Firms' social responsibility and workers' motivation at the industry equilibrium

Victor Hiller, Natacha Raffin

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Abstract

We consider an industry in which firms compete at two levels: the labor market and the product market. In the labor market, two types of workers coexist: socially responsible workers or not. Firms may strategically use responsible activities (CSR) to screen and elicit greater effort from responsible workers. By doing so, virtuous firms lower their production costs and display a competitive advantage in the product market. As a consequence, CSR strategies by firms shape the toughness of the competition in that market. In turn, incentives that firms have to invest in CSR are dampened when competition becomes harsher. Hence, we identify a twofold relationship between CSR and competition. Given the feedback effects on the competitive pressure, an increase in workers' social awareness may reduce the overall level of socially responsible investment in the industry. We also show that an exogenous increase in competition may positively or negatively affect the corporate social performance depending on pre-existing market conditions.

Keywords: Moral Motivation, Corporate Social Responsibility, Screening, Market Competition, Industry Equilibrium

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1 Introduction

Over the past decades, the spread of information technologies, decreasing transport costs, deregulation waves and reductions in trade barriers have contributed to an unprecedented rise in market competition. These evolutions came along with profound changes in Human Ressources Management practices (Bloom and Van Reenen 2010) and the structure of compensation and incentives (Cuñat and Guadalupe 2009 and the recent survey by Ferreira 2019). Indeed, the competitive environment directly affects the value of work effort and thereby the incentives that firms have to motivate employees (Raith 2003) and to retain and attract the most productive workers (Marin and Verdier 2012 or Marin et al. 2018). Nevertheless, employee' motivation does not only respond to financial compensation packages but also to non monetary perks of their job like Corporate Social Responsibility (CSR hereafter) practices of the company they work for (Cassar and Meier 2018). According to a recent body of papers some workers are prone to accept lower wages[1] and to provide extra efforts[2] when working for a virtuous firm. Furthermore a bunch of studies also emphasize the importance of strategic CSR investments by firms in order to *i)* motivate their employees (Flammer and Luo 2017); and *ii)* win the war for high-performing talents (Turban and Greening 1997,

1. See Frank (2004), Nyborg and Zhang (2013), Burbano (2016) and Cassar (2019).

2. See Fehrler and Kosfeld (2014), Imas (2014), Koppel and Regner (2014), Lanfranchi and Pekovic (2014), Tonin and Vlassopoulos (2015), Charness et al. (2016), Kajackaite and Sliwka (2018) and Cassar (2019). The role played by Corporate Social Responsibility (CSR) in the formation of a corporate culture that enhances employees' motivation has also been put forward by several studies in the business and management literature (Branco and Rodrigues 2006, Collier and Esteban 2007, Kim et al. 2010, Hansen et al. 2011 or Mozes et al. 2011).

Albiner and Freeman 2000, Greening and Turban 2000 or Bhattacharya et al. 2008).

The present article aims at building a bridge between these two strands of the literature. First of all, and in accordance with the above mentioned evidences, we model CSR as a tool that firms may strategically use to attract and motivate socially responsible workers. Then, we consider how the use of CSR, as a compensation scheme, interacts with firms' competitive environment, exactly as any other incentive devices do. To do so, we emphasize two market dimensions through which firms compete: the labor market – where they bid to attract the most productive employees – and the product market – where they sell their goods. As we develop below, this framework allows us to identify a twofold relationship between CSR and competition.

Our economy comprises a large number of firms, each producing a variety of a horizontally differentiated good and hiring one employee to manage the production process. Production costs are negatively related to a level of effort chosen by the employee. Workers can be of two types: socially responsible or not. Nonresponsible employees have standard pecuniary preferences, whereas responsible ones enjoy nonpecuniary benefits when working hard for a firm that is deemed to be sufficiently responsible. Preferences are unobservable, but firms may use CSR activities to screen and incentivize responsible workers. Hence, it may be profitable to invest in CSR because, by doing so, they elicit more effort and are better managed.[3]

At the labor market level, firms struggle for responsible workers who are the less expensive to motivate. Two configurations must be distinguished. If the number of responsible workers

3. Examples of companies that implement such CSR initiatives could be *Walt Disney* which chooses to commit itself to protecting the environment and to planting trees in the rain forest; *Starbucks* supporting Ethos Water, which provides safe water in developing countries; *Pfizer* participating to a program, which goal is to encourage malaria prevention and provide access to early anti-malaria treatments.

is sufficiently large, all firms can employ one of them and offer a level of CSR just sufficient to compensate the worker for the disutility of his effort. If the number of firms exceeds the number of responsible workers, then some firms do not engage in CSR and are poorly managed by a nonresponsible employee, whereas the others adopt a virtuous behavior and are competently managed by a responsible worker. Moreover, the intensity of CSR investments by virtuous firms is positively related to the incremental earnings associated with greater managerial efforts. This positive relationship is directly the result of the screening purpose of CSR in a context in which firms compete for talent. Indeed, the level of CSR offered to responsible workers must be sufficiently high to prevent any counteroffer by competitors such that the cost of this CSR investment must coincide with the earnings differential that a firm can expect from hiring a responsible rather than a nonresponsible employee.

At the product market level, we consider a monopolistic competition model with cost heterogeneity. As previously discussed, the production costs of each individual firm are related to its investment in CSR. Those costs being given, firms compete in price. At the equilibrium, the earnings differential between high-cost and low-cost firms is negatively affected by the toughness of competition, measured by the average cost in the industry.

At the industry equilibrium, the cost structure derived from CSR choices made by firms must be consistent with the earnings differential derived from pricing strategies in the product market. Hence, we point out a two-way relationship between CSR and competition. On the one hand, when firms invest in CSR, they elicit more efforts from their employees, and the cost competition intensifies. On the other hand, when cost competition is harsh, the earnings differential between well-managed and poorly managed firms is depressed and firms have less incentive to invest in CSR. Our setting also enables us to provide explicit expressions for the equilibrium levels of corporate social performance (CSP)[4] and the Herfindahl-Hirschman Index (HHI) at the industry level.

Therefore, we assess how does the spread of social awareness among workers affect CSP. At first glance, we expect a positive relationship. Nonetheless, we show that a rise in the proportion of responsible employees displays two opposite effects. The first effect is a direct positive extensive margin effect: more firms invest in CSR to attract and motivate these additional responsible workers. However, the second effect involves a negative intensive margin effect that goes through two channels: *i)* it makes competition on the product market tougher such that each virtuous firm invests less in CSR; and *ii)* it relaxes competition in the labor market by making less useful the use of CSR to attract responsible employees. In some configurations, the intensive margin effect overwhelms the extensive margin effect such that an increasing social consciousness among workers may be harmful for the CSP of the industry.

Then, we wonder whether competition promotes or erodes virtuous behavior in the market by considering the impact of a change in the number of competitors on the CSP. The existing theoretical literature on the CSR-competition nexus has found conflicting results regarding the sign of that linkage.[5] Our model, by encompassing two levels at which firms compete – the labor market and the product market – offers a unified framework to justify these ambiguous results. Indeed, on the one hand, the increase in the number of firms in the industry makes competition tougher in the product market, while on the other hand, it softens competition in the labor market.

4. We define the CSP of the industry as the sum of CSR spending of all firms belonging to the industry.

5. For instance, Bagnoli and Watts (2003) emphasize a negative relationship, whereas the link is positive in Fisman et al. (2006) – see the enlightening discussion in Fernandez-Kranz and Santalo (2010) on this point.

Our comparative statics also provide some interesting insights for empirical studies devoted to the CSR-competition relationship. These works consist of estimating the impact of changes in the HHI on measures of prosocial activities (see, for instance, Gupta and Krishnamurti 2016 or Simon and Prince 2016). Our results highlight that these analyses should be interpreted with caution given the endogenous nature of the HHI with respect to CSR. In particular, the causality – from competition to social performances – could go the other way around.

Our article builds a bridge between two main strands of the economic literature. First, we are in line with a growing body of papers that address agency problems when agents do not respond to standard pecuniary incentives only, but also to non-monetary aspects of their jobs.[6] Most of these papers consider those aspects as given, whereas CSR in our set-up is a strategic variable used by the principal as both a screening and an incentive device. In that respect, our work could also be related to Akerlof and Kranton (2005) who consider that a firm may socialize her employees to a corporate identity, which leads them to behave more or less aligned with her profit maximizing goal. However, the analyze by Akerlof and Kranton (2005) remains at the firm level. As far as we know, Brekke and Nyborg (2008) is the unique paper that explicitely considers CSR investments as a means to attract and incentivize morally motivated agents.[7] However, in their model, CSR is treated as a yes or no, while the intensity of CSR activities is a central element for us. It allows to put forward an intensive margin of CSR that is at the heart of a potentially nonmonotonous relationship between workers' social consciousness and CSP. Moreover, Brekke and Nyborg

6. See Francois (2000), Benabou and Tirole (2003), Besley and Ghatak (2005), Brekke and Nyborg (2008) or Delfgaauw and Dur (2007, 2008).

7. See also the general framework developed in the survey of Cassar and Meier (2018).

(2008) assume perfect competition in the product market and, by the way, have nothing to say about the CSR-competition nexus. To that extent, our article is related to a second strand of the literature, which addresses with the strategic CSR and its relationship with competition (see Bagnoli and Watts 2003, Fisman et al. 2006 or Albuquerque et al. 2019). Among them Albuquerque et al. (2019) is the most closely related to us since they consider an industry equilibrium model in which CSR choices by firms may have feedback effects on the competitive pressure on the product market. Nevertheless, all these papers consider CSR as a product differentiation strategy. To the best of our knowledge, our paper is the first to tackle the CSR-competition relationship while considering CSR as a means to attract motivated employees.

The remainder of the paper is organized as follows. Section 2 presents the model and characterizes the equilibrium of the industry. Section 3 exposes comparative statics. Section 4 concludes.

