1. Managerial bonus as a function of the environmental concern



Source: own elaboration.

in which π_1 are profits in (1), b_1 is the owners' incentive (disincentive) concerning the manager's choice of quantity, and the parameter $e > 0$ is the publicly known

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managers' sensitivity to environmental damage, assumed to be identical across managers in the same industry. In other words, the environmental sensitivity is not the managers' private information. This can be a plausible assumption if one thinks that the manager's environmental sensitivity can be identified, namely, by his or her previous engagement in ECSR activities in other companies and attendance in environmental conferences, seminars, and similar events. To guarantee a positive output and an interior solution in the selection of the abatement technology, we assume that $a-c>e$.

Maximization of (2) with respect to quantity leads the manager to select the optimal output level, $q_1=(a-c+b-ek)/2$. Substituting the optimal output into (2) and maximizing k, the optimal emission level is $k=[(a-c+b)e-4z]/(e^2-4z)$. To ensure an interior solution in the selection of the abatement technology, we assume that $2\sqrt{z}>e$. Inserting the optimal emission level back to the optimal output expression, we obtain $q_1=2z[(a-c-e+b_1)]/(4z-e^2)$, while further substitution of the output and emission values into (1) allows expressing the profit as follows

$$\pi_1=\frac{z(a+b_1-c-e)[(3a+b_1-3c)e^2-4z(a-b_1-c+e)-e^3]}{(e^2-4z)^2}\ . \qquad (3)$$

The owners maximize (3) with respect to the bonus, and optimization yields

$$b_1\equiv-\frac{e[2e(a-c)-e^2-4z]}{(e^2+4z)^2}\underset{<}{\overset{>}{}}0\Rightarrow e\underset{>}{\overset{<}{}}a-c-\sqrt{(a-c)^2-4z} \qquad (4)$$

which implies that $z\in(0,(a-c)^2/4]$, i.e. the abatement technology must be sufficiently efficient. An analytical inspection of (4) reveals that the owners select a bonus incentive to moderate the negative impact of the manager environmental sensitivity on output sales when it is not too excessive, while owners find it is optimal to penalize further output sales when the manager is adequately environmentally oriented. Figure 1 shows the relation between the managerial bonus and the environmental concern. The intuition behind these results is as follows. If the manager's environmental concern is sufficiently low, the abatement cost is not excessively high. Thus, the owners can partially alter the manager's objective through a positive bonus to soften the negative impact on sales. On the other hand, if the environmental concern is high, the abatement cost can become prohibitive. Hence, a penalty for production induces the manager to reduce sales and, in turn, the optimal emission level.

Substituting (4) into (3), the equilibrium profits are (upper script *ME* stands for “monopoly with ECSR”)

$$\pi_1^{ME} = \frac{z(a-c)^2}{e^2+4z}. \tag{5}$$

Cournot Duopoly Outcomes

Let us now consider the (exogenously given) Cournot duopoly market structure. The game is solved in the backward induction method to obtain sub-game perfect Nash equilibria. The sequence of moves is as follows. In the first stage, the firm decides whether to engage in ECSR. If the firm opts not to engage in ECSR, in the second stage a standard Cournot game occurs in which the owners decide on the optimal output. On the other hand, if the firm engages in ECSR via “green” delegation, in the second stage the owners decide the bonus of manager compensation, and then in the third stage the “green” manager decides first on the emission level and, finally, on the output.

First, we derive the results with non-environmentally concerned firms. The (inverse) linear demand for goods is now $p = a - Q$, with p denoting the market price and $Q = \sum_i q_i,\ i = 1,2$ total production. Thus, the firms’ profits are

$$\pi_1 = (a-Q-c)q_1,\ \pi_2 = (a-Q-c)q_2 \tag{6}$$

for Firms 1 and 2, respectively. Standard optimization of (6) leads to the reaction functions $q_i = (a-q_j-c)/2$, $i = 1,2$, $i \neq j$, from which the optimal output, $q_i = q_j = (a-c)/3$, and the equilibrium profits are obtained

$$\pi_1^{DNE} = (a-c)^2/9\ ,\ \pi_2^{DNE} = (a-c)^2/9 \tag{7}$$

in which the upper script *DNE* stands for “duopoly no ECSR” industry.