2 The Model

The industry comprises a mass L of consumers, a mass N of firms (she hereafter) and a mass M of workers (he hereafter), with $M > N$. Each firm employs a worker to produce a variety of a differentiated good. This worker chooses to exert or not an effort to improve the quality of the production process and, thereby, reduce the unit production cost of the firm. Two types of workers coexist: the responsible (socially motivated) and the nonresponsible (selfish). Responsible employees are not only interested in their net payoff (wage minus disutility of effort) but also in the type of firm at which they work. More precisely, these employees can be intrinsically motivated depending on the firm's prosocial behavior. Hence, the intensity of CSR activities may be strategically used by firms to attract and incentivize those workers. In the following, we will refer to responsible employees as "green" (indexed by g) and nonresponsible ones as "brown" (indexed by b), while CSR activities will be, most of the time, termed "abatement". This terminology is adopted for the sake of realism because environmentally friendly actions are a large part of the overall CSR initiatives. Obviously, our framework applies to all other aspects of CSR that may activate workers' intrinsic motivations and, more broadly, to any kind of investment promoting a conducive work culture/environment.

Firms post offers to attract and incentivize workers, some of them green. To do so, they can use two types of devices: wage or/and CSR. The precise timing of the events is as follows.

i Firms choose a level of abatement and a wage rate. Each worker decides whether to accept or not an offer and, if so, which one. Accordingly, he provides a level of effort that affects the unit production cost of the firm.

ii Firms compete in price. Wages are paid to workers and CSR actions are realized.

During stage i, the worker chooses a level of effort $e \in \{e^L, e^H\}$, with $e^H > e^L = 0$. If he exerts high effort (chooses e^H), the unit cost of production is low; otherwise, it is high. The offers posted by firms are driven by the benefits they expect from having an employee who chooses to exert a high rather than a low effort. Those benefits are determined in stage ii when firms compete in price. At this stage, their pricing strategies crucially depend on market conditions and, in particular, the cost structure of the industry. In turn, this variable is shaped by the choices they made to motivate or not their employee during stage i.

We solve the model backward. Stage ii (product market level) is solved in Section 2.1, the cost structure of the industry – that comes from firms' choices made in stage i – being given. Stage i (labor market level) is solved in Section 2.2 the expectations over firms' benefits – that will be derived in stage ii – being given. In Section 2.3, we characterize the industry equilibrium in which the choices made by firms, both in the labor market and in the product market, are consistent with the expectations they have formed. Finally, in Section 2.4, we provide analytical expressions for the aggregate level of abatement (CSP of the industry) and the Herfindahl-Hirschman Index at the industry equilibrium.

2.1 Product market equilibrium

On the product market side, we consider a monopolistic competition model. The industry comprises a mass N of firms, each producing a single variety of a differentiated good. A mass L of consumers have preferences over these varieties and a numéraire good produced outside the industry. In this section, we describe the preferences of consumers and the demand addressed to each producer. Then, we derive the equilibrium earnings of firms.

2.1.1 Consumer preferences and demand

Consumer preferences are given by a linear-quadratic utility function (*à la* Melitz and Ottaviano 2008) defined over a numéraire good (produced outside of the industry) and a continuum of varieties of a differentiated good (indexed by $i \in \Omega$)

$$\mathcal{V} = x_0 + \beta \int_{i\in\Omega} x_i di - \frac{1}{2}\gamma \int_{i\in\Omega} x_i^2 di - \frac{1}{2}\eta \left(\int_{i\in\Omega} x_i di \right)^2 \quad (1)$$

with x_0 and x_i, respectively, the consumptions of the outside good and the differentiated variety i. The demand parameters β, γ and η are positive. The parameter γ captures the degree of product differentiation among the differentiated goods (a larger γ corresponds to a higher differentiation) while β and η describe the substitution pattern between the differentiated varieties and the numéraire good. Finally, Ω is the set of all differentiated products supplied in the industry.

The quadratic form of the utility function leads to a linear market demand D_i for the differentiated product i:

$$D_i = Lx_i = \frac{L}{\gamma}\left(\frac{\gamma\beta}{\gamma+\eta N} - p_i + \frac{\eta N}{\gamma+\eta N}\bar{p}\right) \qquad \text{with} \qquad \bar{p} = \frac{1}{N}\int_{i\in\Omega} p_i di \tag{2}$$

where p_i is the price of variety i and $\bar{p}$ is the average price index.[8] Notice that here the number of varieties produced ($|\Omega|$) in the industry exactly equals the number of firms (N). This is always the case at the equilibrium thanks to a parametric assumption made below (see Assumption 1). Henceforth, we abstract from entry choices by firms that would otherwise complexify the analysis without offering additional insights.

2.1.2 Production and earnings

Each differentiated good i is produced under monopolistically competitive conditions in the following way. Each firm requires a worker to run a production project. Following the implementation of the project, the firm produces the good with a unit production cost c_i expressed in terms of the outside good. Hence, for a given project of cost c_i, the earnings of a firm i write:

$$\pi_i = D_i(p_i - c_i) \tag{3}$$

8. See Appendix A for a precise derivation of expression (2).

A firm i chooses a price p_i to maximize her earnings, with D_i being given by the demand function (2). Earnings maximization yields the following pricing rule:

$$p_i = \frac{1}{2}\left(c_i + \frac{\beta\gamma}{\gamma + \eta N} + \frac{\eta N}{\gamma + \eta N}\bar{p}\right) \tag{4}$$

Integrating out p_i gives

$$\bar{p} = \frac{\gamma + \eta N}{2\gamma + \eta N}\left(\bar{c} + \frac{\beta\gamma}{\gamma + \eta N}\right) \qquad \text{with} \qquad \bar{c} = \frac{1}{N}\int_{i\in\Omega} c_i di \tag{5}$$

where $\bar{c}$ is the average cost index of the industry.

Inserting (4) and (5) into (2) and then into (3), we obtain the equilibrium earnings of a firm i with cost a c_i:

$$\pi_i = \frac{L}{4\gamma}\left(c_D - c_i\right)^2 \tag{6}$$

with

$$c_D = \frac{2\beta\gamma}{2\gamma + \eta N} + \frac{\eta N}{2\gamma + \eta N}\bar{c} \equiv c_D(\bar{c}) \tag{7}$$

The endogenous variable c_D accounts for the cutoff cost level above which a firm prefers to leave the industry. It captures the toughness of cost competition through the average cost $\bar{c}$: A higher value of c_D means that firms evolve in a weaker competitive environment. Obviously, a firm's earnings decrease with her unit production cost but also with the toughness of competition: When c_D is low, competition is exacerbated such that firm i loses market share and reduces her margin.

As previously mentioned we consider two types of firms: low-cost firms, with a unit production cost denoted by c^A, and high-cost firms, with a unit production cost denoted by $c^B > c^A$. Using equation (6), we express π^H and π^L, the earnings of a low-cost and a high-cost firm respectively:

$$\pi^H \equiv \frac{L}{4\gamma}\left(c_D - c^A\right)^2 \qquad \text{and} \qquad \pi^L \equiv \frac{L}{4\gamma}\left(c_D - c^B\right)^2 \tag{8}$$

From these expressions it appears that when c_D is too low some firms may prefer to leave the market. The following assumption ensures that it never happens at the equilibrium and thus all N firms are indeed active (see Appendix A).

Assumption 1 $\Delta c < \frac{2\gamma}{\eta N}(\beta - c^B)$ *with* $\Delta c \equiv c^B - c^A > 0$

Equation (8) also tells us that a fall in c_D reduces the earnings for both types of firms. This happens through two channels: a loss of market shares and a reduction in the unit margin. These two effects are multiplicative and thereby give birth to the quadratic form of π^H and π^L. Hence, c_D has a differentiated marginal impact on a firm's equilibrium earnings, depending on her type: low-cost firms are more affected by a change in c_D than their high-cost counterparts. It implies that the earnings differential ($\Delta\pi \equiv \pi^H - \pi^L$) between low-cost and high-cost firms is increasing in c_D[9]:

$$\Delta\pi = \frac{L\Delta c}{2\gamma}\left(c_D - \frac{c^B + c^A}{2}\right) \equiv \Delta\pi(c_D) \tag{9}$$

Although c_D is given at this price competition stage, it is in fact shaped by the incentives offered by firms in the labor market during the first stage of the game, which we investigate in the following section.

9. Let us notice that, as c_D is increasing in $\bar{c}$, $\Delta\pi$ is also increasing with the average cost in the industry. This positive impact of $\bar{c}$ on $\Delta\pi$ is robust to alternative modelings of the product market competition, similar to a Salop model with cost heterogeneity (see Aghion and Schankerman 2004) or a monopolistic competition model *à la* Dixit-Stiglitz (see Hiller and Verdier 2014).

2.2 Labor market equilibrium

As previously described, if the worker – who supervises the production process – performs high effort (e^H), the unit production cost of the firm is low (c^A) and her earnings equal π^H. Otherwise, the unit production cost is high (c^B), and earnings decline to π^L. The earnings of a firm can be expressed as a function of the effort exerted by the employee:

$$\pi(e) = \begin{cases} \pi^H & \text{if} \quad e = e^H \\ \pi^L & \text{if} \quad e = e^L \end{cases} \tag{10}$$

Hence, $\Delta\pi$ accounts for the incremental earnings associated with having a worker who performs high effort rather than a worker who performs low effort. In this section, we emphasize how expectations over the toughness of competition parameter (c_D) determine the contracts offered by firms, through its effect on the expected incremental earnings. Expectations, formed at the beginning of stage i, over c_D and thus $\Delta\pi$ will be, respectively, denoted c_D^e and $\Delta\pi^e$.[10] Note that, given (9), $\Delta\pi^e = \Delta\pi(c_D^e)$.

2.2.1 Firms' profits and workers' preferences

A firm's profits are simply given by the difference between her earnings (which incorporate the unit cost of production) and the additional costs that include the salary cost (w) paid to the worker that she employs and the cost of the CSR activities that she chooses to afford. Those business practices are denoted by $a \in \mathbb{R}^+$, a level of pollution abatement that induces a cost $\phi(a)$, with, $\phi(0) = 0$, $\phi'(a) > 0$ and $\phi''(a) \geq 0$. Abatement costs are assumed to be independent of the firm's production level and may encompass many types of CSR business

10. Since we consider a continuum of firms and workers, the offer of a given firm has a negligible impact on $\bar{c}$. Hence, no individual firm can influence the value of c_D that will prevail in stage ii. As a consequence, c_D^e can be considered as given by firms in stage i.

practices. Thus, the profits of a firm choosing abatement level a, proposing wage rate w, and hiring a worker who chooses an effort level e are:

$$\Pi(e, w, a) = \pi(e) - w - \phi(a) \tag{11}$$

Two types of workers coexist: a proportion q of responsible workers and a proportion $1-q$ of nonresponsible workers. Brown workers are considered to be standard *homo economicus*: they are only interested in the wage (w) they earn and the effort (e) they expend:

$$U_b(e, w, a) = w - e \tag{12}$$

Green workers may exhibit some intrinsic motivations to exert an extra effort if the firm at which they work is deemed to be sufficiently socially responsible. Formally, the intensity of CSR activities affects the disutility that a green worker associates with working hard:

$$U_g(e, w, a) = w - e + v(e, a) \tag{13}$$

with

$$v(0, a) = 0 \quad , \quad v(e^H, a) \begin{cases} = 0 & \text{if} \quad a = 0 \\ > 0 & \text{if} \quad a > 0 \end{cases} \quad , \quad v'_a(e^H, a) > 0 \quad , \quad v''_{aa}(e^H, a) < 0$$

According to these assumptions, a green employee may experience intrinsic pleasure from work if (and only if) his employer invests in CSR ($v(e^H, 0) = 0$). Moreover, his satisfaction increases with the magnitude of these socially responsible practices ($v'_a(e^H, a) > 0$).

The idea according to which some workers, in specific contexts, may enjoy exerting effort has been put forward by Benabou and Tirole (2003) and Delfgaauw and Dur (2007, 2008). In Delfgaauw and Dur (2007, 2008), this intrinsic motivation effect interacts with the type of job or sector (public *vs.* private)[11] just as it interacts with abatement in our framework. Said differently, by investing in CSR, firms tend to achieve socially oriented missions potentially aligned with the own goals of a responsible employee. By making this assumption, we are in line with the emerging literature that considers that firms are able to choose some aspects of the job likely to generate intrinsic motivation (Akerlof and Kranton 2005, Brekke and Nyborg 2008, Hiller and Verdier 2014, Cassar and Meier 2018 or Cassar and Armouti-Hansen 2019). In particular, the fact that environmentally friendly actions may have the potential for motivating socially oriented workers is already present in Brekke and Nyborg (2008). To that extent, our formulation of workers' utility functions is close to the one that they adopt.

The game between firms and workers unfolds as follows. First, all firms simultaneously decide to post an offer (a wage rate w and a level of abatement a). Second, each worker chooses his preferred offer or remains unemployed.[12] Finally, workers who are hired choose a level of effort. The equilibrium of this game – when firms do not observe the precise type of workers but only know the proportion of green ones – is subsequently described.

2.2.2 Characterization of the labor market equilibrium

Let us first notice that, since $M > N$, some workers are unemployed and their utility is normalized to 0, regardless of their type. Moreover, since we assume that the unit production cost (and then earnings) is verifiable and depends on the effort in a deterministic way, it is as if the effort were contractible. Thus, for analytical convenience, we define the offer designed

11. Similarly, in Besley and Ghatak (2005), some agents value their personal contribution to the output of the firm when their preferences are aligned with the mission of the organization for which they work.

12. If the worker is indifferent between an offer and unemployment, he chooses the job offer. If he is indifferent between different offers, he accepts each of them with equiprobability.

for a worker of type j as a triplet (e_j, w_j, a_j) that must satisfy the following set of constraints. First, the worker should be willing to accept the contract such that the individual rationality (IR) constraint is fulfilled:

$$U_j(e_j, w_j, a_j) \geq 0 \quad \text{for all} \quad j \in \{b, g\} \tag{IR}$$

Hence, the utility derived from accepting the contract is at least equal to the utility of being unemployed. Second, we assume limited liability (LL) so that the monetary payoff is bounded below by zero:

$$w_j \geq 0 \quad \text{for all} \quad j \in \{b, g\} \tag{LL}$$

Third, the incentive compatibility (IC) constraint ensures that a worker never picks the offer designed for the other type:

$$U_j(e_j, w_j, a_j) \geq U_j(e_k, w_k, a_k) \quad \text{or} \quad U_j(e_k, w_k, a_k) \leq 0 \quad \text{for all} \quad j, k \in \{b, g\} \text{ with } j \neq k \tag{IC}$$

Two broad families of contracts can then be distinguished according to the level of effort that firms want to induce. If firms target low effort $e^L = 0$, the wage is set to zero and no investment in abatement is made. However, to attract an employee who exerts high effort, they can use two types of instruments: for brown workers, monetary rewards only; for green ones, monetary rewards or/and CSR investments. In the last case, two polar situations can also be identified. In the first situation, firms use wages only to compensate for the high level of effort such that $w \geq e^H$. In the second situation, they use abatement only, and thus, $a \geq \tilde{a}$, defined as:

$$v(e^H, \tilde{a}) = e^H$$

Then, $\tilde{a}$ is the level of abatement just sufficient to compensate a green for the disutility cost of his effort, when the wage rate is fixed to zero. The cost of $\tilde{a}$ is denoted $\tilde{\phi} \equiv \phi(\tilde{a})$.

If firms use both wage and abatement, they have to evaluate the benefits they obtain when they substitute between the two devices. Investing more in abatement involves a marginal cost $\phi'(a)$, whereas it allows a reduction in the salary cost by $v'_a(e^H, a)$. Hence, firms should substitute wage with abatement until a^* defined as:

$$\phi'(a^*) = v'_a(e^H, a^*)$$

so that the marginal cost of abatement equals its marginal benefit. In the rest of the paper, we will refer to a^* as the first-best level of abatement and denote by $\phi^* \equiv \phi(a^*)$ the induced cost. Note that the LL constraint may prevent firms to propose the first-best level of abatement to green workers since the optimal mix between monetary incentives and abatement could induce negative wages.

To focus our analysis on relevant cases for our purpose, we make the following assumption:

Assumption 2 $v(e^H, a^*) > e^H > \phi^*$

The first part of Assumption 2 ($v(e^H, a^*) > e^H$) implies that $\tilde{a} < a^*$ with $\tilde{a}$ the level of abatement such that both the IR and LL constraints are binding for a green employee who exerts high effort. If $\tilde{a}$ were higher than a^*, it would always be possible for firms to offer the first-best level of abatement while binding the IR constraint and offering a positive wage. Then, they should always do so. On the contrary, the condition $\tilde{a} < a^*$ entails that, in some configurations, firms may induce high effort from their green employees while relying on a level of abatement different from a^*. As this (second-best) level of CSR will be used by firms to attract motivated workers, it could be determined by the toughness of competition both on the product market and the labor market.

The second part of Assumption 2 ($e^H > \phi^*$) implies that $\tilde{\phi} < e^H$ such that it is less costly for firms to rely on intrinsic motivation rather than monetary rewards to incentivize green workers. Should this not be the case, firms never invest in CSR.

In the following proposition, we derive the contracts $(\hat{e}_j, \hat{w}_j, \hat{a}_j)$ offered by firms to each type of worker, for a given expectation c_D^e.

Proposition 1 *Let $\tilde{c}_D$, c_D^* and c_D' be defined respectively as the values of c_D^e so that*

$$\Delta\pi(c_D^e) = \tilde{\phi}, \;\; \Delta\pi(c_D^e) = \phi^* \;\text{and}\; \Delta\pi(c_D^e) = e^H.$$

Under Assumptions 1 and 2:

If $q \geq N/M$, all potential entrants offer the triplet $(\hat{e}_g, \hat{w}_g, \hat{a}_g)$ with:

$$(\hat{e}_g, \hat{w}_g, \hat{a}_g) = \begin{cases} (0,0,0) & \text{if } \; c_D^e < \tilde{c}_D \\ (0,0,0) \cup \left(e^H, 0, \tilde{a}\right) & \text{if } \; c_D^e = \tilde{c}_D \\ \left(e^H, 0, \tilde{a}\right) & \text{if } \; c_D^e > \tilde{c}_D \end{cases} \tag{14}$$

N green workers pick this offer, and all brown workers as well as $qM - N$ green workers are unemployed.