Let us now consider the case of ECSR adoption ($k \in (0,1)$). The profit functions now have the following form

$$\pi_1 = (a-Q-c)q_1 - z(1-k_1)^2\ ,\ \pi_2 = (a-Q-c)q_2 - z(1-k_2)^2\ . \tag{8}$$

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Therefore, the managers' utility is now

$$U_i = \pi_i + (b_i - ek_i)q_i, \ i = 1,2, \tag{9}$$

in which π_i is as in (8). The maximization of (9) leads to managers' reaction functions given by $q_i = (a - q_j - c + b_i - ek_i)/2$, $i = 1,2$, $i \neq j$. By solving the system composed by the reaction functions the optimal output becomes $q_i = [a - c + 2(b_i - ek_i) - (b_j - ek_j)]/3$. After the substitution of the optimal production into (9), the maximization with respect to k_i leads to

$$k_i = \frac{2e^2 k_j + [2(a-c) + 2(2b_i - b_j)]e - 9z}{4e^2 - 9z} \tag{10}$$

with $\partial k_i/\partial k_j < 0$: the emission level game is in strategic substitutes. To guarantee an interior solution in the selection of the abatement technology, we assume that $(3/2)\sqrt{z} > e$. A direct comparison reveals that the non-negativity condition on the choice of the abatement technology under a duopoly is more restrictive than that under a monopoly. Solving the system of the reaction functions in the emission level space, the equilibrium level of k is

$$k_i^* = \frac{[4(a - c + b_i)e^3 - 18e^2 z - 6z(a - c + 2b_i - b_j)e + 27z^2]}{(2e^2 - 9z)(2e^2 - 3z)}, \ i = 1,2. \tag{11}$$

Inserting first (11) into the optimal output expression and then again (11) and the obtained expressions of output as a function of bonuses into (8), the maximization with respect to b_i leads to the following reaction function in the bonus space:

$$b_i = \frac{[(-48a + 48c + 32b_j)e^8 - 216e^7 z + 936e^6 z(a - c - \frac{5}{13}b_j) - 108z^2 e^5 - 3456z^2 e^4(a - c - \frac{19}{32}b_j) + 3078e^3 z^3 + 3726z^3 e^2(a - c - b_j) - 3645ez^4 - 729(a - c - b_j)]}{32e^8 - 576e^6 z + 1944e^4 z^2 - 648e^2 z^3 - 2916z^4}$$

Solving the system, the optimal bonus in equilibrium is

$$b_i = \frac{[(-81a + 81c - 405e)z^3 + 360e^2(a - c + \frac{e}{5})z^2 - 144(a - c - \frac{e}{4})e^4 z + 8e^6(a - c)]}{9z(2e^2 + 9z)(2e^2 - 5z)} \tag{12}$$

Substituting (12) into (8), the equilibrium profits finally produce

$$\pi_i^{DE} = \frac{2(a-c)^2(27z^2+18e^2z-8e^4)(27z^2-18e^2z+2e^4)}{(5z-2e^2)^2(2e^2+9z)z} \tag{13}$$

in which the upper script *DE* stands for "duopoly with ECSR." An analytical inspection of (13) reveals that $\pi_i^{DE} \geq 0$ if $(1/2)\sqrt{6z(3-\sqrt{3})} \geq e \equiv e$, which is a technical condition more restrictive than $(3/2)\sqrt{z} > e$. To compare all the strategic profiles, we assume in the rest of the paper that the condition $e \leq e^T$ always holds.

Finally, let us consider the asymmetric case, in which one firm does not engage in ECSR, while the rival does. Assume that Firm 1 adopts ECSR, while Firm 2 does not (a similar reasoning applies for the opposite situation, because the Firm 2's fixed costs do not alter the choice of the relevant variables). The profit functions are

$$\pi_1 = (a-Q-c)q_1 - z(1-k)^2,\ \pi_2 = (a-Q-c)q_2 \tag{14}$$

for Firms 1 and 2, respectively. Thus, Firm 1's manager utility is as in (9), while Firm 2 solves a pure profit-maximizing problem. The maximization of π_1 in (14) leads to the manager's reaction function $q_i = (a-q_j-c+b_i-ek_i)/2$, while the reaction function for Firm 2 is $q_j = (a-q_i-c)/2$. Solving the system composed by the firms' reaction functions, the optimal output is $q_1 = [a-c+2(b_1-ek_1)]/3$ for the Firm 1 and $q_2 = [a-c-(b_1-ek_1)]/3$ for the Firm 2. After the substitution of the optimal production levels into π_1 in (14), Firm 1's manager maximization with respect to k_1 leads to

$$k_1^* = \frac{2e(a-c+2b_1)-9z}{4e^2-9z}. \tag{15}$$

Inserting first (15) into the optimal output expression and the obtained expressions of output as function of the bonus into π_1 in (14), the following is obtained:

$$\pi_1 = -\frac{z[a-c+2(b_1-e)][(10a+8b_1-10c)e^2-9z(a-b_1-c+e)-8e^3]}{(4e^2-9z)^2}. \tag{16}$$

The owners maximize (16) with respect to the bonus, and optimization yields

$$b_1 = -\frac{(28e^2-9z)(a-c)-4e(8e^2+9z)}{4(8e^2+9z)^2} \gtrless 0 \Rightarrow e \lessgtr e(a,c,z). \tag{17}$$

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The analytical expression of the environmental sensitivity is algebraically complex and not reported for the economy of space. However, the economic interpretation is qualitatively similar to the monopoly case. Substituting (17) into the output levels and then into (14), the equilibrium profits finally obtain

$$\pi_1^{DE/NE} = \frac{9(a-c)^2 z}{8(e^2+9z)}, \quad \pi_2^{DE/NE} = \frac{(16e^2+9z)^2(a-c)^2 z}{16(8e^2+9z)^2} \tag{18}$$

in which the upper script *DE*/*NE* stands for "duopoly, one ECSR/ one no ECSR."

The obtained outcomes allow for the construction of Table 1. The intersections between all of the firms' duopoly outcomes in Table 1 and the condition $e \le e^T$ generate six regions in the relevant (z,e)-space, as Figure 2 depicts.

Table 1. Firm's payoffs in duopoly

Firm 2→ Firm 1 ↓	ECSR	No ECSR
ECSR	$\frac{2(a-c)^2(27z^2+18e^2z-8e^4)(27z^2-18e^2z+2e^4)}{(5z-2e^2)^2(2e^2+9z)z}; \frac{2(a-c)^2(27z^2+18e^2z-8e^4)(27z^2-18e^2z+2e^4)}{(5z-2e^2)^2(2e^2+9z)z}$	$\frac{9(a-c)^2 z}{8(e^2+9z)}; \frac{(16e^2+9z)^2(a-c)^2 z}{16(8e^2+9z)^2}$
No ECSR	$\frac{(16e^2+9z)^2(a-c)^2 z}{16(8e^2+9z)^2}; \frac{9(a-c)^2 z}{8(e^2+9z)}$	$\frac{(a-c)^2}{9}; \frac{(a-c)^2}{9}$

Source: own elaboration.

In the regions I-VI of the (z,e)-space, the following duopoly profit rankings apply:

Region I: $\pi_1^{\text{DNE/E}} > \pi_i^{\text{DN}} > \pi_i^{\text{DE}} > \pi_1^{\text{DE/NE}}$, $i=1,2$. No ECSR is the dominant strategy for firms.

Region II: $\pi_i^{\text{DN}} > \pi_1^{\text{DNE/E}} > \pi_i^{\text{DE}} > \pi_1^{\text{DE/NE}}$, $i=1,2$. No ECSR is the dominant strategy for firms.

Region III: $\pi_i^{\text{DN}} > \pi_1^{\text{DNE/E}} > \pi_1^{\text{DE/NE}} > \pi_i^{\text{DE}}$, $i=1,2$. No ECSR is the dominant strategy for firms.