If $q < N/M$, qM firms offer the triplet $(\hat{e}_g, \hat{w}_g, \hat{a}_g)$, while $N - qM$ firms propose $(\hat{e}_b, \hat{w}_b, \hat{a}_b)$ with:

$$(\hat{e}_b, \hat{w}_b, \hat{a}_b) = \begin{cases} (0,0,0) & \text{if } \; c_D^e < c_D' \\ (0,0,0) \cup \left(e^H, e^H, 0\right) & \text{if } \; c_D^e = c_D' \\ \left(e^H, e^H, 0\right) & \text{if } \; c_D^e > c_D' \end{cases} \tag{15}$$

$$(\hat{e}_g, \hat{w}_g, \hat{a}_g) = \begin{cases} (0,0,0) & \text{if } \; c_D^e < \tilde{c}_D \\ (0,0,0) \cup \left(e^H, 0, \phi^{-1}(\Delta\pi^e)\right) & \text{if } \; c_D^e = \tilde{c}_D \\ \left(e^H, 0, \phi^{-1}(\Delta\pi^e)\right) & \text{if } \; c_D^e \in (\tilde{c}_D, c_D^*] \\ \left(e^H, \Delta\pi^e - \phi^*, a^*\right) & \text{if } \; c_D^e \in (c_D^*, c_D'] \\ \left(e^H, e^H - \phi^*, a^*\right) & \text{if } \; c_D^e > c_D' \end{cases} \tag{16}$$

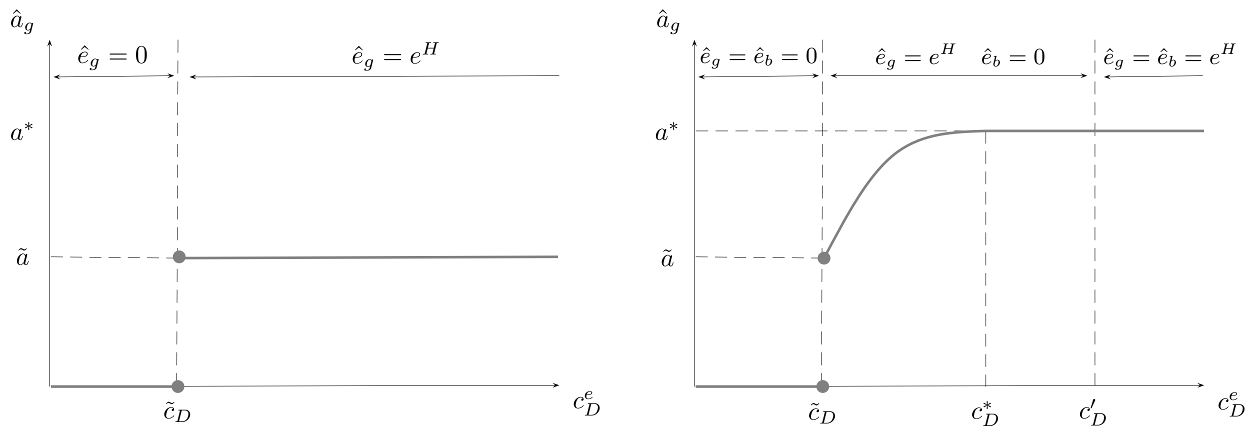
All green workers pick the offer $(\hat{e}_g, \hat{w}_g, \hat{a}_g)$, $N - qM$ brown workers pick the offer $(\hat{e}_b, \hat{w}_b, \hat{a}_b)$, and the remaining $M - N$ brown workers are unemployed.

Proof. See Appendix B ■

Proposition 1 distinguishes two configurations: the one in which all firms can hire a green worker ($q \geq N/M$) and the one in which the number of firms exceeds the number of green workers ($q < N/M$).

Case 1: $q \geq N/M$. The nature of the equilibrium contracts depend on c_D^e through its impact on the expected size of the incremental earnings. If c_D^e and thus $\Delta\pi^e$ are low, firms have no incentive to induce high effort from their employees regardless of their type. Then, they never spend any resources on abatement, and a zero wage binds both the IR and LL constraints. Hence, the optimal contract is $(0, 0, 0)$, and the associated profits for the firm equal π^L. When c_D^e increases, firms can expect some economic rewards from inducing high effort. To do so, they can hire a brown worker and compensate him for the disutility of his effort by offering a wage equal to e^H, and the profit they expect is $\pi^H - e^H$. Alternatively, they can use abatement to attract and motivate a green. Nonetheless, if the first-best level of abatement a^* is offered, the wage that enables the firm to bind the IR constraint is negative, which violates the LL constraint. Therefore, firms adopt a second-best solution by offering the level of abatement $\tilde{a}$ combined with a zero wage. This contract $(e^H, 0, \tilde{a})$ yields an expected level of profit $\pi^H - \tilde{\phi}$. Finally, under Assumption 2, the expected profits of a firm inducing high effort from a green $(\pi^H - \tilde{\phi})$ are always larger than those of a firm motivating a brown $(\pi^H - e^H)$. Since the total number of green workers exceeds the number of firms, only green workers are employed at the equilibrium. Figure 1(a) illustrates how the optimal effort of abatement, $\hat{a}_g$, evolves with the expected cutoff cost c_D^e.

When $c_D^e < \tilde{c}_D$ $(\Delta\pi^e < \tilde{\phi})$, firms do not motivate their green employee and thus, $\hat{a}_g = 0$. As soon as $c_D^e > \tilde{c}_D$, the cost induced by the minimal level of abatement required to incentivize a green $(\tilde{\phi})$ will be more than compensated by the expected incremental earnings associated with the extra effort that the employee exerts. Then, investing in CSR up to $\tilde{a}$



(a) $q \geq N/M$ (b) $q < N/M$

Fig. 1. *Equilibrium level of abatement*

increases the expected profitability of firms that hire a green worker.

***Case 2:* $\boldsymbol{q < N/M}$.** As in the previous case, when $c_D^e < \tilde{c}_D$, the optimal contract is $(0, 0, 0)$ and the expected profits for the firm are π^L. However, when c_D^e increases, we depart from the previous configuration because green workers are now in limited supply. Firms that hire a green worker have a comparative advantage since these employees are less expensive to motivate (see Assumption 2). Then, those firms have to afford a sufficiently large rent to their employee to prevent competitors from providing a more attractive offer. To do so, they offer the green employee either a higher wage or an increased investment in CSR, up to the point at which all firms are indifferent between attracting a green or a brown worker. When $c_D^e \in [\tilde{c}_D, c'_D)$, the indifference condition is written:

$$\pi^L = \pi^H - w_g - \phi(a_g) \qquad \Leftrightarrow \qquad w_g + \phi(a_g) = \Delta\pi^e \tag{17}$$

Equation (17) states that any increase in expected incremental earnings is captured by green workers as a form of additional abatement or wages. Until the first-best level of abatement

a^* has not been reached, it is more profitable for a firm to distribute the rent to her green worker as a form of CSR only. Hence, for $c_D^e \in [\tilde{c}_D, c_D^*)$, the indifference condition leads to $\hat{w}_g = 0$ and $\hat{a}_g = \phi^{-1}(\Delta\pi^e)$. When $c_D^e \in [c_D^*, c_D')$, $\hat{a}_g = a^*$ and equation (17) pins down the wage rate to $\hat{w}_g = \Delta\pi^e - \phi^*$.

Finally, when $c_D^e \geq c_D'$, monetary incentives are offered to browns. Therefore, the indifference condition becomes:

$$\pi^H - e^H = \pi^H - w_g - \phi(a_g) \qquad \Leftrightarrow \qquad w_g + \phi(a_g) = e^H \tag{18}$$

Firms propose the first-best level of abatement to greens $\hat{a}_g = a^*$ and the indifference condition (18) leads to $\hat{w}_g = e^H - \phi^*$. By relying on intrinsic motivations, the wage proposed to green employees is lower than the one offered to browns, even though they perform the same level of effort. This result echoes the empirical findings mentioned in the Introduction (see Footnote 1). All of these results are depicted in Figure 1(b).

2.3 Industry equilibrium

From Proposition 1, we deduce the average cost within the industry, $\bar{c}$, compatible with the labor market equilibrium, for a given expectation c_D^e.

If $q \geq N/M$,

$$\bar{c} \begin{cases} = c^B & \text{if} \quad c_D^e < \tilde{c}_D \\ \in [c^A, c^B] & \text{if} \quad c_D^e = \tilde{c}_D \\ = c^A & \text{if} \quad c_D^e > \tilde{c}_D \end{cases} \tag{19}$$

If $q < N/M$,

$$\bar{c} \begin{cases} = c^B & \text{if} \quad c_D^e < \tilde{c}_D \\ \in [q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B, c^B] & \text{if} \quad c_D^e = \tilde{c}_D \\ = q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B & \text{if} \quad c_D^e \in (\tilde{c}_D, c'_D) \\ \in [c^A, q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B] & \text{if} \quad c_D^e = c'_D \\ = c^A & \text{if} \quad c_D^e > c'_D \end{cases} \tag{20}$$

In both configurations, when $c_D^e < \tilde{c}_D$ firms prefer not to induce high effort and all of them offer the contract $(0, 0, 0)$. Hence, none of them exhibit a low unit production cost and the average cost of the industry equals c^B. If c_D^e overcomes $\tilde{c}_D$, it becomes profitable to motivate green employees through the spread of pro-environmental activities. When $q \geq N/M$, responsible workers are sufficiently abundant, all firms hire one of them, and $\bar{c} = c^A$.[13] When $q < N/M$, until c_D^e has not reached c'_D, firms provide incentives only to the qM existing green workers so that the average cost in the industry equals $q\frac{M}{N}c^A + \left(1 - q\frac{M}{N}\right)c^B$. As soon as c_D^e exceeds c'_D, brown workers are motivated and all firms display a low unit production cost.[14]

Through equations (19) and (20), we have established that the value of $\bar{c}$, derived from the labor market equilibrium, depends on c_D^e. In turn, at the equilibrium, this expectation must be consistent with the cutoff cost level determined in the product market as the result of the price-competition stage and that varies with the endogenous cost structure parameter

13. When c_D^e exactly equals $\tilde{c}_D$, firms are indifferent between investing or not in CSR: some of them offer the triplet $(0, 0, 0)$ that does not incentivize workers and the residual fraction offers $(e^H, 0, \tilde{a})$ that encourages responsible employees to work hard. Consequently, $\bar{c}$ belongs to the interval $[c^A, c^B]$.

14. When c_D^e exactly equals $\tilde{c}_D$ (resp. c'_D), firms are indifferent between incentivizing or not a green (resp. a brown in addition to greens). Hence, $\bar{c}$ belongs to $[q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B, c^B]$ (resp. $[c^A, q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B]$).

$\bar{c}$. Hence it must be the case that:

$$c_D^e = c_D(\bar{c}) \tag{21}$$

with $c_D(\bar{c})$ given by (7).

Thus, the industry equilibrium is defined as follows:

Definition 1 *An industry equilibrium is a pair $(c_D, \bar{c})$ that solves:*

- *the system of equations (19) and (21) if $q \geq N/M$; or*
- *the system of equations (20) and (21) if $q < N/M$.*

In order to characterize this industry equilibrium let us assume that the following conditions apply:

Assumption 3 $\tilde{c}_D < c_D(c^A) < c_D^* < c_D(c^B) < c_D'$

Assumption 3 is made to abstract from cases in which all firms exhibit the same unit production cost. Since c_D is always larger than $\tilde{c}_D$, we do not consider the configuration in which workers are not motivated at all regardless of their type. Because c_D is always lower than c_D', we also omit the configuration in which both greens and browns are induced to work hard. Put differently, we neglect the cases for which individual abatement is constant and thus are less relevant for our purpose. Then, we claim that

Proposition 2 *Under Assumptions 1-3, an industry equilibrium exists, is unique, and is characterized by:*

$$c_D = \begin{cases} c_D\left(q\frac{M}{N}c^A + \left(1 - q\frac{M}{N}\right)c^B\right) & \text{if } \; q < N/M \\ c_D(c^A) & \text{if } \; q \geq N/M \end{cases} \tag{22}$$

$$\bar{c} = \begin{cases} q\frac{M}{N}c^A + \left(1 - q\frac{M}{N}\right)c^B & \text{if } \; q < N/M \\ c^A & \text{if } \; q \geq N/M \end{cases} \tag{23}$$

Proof. See Appendix C ■

Combining the results of Propositions 1 and 2, we can deduce the equilibrium contract proposed by firms to each type of worker:

Corollary 1 *Under Assumptions 1-3:*

$$(\hat{e}_b, \hat{w}_b, \hat{a}_b) = (0,0,0) \tag{24}$$

$$(\hat{e}_g, \hat{w}_g, \hat{a}_g) = \begin{cases} \left(e^H, \Delta\pi - \phi^*, a^*\right) & \text{if } \; q \leq q^* \\ \left(e^H, 0, \phi^{-1}(\Delta\pi)\right) & \text{if } \; q \in (q^*, N/M) \\ \left(e^H, 0, \tilde{a}\right) & \text{if } \; q \geq N/M \end{cases} \tag{25}$$

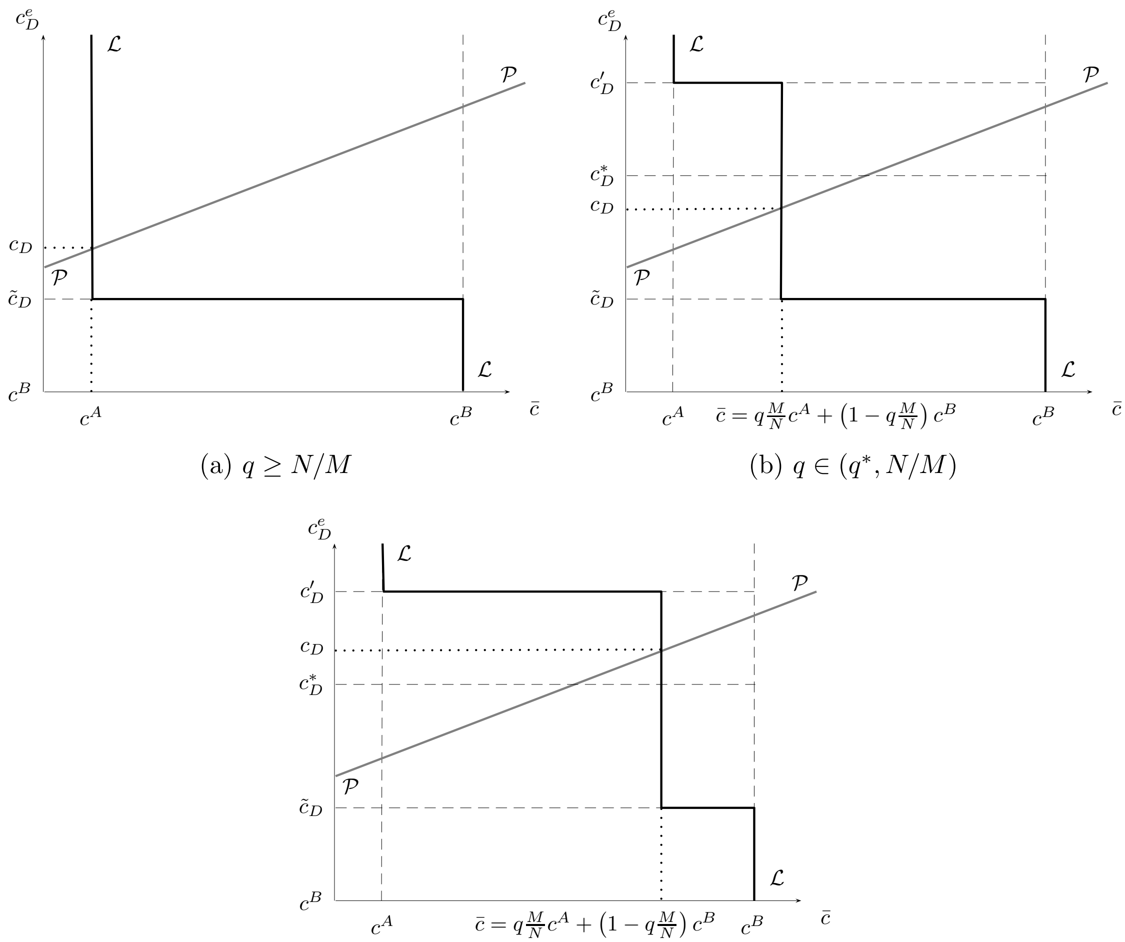
with $\Delta\pi$ given by (9), c_D given by (22) and

$$q^* = \frac{c^B}{\Delta c} + \frac{2\beta\gamma - (2\gamma + \eta N)c^*_D}{\eta M \Delta c}$$

Formally, the industry equilibrium is determined by a fixed point condition equating the expected cutoff cost level (c^e_D) and the actual cutoff cost level (c_D). Graphically, in Figure 2, we draw the $\mathcal{LL}$ curve that represents the value of $\bar{c}$, as a function of c^e_D, derived from the labor market equilibrium (equations (19) and (20)) and the $\mathcal{PP}$ curve that represents the value of c^e_D consistent with the functioning of the product market, being given $\bar{c}$ (equation (22)). The industry equilibrium corresponds to the crossing point between these two curves and, at the industry equilibrium, c_D must be equal to the equilibrium value of c^e_D.

When q is high (see Figure 2(a)), there is no competition in the labor market because the pool of responsible employees is sufficiently large to enable all firms to hire a green worker. Hence, the unique equilibrium involves N green workers being motivated through abatement and the proportion of low-cost (virtuous) firms reaching one.

When $q < N/M$, both types of workers are hired at the equilibrium. Since it is not in the interest of firms to provide incentives to brown workers (Assumption 3), the proportion of low-cost firms equals qM/N. In addition, firms now engage in a war for greens and leave them a rent that amounts to $\Delta\pi$. The contract they offer reflects the nature of this rent, which crucially depends on q. When $q \in (q^*, N/M)$ (see Figure 2(b)), the cost competition in the product market is harsh ($c_D \in (\tilde{c}_D, c^*_D)$) such that the equilibrium incremental earnings



(a) $q \geq N/M$ (b) $q \in (q^*, N/M)$

(c) $q \leq q^*$

Fig. 2. *The industry equilibrium*

are depressed ($\Delta\pi \in (\phi^H, \phi^*)$). Firms cannot afford the first-best level of abatement and still distribute the rent exclusively as a form of abatement: $\hat{a}_g = \phi^{-1}(\Delta\pi)$. When $q < q^*$ (see Figure 2(c)), the cost competition in the product market is softened ($c_D > c_D^*$) and $\Delta\pi > \phi^*$: firms invest in CSR up to a^* and the remaining rent is transferred as an extra wage.

Interestingly, the interactions between the competition in the labor market (captured by the $\mathcal{LL}$ curve) and the competition in the product market (captured by the $\mathcal{PP}$ curve) transit through the abatement choices made by firms. On the one hand, virtuous firms invest in CSR all the more that incremental earnings are high (labor market level). On the other hand, abatement strategies shape the cost competition in the product market. Hence, crucial to our results, the aggregate social performance and the competitive pressure of the industry are jointly determined.

2.4 Social performance and competitive pressure at the industry equilibrium

At the industry level, we measure the corporate social performance (CSP) by the aggregate level of abatement denoted as A and the competitive pressure in the product market by the Herfindahl-Hirschman Index (HHI) denoted as H. The equilibrium values of A and H are provided in Corollaries 2 and 3.[15]

Corollary 2 *Under Assumptions 1-3:*

$$A = \begin{cases} qMa^* & \text{if} \quad q \leq q^* \\ qM\phi^{-1}(\Delta\pi) & \text{if} \quad q \in (q^*, N/M) \\ N\tilde{a} & \text{if} \quad q \geq N/M \end{cases} \tag{26}$$

The CSP depends on two components: the number of firms that engage in CSR (*extensive margin*) and the intensity of their investment (*intensive margin*). When q is larger than N/M, all firms employ and motivate a green worker, and the extensive margin equals N. Otherwise, it equals qM, that is, the number of greens among all workers. In addition, when there is no competition in the labor market ($q \geq N/M$), the intensive margin equals $\tilde{a}$, which is just sufficient to compensate a green worker for his disutility of working hard. In contrast, when firms compete for a limited pool of responsible workers ($q < N/M$), they have to offer a higher level of abatement to attract them. Then, the intensive margin equals either a^*, when $q < q^*$, or $\phi^{-1}(\Delta\pi)$, when $q \in (q^*, N/M)$. What is relevant for our purpose is that this intensive margin is driven by market conditions through $\Delta\pi$, which depends on