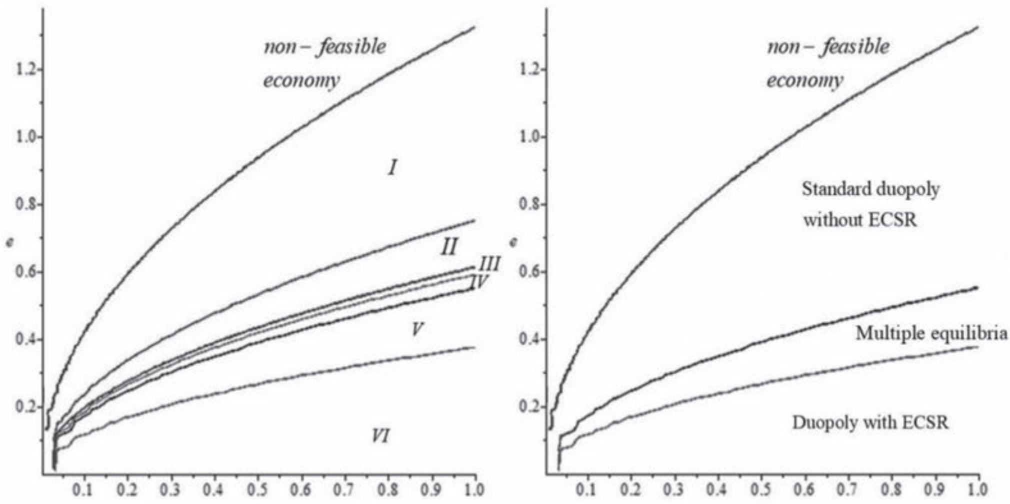
Region IV: $\pi_i^{\text{DN}} > \pi_1^{\text{DE/NE}} > \pi_1^{\text{DNE/E}} > \pi_i^{\text{DE}}$, $i=1,2$. No ECSR is the dominant strategy for firms.

Region V: $\pi_i^{\text{DN}} > \pi_1^{\text{DE/NE}} > \pi_i^{\text{DE}} > \pi_1^{\text{DNE/E}}$, $i=1,2$. Both no ECSR and ECSR arise as Nash equilibria, thus there are multiple symmetric equilibria.

Region VI: $\pi_1^{\mathrm{DE/NE}} > \pi_i^{\mathrm{DN}} > \pi_i^{\mathrm{DE}} > \pi_1^{\mathrm{DNE/E}},\ i = 1, 2$. Engagement in ECSR is the dominant strategy for firms; however, the game has a prisoner's dilemma structure.

Those findings can be summarized in Proposition 1.

Figure 2. Duopoly profits in the (z, e)-space and game equilibria



Note: the term $(a-c)^2$ enters all expressions in the same way and, therefore, the functional forms in Table 1 are unaffected by it. The graphs are depicted assuming that $(a-c)^2 = 1$.

Source: own elaboration.

Proposition 1. In a duopoly market: 1) if the environmental sensitivity of the managers is very low, then the hiring of a "green" manager and engaging in ECSR is the dominant strategy for the firms, regardless of the efficiency level of the abatement technology. However, firms face a prisoner's dilemma situation. 2) If the environmental sensitivity of the managers is low/intermediate, then a) no ECSR arises if the abatement technology is adequately efficient, b) multiple symmetric equilibria emerge in equilibrium for intermediate efficiency levels of the abatement technology, and c) engagement in ECSR arises in equilibrium if the abatement technology is not highly efficient. 3) If the environmental sensitivity of the managers is sufficiently high, then the unique equilibrium is no "green" delegation and, thus, there is no ECSR engagement, regardless of the efficiency level of the abatement technology.

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Thus, in a delegation game with environmental concerns, the set of equilibria is richer than in a standard delegation game. In fact, in a standard delegation game, managerial delegation is the unique equilibrium, and the game is characterized by a prisoner's dilemma. On the other hand, in the presence of "green" managers, multiple equilibria and no delegation arise as well. The rationale for this result can be explained as follows. If the environmental sensitivity of the manager is rather low, the usual mechanism of the managerial delegation (Vickers, 1985; Fershtman, 1985; Fershtman and Judd, 1987; Sklivas, 1987) applies: owners design compensation contracts to conduct a more aggressive behavior to gain a competitive advantage in the market. On the other hand, if the managers' environmental concern is intermediate, the emerging equilibrium of the game depends on the efficiency of the abatement technology: if the technology has a high level of efficiency, the owners design a contract to expand output, the fixed cost of the abatement technology becomes low, profits are close to the standard ones, and it is therefore not advantageous to hire the "green" manager who engages in ECSR. Nevertheless, if the available technology is not efficient, it turns out that both symmetric equilibria arise and – when the abatement technology is relatively inefficient – engagement in ECSR emerges in an equilibrium, because the owners design a managerial contract that penalizes production, so that prices and revenues are sustained and ECSR is not excessively costly. Finally, if manager sensitivity is high, then the owners design a contract that tends to penalize excessive production, irrespective of the efficiency level of the abatement technology. Thus, not following ECSR becomes the dominant strategy.

Entry Game

Consider now a standard entry game in which the monopolist faces a threat of entry. For the scope of analysis, the paper follows the simplified version of the Spence-Dixit model presented in Shy (1995, p. 188–192). Firm 1 is the incumbent, and Firm 2 the entrant. The potential entrant must face an exogenous fixed cost, G, such as investments in a production plant and new capital equipment, thus different from the fixed cost of the abatement technology paid by the incumbent. Post-entry competition is on quantity and, as commonly assumed in the literature, takes place following Stackelberg. To see the impact of ECSR on entry, we assume that the incumbent is already engaged in activities of social responsibility. One may think that the incumbent adopts ECSR given the customary toughness (pressure) of stakeholders. However, as in Graf and Wirl (2014; although in a different setting), we assume that the entrant cannot engage in ECSR, because this is a "credence good" attribute. In fact, consumers are unable to check it even after consumption. Thus, no reason exists for consumers to believe ECSR claims of a newcomer lacking consumer recognition. Undeniably, the entry of a widely known firm in this industry is not suitable in the current setup.

The game has a three-stage structure. At stage 1, the incumbent fixes the managerial bonus b_1. At stage 2, the “green” manager decides first the emission level k_1, and then the output q_1. At stage 3, after observing the incumbent’s owners and manager moves, the entrant chooses whether to enter and, in such a case, its own production level is q_2. Therefore, if an entry occurs, the market is characterized by a duopoly structure and the firms’ profit functions are

$$\pi_1 = (a - Q - c)q_1 - z(1-k)^2,\ \pi_2 = (a - Q - c)q_2 - G\,.$$

On the other hand, in the case of no-entry, $q_2 = 0$, and the profit functions are

$$\pi_1 = (a - q_1 - c)q_1 - z(1-k)^2,\ \pi_2 = 0\,.$$

As usual, the game is solved with backward induction.

Blockaded Entry

The first step is to identify the threshold of the fixed cost, such that the potential competitor’s entry is blockaded. As known (see e.g. Shy, 1995), entry is defined as blockaded if the competitor does not enter the market even though the incumbent’s output choice equals what would be optimal (for the incumbent) without a threat of entry.

Without a threat of entry, the incumbent produces the monopoly output level. Thus, the incumbent’s owners set the managerial bonus to induce the “green” manager to maximize (2) with respect to the emission level and the output, which leads to profits in (5). The maximum profit that Firm 2 can earn in case of entry is obtained as follows. First, substitute Firm’s 2 reaction function $q_2 = (a - q_1 - c)/2$ into $\pi_2 = (a - Q - c)q_2 - G$ to obtain the profits as a function of the incumbent’s output, which is $\pi_2 = [(a - q_1 - c)/2]^2 - G$. Second, recalling that with no entry $\pi_2 = 0$, after insertion of the optimal monopolist output in the latter expression, one solves the equation for the fixed costs and obtains that, if $G \geq G^B \equiv \left[(a-c)(e^2+2z)/(e^2+4z)\right]^2$, then entry in the industry is blockaded (upper script B).[3]

[3] Full analytical derivations are available upon request from the authors.

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Deterred Entry

The incumbent can also make strategic moves so that the potential competitor stays out of the market. Indeed, entry is defined as deterred when the potential competitor does not enter because of a suboptimal (for the incumbent) strategic decision with respect to the case of absence of the threat of entry.