15. Proofs of Corollaries 2 and 3 are omitted because they can be directly derived from Proposition 2 and Corollary 1.

the equilibrium value of c_D. This novel feature of our model, with respect to the existing literature, is more deeply investigated in the next section when studying the relationship between the CSP and workforce environmental awareness (q).[16]

The HHI is defined as the sum of the squared market shares: $H = N\rho(\sigma^A)^2 + N(1-\rho)(\sigma^B)^2$, with σ^A (resp. σ^B) the equilibrium market share of a firm with a unit production cost c^A (resp. c^B) and ρ the proportion of low-cost firms. Denoted D^A (resp. D^B) the demand addressed to a firm with a unit production cost c^A (resp. c^B), we get that:[17]

$$\begin{aligned} \sigma^A &\equiv \frac{D^A}{N[\rho D^A + (1-\rho)D^B]} = \frac{c_D - c^A}{N[c_D - \rho c^A - (1-\rho)c^B]} \\ \sigma^B &\equiv \frac{D^B}{N[\rho D^A + (1-\rho)D^B]} = \frac{c_D - c^B}{N[c_D - \rho c^A - (1-\rho)c^B]} \end{aligned}$$

Then, the HHI can be expressed as the following function of ρ and N:

$$H = \frac{\rho(c_D - c^A)^2 + (1-\rho)(c_D - c^B)^2}{N[c_D - \rho c^A - (1-\rho)c^B]^2} \tag{27}$$

From Proposition 2, we obtain the following:

Corollary 3 *Under Assumptions 1-3:*

$$H = \begin{cases} \dfrac{\frac{qM}{N}\left[c_D\left(c^B - \frac{qM}{N}\Delta c\right) - c^A\right]^2 + \left(1-\frac{qM}{N}\right)\left[c_D\left(c^B - \frac{qM}{N}\Delta c\right) - c^B\right]^2}{N\left[c_D\left(c^B - \frac{qM}{N}\Delta c\right) - \frac{qM}{N}c^A - \left(1-\frac{qM}{N}\right)c^B\right]^2} & \text{if} \quad q < N/M \\ 1/N & \text{if} \quad q \geq N/M \end{cases} \tag{28}$$

Because the CSP and the HHI are jointly determined at the equilibrium, our framework is particularly appropriate to investigate the CSR-competition nexus. The endogenous feature of the HHI and the consequences on this specific issue will be more deeply discussed in Section 4. Before that, we focus our analysis on some determinants of the firms' virtuous

16. Let us note that, all the comparative statics results we derive in Section 3 would have hold unchanged if we had considered, instead of total abatement (A), the total value of abatement (sum of all $v(a,e)$) or the total net value of abatement (sum of all $v(a,e) - \phi(a)$).

17. See Appendix A for the expressions of D^A and D^B. The equilibrium value of ρ can be directly deduced from the equilibrium value of the average cost since $\bar{c} = \rho c^A + (1-\rho)c^B$.

behaviors at the industry level.

3 Comparative statics

In this section, we investigate how the CSP varies with the workforce environmental awareness captured by the share q of responsible workers (Section 3.1). Then, to isolate the impact of competition on the aggregate corporate social performance, we focus our analysis on the environmental outcomes induced by an exogenous variation in the competitive pressure captured by a change in the number of competitors N (Section 3.2).

3.1 Workforce environmental awareness

Intuitively, the spread of environmental awareness among workers should support a better CSP. Indeed, abatement is strategically used by firms to incentivize green employees. Hence, the more the responsible workers, the more the virtuous firms, which typically refers to the extensive margin effect. However, we shed light on a countervailing force: a negative intensive margin effect that goes through two channels. First, a rise in q involves exacerbated competition in the product market (it lowers $\bar{c}$ and then c_D) and thus a depressed $\Delta\pi$. Consequently, each green firm can afford less CSR. Second, it also implies softened competition in the labor market, which makes less useful the use of abatement to attract greens. Overall, the negative intensive margin effect may overcome the positive extensive one. Hence, surprisingly, the spread of environmental awareness among the workforce may lead to a deteriorated CSP. In subsequent paragraphs, we provide more details on the mechanisms at stake.

When q is lower than N/M, all of the qM responsible employees are incentivized to work hard and receive a rent equal to $\Delta\pi$. Furthermore, each additional green worker exacerbates competition in the product market that, in turn, deteriorates $\Delta\pi$. When $q \leq q^*$, virtuous firms offer the first-best level of abatement and the reduction in $\Delta\pi$ translates into lower wages. Because the individual level of abatement a^* is invariant with q, only the extensive margin plays a role, and the CSP increases linearly with workers' environmental awareness. In contrast, when $q \in (q^*, N/M)$, the decline in $\Delta\pi$ entails a reduction in CSR investments realized by each virtuous firm. Hence, an increase in q also has a negative effect on the individual effort of abatement. In this configuration, the global effect of workers' environmental awareness on the CSP of the industry depends on the relative strength of the positive extensive margin effect with regard to the negative intensive margin effect. Finally, when $q \geq N/M$, the CSP is invariant with q. Indeed, all firms employ a green worker and choose the minimal level of abatement $\tilde{a}$ to ensure that their employee is working hard.

The impact of q on the CSP can be summarized in the following proposition:

Proposition 3 *Under Assumptions 1-3:*

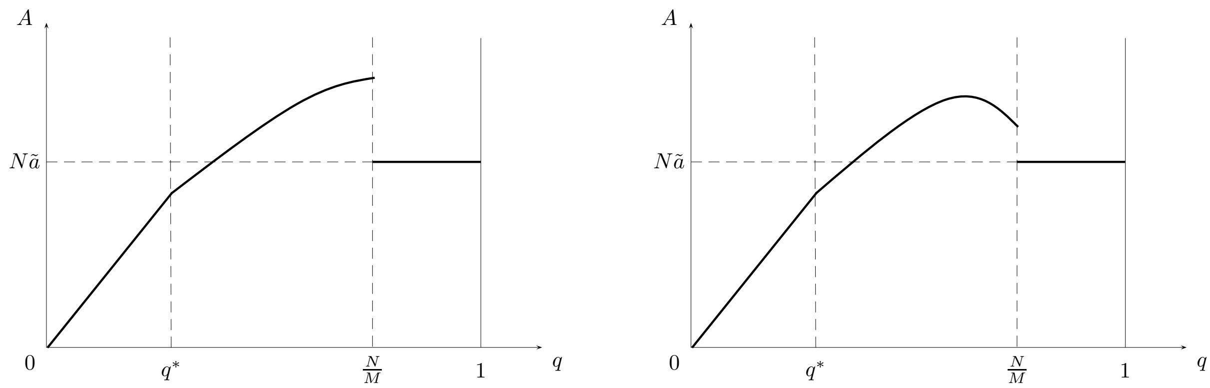
- *If $\varepsilon_{\phi,a} \geq -\varepsilon_{\Delta\pi,q}$ for $q = N/M$, A is increasing for $q \in [0, N/M)$ and is constant for $q \in [N/M, 1]$ with a downward shift in $q = N/M$;*
- *If $\varepsilon_{\phi,a} < -\varepsilon_{\Delta\pi,q}$ for $q = N/M$, A is hump-shaped for $q \in [0, N/M)$ and is constant for $q \in [M/N, 1]$ with a downward shift in $q = N/M$;*

with $\varepsilon_{x,y}$ the elasticity coefficient between x and y. Moreover, for $q = N/M$ we have:

$$\varepsilon_{\Delta\pi,q} = -\frac{2\eta N\Delta c}{4\beta\gamma - 2\gamma(c^A + c^B) - N\eta\Delta c}$$

Proof. See Appendix D ■

Figure 3 depicts the results stated in Proposition 3. In each configuration, when q is larger than N/M, A is constant and equal to $N\tilde{a}$. In addition, when $q \leq q^*$, A is linearly increasing in q, through the sole extensive margin effect. For intermediate values of q, a negative intensive margin effect also arises.



(a) $\varepsilon_{\phi,a} \geq -\varepsilon_{\Delta\pi,q}$ for $q = N/M$ (b) $\varepsilon_{\phi,a} < -\varepsilon_{\Delta\pi,q}$ for $q = N/M$

Fig. 3. *CSP and workers' green consciousness*

According to Proposition 3, this intensive margin effect may dominate for q sufficiently large. In fact, an increase in q weakens the extensive margin effect while it strengthens the intensive margin effect. On the one hand, as q grows, each green firm invests a smaller amount in CSR. Thus, the marginal impact of an additional green worker on the aggregate abatement is decreasing in q. On the other hand, since abatement costs are convex, the decline in a required to compensate for a given reduction in $\Delta\pi$ is increasing in q. In addition, the intensive margin effect is magnified when *i)* the elasticity of the abatement cost function is low; and *ii)* the elasticity of the incremental earnings with respect to the proportion of low-cost firms in the industry is high, such that the hump-shaped pattern occurs when $\varepsilon_{\phi,a} < -\varepsilon_{\Delta\pi,q}$ at the point $q = N/M$.[18] Figure 3(a) illustrates the case in which this condition is not satisfied, and the intensive margin effect is always dominated, whereas

18. Indeed, *i)* if $\phi(a)$ is poorly sensitive to abatement, a small decline in $\Delta\pi$ – induced by an increase in q – involves a large reduction in abatement to ensure that the equality $\Delta\pi = \phi(a)$ is still satisfied; and *ii)* the more the incremental earnings are sensitive to q, the larger the decline in $\Delta\pi$ when the number of greens increases.

Figure 3(b) shows the case in which the intensive margin effect overcomes the extensive margin effect when q becomes sufficiently close to N/M.