In fact, if $G < G^B$, an entry will occur if the incumbent disregards the competitor's opportunity of entry and the monopoly output level is produced. However, if the incumbent's owners select an adequate bonus level, the "green" manager can be induced to expand output to such a level that an entry can become unprofitable for the competitor. The output's threshold level q_1^{ED} (the upper script ED stands for "entry deterrence") incentivizes the "green" manager to produce such that the entrant becomes indifferent whether to enter or to stay out the industry is found as follows. First, one substitutes the optimal monopolist's output as a function of the managerial bonus, $q_1 = 2z[(a-c-e+b_1)]/(4z-e^2)$ into $G = [(a-q \;\; -c)/2]$, and then one solves the latter equation for the managerial bonus. The solution is

$$b_1 = [2(a-c+e)z - e^2(a-c) + 2(e^2-4z)\sqrt{G}]/2z\,,$$

which leads to the entry that deters output $q_1^{ED} = a-c-2\sqrt{G}$ and the optimal level of the abatement technology $k_1^{ED} = [2z-(a-c)e+2e\sqrt{G}]/2z$. As a consequence, the deterring profits are

$$\pi_1^{ED} = \frac{(a-c-2\sqrt{F})[2(e^2+4z)\sqrt{F}-(a-c)e^2]}{4z} \tag{19}$$

Accommodated Entry

If the entrant's fixed costs of entry are adequately low, the incumbent allows entry: the owners adjust the bonus so that the "green" manager produces the Stackelberg output after entry.

The substitution of the entrant's reaction function into the Stackelberg's "green" manager utility function leads to

$$U_1 = \frac{(a-c-q_1)}{2}q_1 - z(1-k_1)^2 + (b_1 - ek_1)q_1\,. \tag{20}$$

Differentiation with respect to output yields $q_1 = [a-c+2(b_1-ek_1)]/2$. Substituting the latter value back into (20) and maximizing with respect to the emission level, one obtains the optimal emission level chosen by the "green" manager, $k_1 = [(a-c)e + 2eb_1 - 4z)]/2(e^2 - 2z)$, from which one may easily derive the output level as a function of the environmental concern, available technology, and managerial bonus: $q_1 = z(a-c-2e+2b_1)/(2z-e^2)$. The optimal entrant's output is obtained by substituting the optimal incumbent's production into the entrant's reaction function, $q_2 = (a - q_1 - c)/2$. Thus, the solution is obtained as $q_2 = [(a-c)e^2 - z(a-c+2e-2b_1)]/(4z-2e^2)$. Further substitutions of q_1, q_2, and k_1 in (8) – along with profit maximization with respect to the managerial incentive by the incumbent's owners – lead to the optimal bonus in the "green" managerial contract: $b_1 = e[e^2 + 2z - (a+c)e)]/(e^2 + 2z)$. By inserting the optimal bonus into the incumbent and entrant's output expressions, further substitution into the profit functions leads to the incumbent and entrant's accommodated (upper script A) profits in equilibrium, which are respectively equal to

$$\pi_1^A = \frac{(a-c)^2 z}{4(e^2+2z)}, \ \pi_2^A = \frac{(a-c)^2 (e^2+z)^2}{4(e^2+2z)^2}. \tag{21}$$

Therefore, the incumbent's entry deterring profits in (19) is larger than accommodating profits in (21) if

$$\frac{(a-c-2\sqrt{G})[2(e^2+4z)\sqrt{G}-(a-c)e^2]}{4z} \geq \frac{(a-c)^2 z}{4(e^2+2z)},$$

which implies

$$G \geq G^{ED} \equiv \frac{(a-c)^2[e^6+6e^4z+15e^2z^2+12z^3-2(e^2+2z)\sqrt{3e^4z^2+10e^2z^3+8z^4}\,]}{(e^2+2z)(e^2+4z)^2},$$

with $G^{ED} < G^B$, as Figure 3 shows. As a consequence, entry is accommodated for $G \leq G^{ED}$, while entry is deterred for $G^{ED} < G \leq G^B$, with the incumbent producing the output level $q_1^{ED} = a - c - 2\sqrt{G}$. On the other hand, entry is blockaded for $G^B < G$.