This negative relationship between the green consciousness of workers and the aggregate abatement stems from feedback effects involved by harsher competition in the product market. This seemingly counterintuitive pattern may also directly emerge due to change in the competitive pressure in the labor market. For $q \geq N/M$, firms are on the short side of the labor market such that all of them can employ a green worker and offer the minimal level of abatement $\tilde{a}$. The sole role of CSR is to motivate employees to exert high effort. In contrast, when q is lower, CSR investments have an additional role to play: they are strategically used by firms in their competition to attract a green worker, and abatement efforts are strictly higher than $\tilde{a}$. Hence, as q approaches N/M, almost all firms employ a green worker but still must offer a high level of CSR. When q reaches N/M, the extensive margin effect vanishes while competition on the labor market is suddenly relaxed. As a consequence, only a negative intensive margin effect arises, which explains the downward shift of A.

With regards to the existing literature on the strategic use of CSR, the framework we propose has the advantage of taking into account *i)* both the number of firms that invest in CSR and the intensity of their own investment; and *ii)* the industry equilibrium effects. These two dimensions may help figure out the feedback effects that may arise when more workers become responsible. In particular, this assessment justifies the unexpected conclusion according to which the spread of environmental awareness among workers might induce a lower aggregate corporate social performance.

Let us remark that, if q were interpreted as the share of socially responsible individuals in the whole population, an increase in q would also have generated a spread in the green consciousness among consumers. If it were the case, the negative feedback effects of a rise in q on the CSP could have been mitigated by an increase in the demand addressed to green firms. This kind of mechanisms is clearly beyond the scope of the current paper and we can argue that the proportion q of socially responsible individuals within our population of workers is only partially connected to the proportion of socially responsible consumers. Indeed, a significant fraction of CSR spendings are directly targeted towards employees (see Flammer and Luo 2017) and consumers might not care so much about this kind of CSR programs.[19] Moreover, the characteristics of each industry may affect the composition of the available pool of workers (in terms of skills or preferences). This may translate into cross-industry differences in the proportion q of responsible workers. Yet, the composition of the demand has no reason to reflect those variations.

3.2 Number of competitors

In this section, we aim to answer the following question: "Does competition erode social responsibility?" To do so, we explore the evolution of the CSP involved by a change in the number of competitors (N). An increase in N exacerbates competition in both the product and the labor markets, with opposite consequences on the CSP. On the one hand, enhanced competition reduces the firms' profit margins and, thus, incremental earnings. Abatement investments are accordingly slackened. On the other hand, it intensifies the war for greens and enhances the use of CSR to attract them. Whether these two mechanisms at stake occur or not depends on the prevailing market conditions as claimed in the following Proposition:

Proposition 4 *Under Assumptions 1-3: If $q > q^*$, A is increasing in N when $N \leq qM$ and then decreasing in N when $N > qM$ with an upward shift in $N = qM$.*

19. Accordingly, it could be interesting to test the predictions of the model by distinguishing between employee-related CSR from other kinds of CSR investments (see our discussion in Section 4).

Proof. See Appendix E ■

The results of this Proposition are illustrated in Figure 4. When $N < qM$, the number of

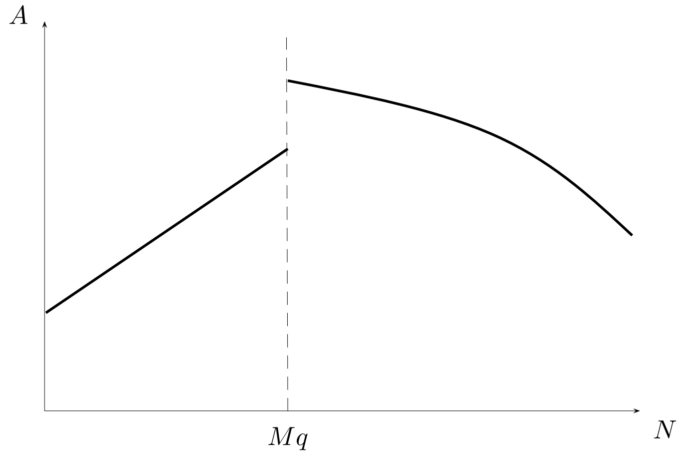


Fig. 4. *CSP and the number of competitors*

green workers exceeds the number of firms and all of them invest an amount $\tilde{a}$ in abatement. Hence, an additional firm in the industry mechanically increases the aggregate abatement through an extensive margin effect. Further, when N reaches qM, firms initiate a war to attract green employees who are now in limited supply. To that end, they suddenly increase their investment in CSR such that A is upward shifted. When $N > qM$, an increase in the number of competitors does not qualitatively alter the toughness of the competition in the labor market because the latter is already harsh. Henceforth, an increase in N affects aggregate abatement only at the product market level. In particular, such an increase dilutes profits margins and reduces incremental earnings[20], causing firms to reduce their investment in CSR. This negative margin effect explains the downward trend of A.

20. An increase in N also has an indirect positive impact on c_D and finally $\Delta\pi$. Indeed, this increase reduces the proportion of low-cost firms, but this effect is always dominated by the negative dilution effect. See Appendix E

Whether competition favors or erodes virtuous behaviors by firms depends on prevailing market conditions captured by the existing number of competitors as well as the number of green workers. As underlined by Fernandez-Kranz and Santalo (2010), in the existing literature, a rise in the competitive pressure displays an unequivocal effect on CSR investments, be it positive like in Fisman et al. (2006) or negative like in Bagnoli and Watts (2003). Our set-up offers a unified framework that clarifies the conditions under which one configuration or the other occurs. In particular, we bring out the importance of considering the differentiated impact of N on both the product and the labor markets.[21]

4 Discussion and Conclusion

An increasing number of companies provide efforts – sometimes heavily costly – to appear socially responsible. The present paper contributes to our understanding of CSR decisions by firms. In particular, we investigate how these decisions relate to their competitive environment. To that end, we emphasize two market dimensions through which firms compete – the labor market and the product market – as well as two channels through which market conditions impact CSR decisions: the intensive and the extensive margins. Our framework allows light to be shed on a bidirectional relationship between CSR and competition. On the one hand, the incentives that firms have to attract motivated workers through abatement depend on market conditions. On the other hand, the competitive environment is affected

21. We could have considered alternative measures of product market competition instead of the number N of firms. The utility function parameter γ constitutes a natural candidate. Indeed, γ measures the substituability between the different varieties of the differentiated good (a lower γ implies a higher degree of substituability). Unlike N, γ affects the degree of competition on the product market only. However, we show in the Online Appendix that the impact of a change in γ on the CSP of the industry may also be non-monotonous. This comes from the fact that a rise in γ has two opposite effects on $\Delta\pi$. First, it softens competition (it increases c_D) since it enhances the market power of each individual firm. As a consequence, $\Delta\pi$ grows. Second, for a given level of c_D, it implies that high-cost firms have a more captive market, such that they suffer less from their competitive disadvantage. Hence $\Delta\pi$ reduces.

by firms' CSR decisions. One striking implication is in the fact that the spread of a green consciousness among the workforce has feedback impacts on both the labor and the product markets, which could lead to poorer CSP. More broadly, our analysis highlights the value of taking into account the interactions between the labor and the product markets rather than studying one or the other in isolation. Indeed, the competitive pressure on the product market impacts CSR strategies by firms provided that the competition in the labor market is sufficiently harsh.

By offering analytical expressions for the CSP and the HHI of the industry, we also point out interesting insights for an empirical analysis of the CSR-competition linkage. Empirical studies often assess this relationship by estimating the impact of the HHI on the CSP at the sectoral level. Our results indicate that this kind of estimation should be cautiously interpreted as causal, from competition to CSP, due to an endogeneity issue. Furthermore, our theoretical framework allows us to revisit this issue. In particular, we emphasize the role played by the social consciousness of the workforce as a determinant of both the HHI and the CSP of an industry.

Beyond the identification of a causal relationship from competition to CSR, we may want to assess the relevance of the mechanisms proposed in the model and to disentangle our supply-side effects (CSR may be used to attract/motivate employees) from demand-side effects (CSR may be used as a differentiation strategy allowing to increase market shares). In the existing empirical literature, the supply-side effects have mainly been investigated thanks to experimental data. While those experiments (either in the field or in the lab) convincingly highlight a positive impact of CSR on the welfare and the motivation of some workers[22], they

22. In particular, the results obtained by Hedblom et al. (2019) strongly support our theoretical framework.

are not fully appropriate for taking into account firms' competitive environment. In a recent paper, Flammer and Luo (2017) take another avenue. They consider an exogenous shock on the labor market – an increase in the unemployment insurance benefits – that enhances the bargaining position of employees compared to employers. In our framework this shock induces harsher labor market competition. Then, as predicted by our model, Flammer and Luo (2017) conclude that firms react by increasing their investments in employee-related CSR.

Similar strategies have been adopted in order to study the impact of competition at the product market level on CSR spending. In particular, Fernandez-Kranz and Santalo (2010) and Flammer (2015) conclude that those investments positively react to exogenous increases in product market competition. One issue to interpret these results lies in the fact that they can be driven by the combination of supply-side and demand-side effects. One way to disentangle these two channels could be to consider separately employee-related CSR, which should constitute the main driving force for the supply-side effects, from CSR spending more oriented towards customers.

Our model also enables to derive some predictions regarding the relationship between CSR investments and wages offered by firms. In particular, the labor market equilibrium (Proposition 1) tells us that green firms may either propose higher wages or lower wages than their brown counterparts. More precisely, when the competition is soft, both types of firms induce high efforts from their employees and brown firms do so by offering higher wages than green ones. Conversely, when competition is harsher, only green firms incentivize

Using a structural estimation based on experimental data, they show that CSR investments may be used to motivate existing employees and to attract new highly productive workers and, by the way, permit to lower the firm's unit production costs.

their workers by combining higher wages with investments in CSR. According to this result, some studies on the link between CSR and wages, as the ones proposed by Frank (2004) or Nyborg and Zhang (2013), may underestimate the motivational effect of CSR. Those studies consist in estimating a relationship between a firm's reputation as socially responsible and the wage level of this firm's employees. However, as claimed in our Proposition 1, the intrinsic utility that motivated workers derive from their employer's CSR investment may be traded for wages and/or efforts. More broadly, our prediction according to which, in highly competitive environments, firms may substitute non-monetary benefits with monetary incentives while these two devices will be used together when the competition is softer, deserves to be empirically investigated.