Moreover, Figure 3 shows that the increasing environmental concern of the "green" manager extends the area in which entry is accommodated and shrinks the area in which entry is blockaded (analytically, $\partial G/\partial e > 0$); the more efficient is the available technology, the more likely is the market entry to occur. This means that the presence of ECSR makes the market more contestable. In other words, the stakeholders' pressure on the incumbent creates opportunities for potential polluting newcomers to enter the market, thus making the industry more competitive. Nonetheless, the incumbent

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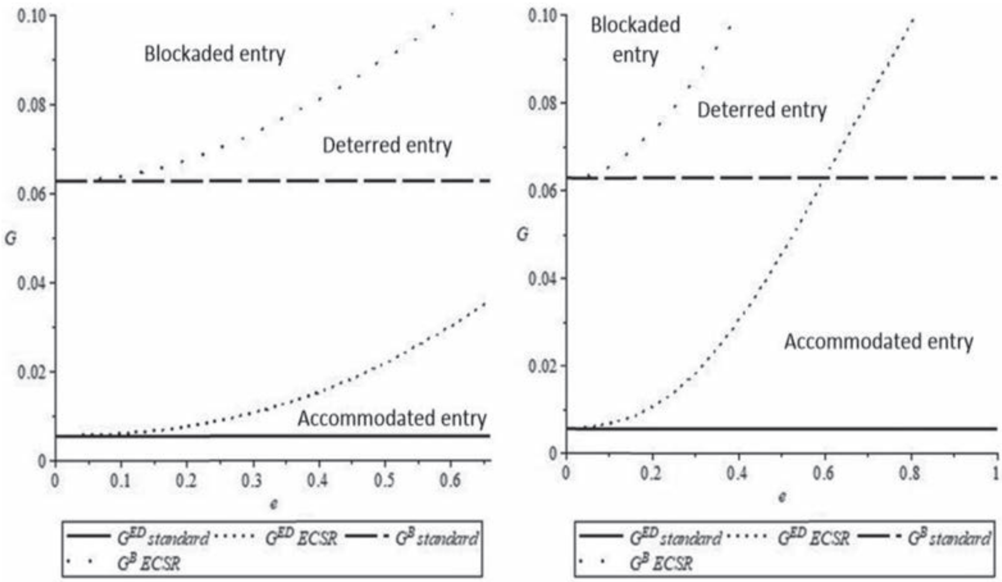
has still room to preserve its dominant position. In fact, the incumbent expands output to deter entry. However, if the "green" manager has sufficiently high environmental concerns, output expansion is restrained, and the incumbent can strategically deter entry when the fixed costs are relatively high. As long as the available technology becomes increasingly efficient (the value of z lowers), entry becomes relatively likely but, if the "green" manager simultaneously has no strong environmental concerns, entry can be more easily deterred. Those results are summarized in the following proposition.

> **Proposition 2.** ECSR increases both the likelihood of entry accommodation and entry deterrence. As a consequence, entry is relatively "less blockaded" but can be "more deterred" than in industries without social responsibility.

Figure 3. Fixed costs thresholds for blockaded and deterred entry in the "Spence-Dixit" framework, with and without ECSR, for given levels of the technical progress index



Note: Left box: $z = 1/4$. Right box: $z = 1/9$. The graphs are drawn for $(a-c)^2 = 1$.

Source: own elaboration.

Table 2. Similarities/differences with the relevant literature

	Similarities to the present work	Differences with the present work
Simultaneous moves (Cournot competition)		
Vickers (1985), Fershtman and Judd (1987), and Sklivas (1987)	▪ Managerial firms;	▪ No ECSR; managers do not care about the environment; ▪ Depending on technology efficiency and environmental sensitivity, different equilibria can arise instead of a unique (Pareto-inefficient) equilibrium.
Maxwell et al. (2000)	▪ Firms engage in ECSR (voluntary abatement);	▪ No managerial firms; ▪ ECSR delegated to managers; ▪ firms and consumers engage in interest-group rivalry to influence pollution control policy.
Poyago-Theotoky and Yong (2019)	▪ Managerial firms; ▪ ECSR (voluntary abatement) is an equilibrium;	▪ Exogenous instead of endogenous choice of the managerial contract incentivizing ECSR; no information about the efficiency nature of the equilibrium; ▪ the government sets an emission tax; ▪ managers do not have environmental sensitivity; ▪ the choice of ECSR depends on the managerial contract which includes an incentive to abate emission.
Sequential moves		
No market entry (Stackelberg competition)		
Hirose et al. (2017)	▪ Managerial firms; ▪ The leader engages in ECSR (voluntary abatement) because it represents a commitment device to keep a dominant position (first-mover advantage);	▪ Price instead of quantity competition with differentiated products; ▪ ECSR modelled as internal emission price; ▪ managers do not have environmental sensitivity; ▪ the choice of ECSR depends on the managerial contract which includes an incentive to abate emission.
Lee et al. (2019)	▪ Managerial firms; ▪ ECSR (voluntary abatement);	▪ Price instead of quantity competition with differentiated products; ▪ ECSR modelled as internal emission price; ▪ managers do not have environmental sensitivity; ▪ the choice of ECSR depends on the managerial contract which includes an incentive to abate emission; ▪ The follower engages in lower ECSR (second-mover advantage);

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Market entry (Dixit-Spence framework)		
Spence (1977); Dixit (1980)	▪ Quantity competition; ▪ strategic behavior of the incumbent to deter entry;	▪ No managerial firms; ▪ No ECSR; ▪ ECSR as deterrence tool.
Milgrom and Roberts (1985);	▪ Strategic behavior to deter entry;	▪ price competition; ▪ predatory behavior (price cutting); ▪ No managerial firms; ▪ No ECSR.

Source: own elaboration.

Nonetheless, this result of the entry game has non-trivial policy implications. On the one hand, due to increased competition, the welfare of consumers improves thanks to lower prices for the goods. On the other hand, the entry of a polluting firm increases emissions as well. Higher emissions damage consumers and lower the overall social welfare when the government is environmentally concerned. As a consequence, an overall welfare analysis is called for to investigate the government's potential regulatory intervention.

Conclusion

Making use of simple product market competition models in an industry with polluting production processes, this work investigated the impact on market structures of the engagement in ECSR through "green" managerial delegation, i.e. the hiring of a manager with environmental concerns to whom the owners delegate both sales and decisions regarding the optimal level of cleaning technology.

We showed with a Cournot duopoly that – if the "green" managers' environmental sensitivity is very low – the engagement in ECSR is the dominant strategy regardless of the efficiency level of the available abatement technology; however, firms face here a prisoner's dilemma. On the other hand, if the "green" manager has a low/intermediate environmental sensitivity, then no ECSR, multiple symmetric equilibria, or ECSR engagement will emerge, depending on the efficiency levels of the abatement technology. Finally, if the environmental sensitivity of managers is sufficiently high, then firms do not engage in ECSR, regardless of the efficiency level of the abatement technology.

On the other hand, in a monopoly with the threat of entry – and characterized by the Stackelberg post-entry competition – in which the incumbent engages in ECSR while the entrant does not, we found that the presence of ECSR makes the market more contestable. However, the incumbent can use ECSR to guarantee its dominant position provided that it hires a "green" manager with adequate environmental concerns. What is crucial is the role played by the available technology. In fact, when technology becomes increasingly efficient, an entry can occur more easily, but it can simultaneously be more easily deterred.

This paper contributes to the literature on managerial economics, but also on market structures (see Table 2). Moreover, our results provide additional and alternative reasons to those already present in the literature for the recently observed widespread diffusion of ECSR activities related to carbon emission reductions and their reporting. However, the paper builds on a set of precise assumptions. To check the robustness of the results first, the suitable direction of research is whether the price (Bertrand) competition model with differentiated products can alter the equilibria of the game. Second, the article considered only the environmental concern of the managers, while it completely disregarded the impact that consumers' and governments' environmental concerns may have on a firms' ECSR activities. Hence, if a government is environmentally concerned, an overall welfare analysis is necessary to study the government's potential regulatory intervention. These questions remain for future research.

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