Appendices

A Derivation of the equilibrium demands

The consumer's optimization problem is given by

$$\begin{aligned} \max_{\{q_i\}_{i\in\Omega}} \quad & \mathcal{V} = x_0 + \beta \int_{i\in\Omega} x_i di - \tfrac{1}{2}\gamma \int_{i\in\Omega} x_i^2 di - \tfrac{1}{2}\eta \left(\int_{i\in\Omega} x_i di\right)^2 \\ \text{s.t.} \quad & x_0 + \int_{i\in\Omega} p_i x_i \leq I \end{aligned}$$

where I is the consumer's income. The associated Lagrangian writes as $\mathcal{L} = \mathcal{V} - \lambda[x_0 + \int_{i\in\Omega} p_i x_i - I]$. The first derivative with respect to x_0 leads to $\lambda = 1$. Hence, the first derivative with respect to x_i may be rewritten as:

$$p_i = \beta - \gamma x_i - \eta Q \quad \text{with} \quad Q = \int_{i\in\Omega} x_i di \tag{A.1}$$

Integrating out this expression gives:

$$\bar{p} = \frac{1}{N}\int_{i\in\Omega} p_i = \beta - \frac{\gamma + \eta N}{N} Q \quad \Leftrightarrow \quad Q = \frac{N\beta}{\gamma + \eta N} - \frac{N}{\gamma + \eta N}\bar{p} \tag{A.2}$$

Putting this expression of Q into (A.1) allows us to obtain expression (2) of the demand addressed to firm i.

In order to obtain the equilibrium value of the demand addressed to firm i, we replace p_i and $\bar{p}$ by their equilibrium expressions, (4) and (5), into (2). It yields $D_i = \frac{L}{2\gamma}(c_D - c_i)$ with c_D given by (7). The equilibrium demand addressed to a firm with a unit production cost c^A (resp. c^B) is obtained by replacing c_i by c^A (resp. c^B) in the expression above:

$$D^A = \frac{L}{2\gamma}\left(c_D - c^A\right) \qquad \text{and} \qquad D^B = \frac{L}{2\gamma}\left(c_D - c^B\right) \tag{A.3}$$

Both D^A and D^B are positive if c_D is always larger than c^B. Yet, c_D is minimal when $\bar{c}$ equals c^A. Hence, the condition that has to be satisfied is the following:

$$\frac{2\beta\gamma}{2\gamma + \eta N} + \frac{\eta N}{2\gamma + \eta N} c^A > c^B$$

Simple algebra yields Assumption 1.

B Proof of Proposition 1

Let us successively address the cases where q is larger, and then, lower than N/M.

Case 1. $q \geq N/M$

Lemma 1 *When* $c_D^e \leq \tilde{c}_D$*, at the equilibrium all firms propose the contract* $(0, 0, 0)$.

Proof. The contract $(0, 0, 0)$ satisfies the IR and LL constraints for both green and brown workers and yields a profit equal to π^L, which is positive under Assumption 1. In the situation in which all firms propose this unique contract, the IC constraint becomes irrelevant. Let us show that there is no profitable deviation from this situation. We first note that there is no alternative contract inducing the low effort e^L that would allow for a profit higher than π^L. Hence, any profitable deviation implies to induce high effort from the employee. To do so, the deviating firm attracts either a brown or a green worker. In the first case, she must compensate the high effort through an increased wage and thus, the profit will be at best equal to $\pi^H - e^H$. Yet, since, by Assumption 2, $c_D^e \leq \tilde{c}_D < c_D'$ we must have $\Delta\pi^e \leq \tilde{\phi} < e^H$ such that the deviation is not profitable. In the second case, she offers a contract that satisfies both the IR and LL constraints for a green worker such that $e^H \geq v(e^H, a_g)$, which implies $a_g \leq \tilde{a}$. Under this constraint, the firm chooses a_g to maximize the following expression of her profits: $\pi^H - e^H + v(e^H, a_g) - \phi(a_g)$. The solution to this program is $\tilde{a}$, since, by Assumption 2, $\tilde{a} < a^*$. Then, profits of the deviating firm equal $\pi^H - \tilde{\phi}$, which is lower than π^L (since $c_D^e \leq \tilde{c}_D$). Again, the deviation is not profitable. ∎

Lemma 2 *When $c_D^e \geq \tilde{c}_D$, at the equilibrium all firms propose the contract $(e^H, 0, \tilde{a})$ and only green workers are employed.*

Proof. The contract $(e^H, 0, \tilde{a})$ satisfies the IR and LL constraints for green workers and yields a profit equal to $\pi^H - \tilde{\phi}$. Moreover, brown workers prefer to be unemployed rather than to accept this contract such that the IC constraint is satisfied. Let us show that there is no profitable deviation from the situation in which all firms propose this contract. One possible deviation would consist in proposing a contract that induces the low effort. Such a deviation would yield a profit at most equal to π^L and is not profitable. Indeed, $c_D^e \geq \tilde{c}_D$ implies that $\pi^L \leq \pi^H - \tilde{\phi}$. Another possible deviation would consist in inducing high effort from a brown worker. Such a deviation would yield a profit at most equal to $\pi^H - e^H$ and is not profitable because, through Assumption 2, $\tilde{\phi} < e^H$. The last possible deviation would consist in proposing an alternative contract inducing high effort from a green worker. Such a contract must be $(e^H, \varepsilon, \tilde{a} - \eta)$ with $\varepsilon \geq 0$, due to the LL constraint, and $\varepsilon \leq e^H$ to avoid attracting a brown worker. This contract would allow to attract a green worker if $\varepsilon > e^H - v(e^H, \tilde{a} - \eta)$; and would yield higher profits if $\varepsilon < \phi(\tilde{a}) - \phi(\tilde{a} - \eta)$. These two conditions can be simultaneously satisfied if and only if $v(e^H, \tilde{a}) - v(e^H, \tilde{a} - \eta) < \phi(\tilde{a}) - \phi(\tilde{a} - \eta)$. Yet, the latter condition cannot be satisfied because $\tilde{a} < a^*$ and for all $a_g < a^*$, $\phi'(a_g) < v'_a(e^H, a_g)$. ■

Case 2. $q < N/M$

When $c_D^e \leq \tilde{c}_D$, at the equilibrium, all firms propose the contract $(0, 0, 0)$. The proof is similar to the one of Lemma 1.

Lemma 3 *When* $c_D^e \in [\tilde{c}_D, c_D^*]$, qM *firms offer* $(e^H, 0, \phi^{-1}(\Delta\pi^e))$ *to green workers and* $N - qM$ *firms offer* $(0, 0, 0)$ *to brown workers.*

Proof. The two contracts satisfy the IR, LL and IC constraints for brown and green workers and yield a profit π^L. Let us show that there is no profitable deviation from the situation described in Lemma 3. Similar to the proof of Lemma 2, the only possible deviation that should be considered is the one that consists in offering an alternative contract to green workers that induces high effort and that is characterized by a higher wage and a lower investment in CSR: $(e^H, \varepsilon, \phi^{-1}(\Delta\pi^e) - \eta)$ with $\varepsilon \in [0, e^H]$. This contract would allow to attract a green worker if $\varepsilon > v(e^H, \phi^{-1}(\Delta\pi^e)) - v(e^H, \phi^{-1}(\Delta\pi^e) - \eta)$; and would yield higher profits if $\varepsilon < \phi(\phi^{-1}(\Delta\pi^e)) - \phi(\phi^{-1}(\Delta\pi^e) - \eta)$. These two conditions can be simultaneously satisfied if and only if $v(e^H, \phi^{-1}(\Delta\pi^e)) - v(e^H, \phi^{-1}(\Delta\pi^e) - \eta) < \phi(\phi^{-1}(\Delta\pi^e)) - \phi(\phi^{-1}(\Delta\pi^e) - \eta)$. Yet, the above condition cannot be satisfied because $\phi^{-1}(\Delta\pi^e) \leq a^*$ and for all $a_g \leq a^*$,

$\phi'(a^g) \leq v'_a(e^H, a_g)$. ■

Lemma 4 *When* $c^e_D \in (c^*_D, c'_D]$, *qM firms offer* $(e^H, \Delta\pi^e - \phi^*, a^*)$ *to green workers and* $N - qM$ *firms offer* $(0, 0, 0)$ *to brown workers.*

Proof. The two contracts satisfy the IR, LL and IC constraints for brown and green workers and yield a profit π^L. Again, a relevant deviation would be such that the deviating firm offers an alternative contract to greens that induces high effort. However, since a^* is the first-best level of abatement, there is no such an alternative contract allowing for attracting a green worker while having higher profits. ■

Lemma 5 *When* $c^e_D \geq c'_D$, *qM firms offer* $(e^H, e^H - \phi^*, a^*)$ *to green workers and* $N - qM$ *firms offer* $(e^H, e^H, 0)$ *to brown workers.*

Proof. The two contracts satisfy the IR, LL and IC constraints for brown and green workers and yield a profit equal to $\pi^H - e^H$. One relevant possible deviation would consist in proposing an alternative contract to greens that induces high effort. However, since a^* is the first best-solution, there is no such an alternative contract allowing for attracting a green worker while having higher profits. ■

C Proof of Proposition 2

Case 1: $q \geq N/M$. The equilibrium values of c_D and $\bar{c}$ are simply given by the crossing points between the curves described by equations (19) and (21), respectively. Through (21), c^e_D is linearly increasing in $\bar{c}$, whereas through (19), $\bar{c}$ is a step function equals to c^B when $c^e_D < \tilde{c}_D$, c^A when $c^e_D > \tilde{c}_D$ and any value between the two when $c^e_D = \tilde{c}_D$. Moreover, according to Assumption 3, $c_D(c^A)$ is above $\tilde{c}_D$. Hence, the only possible intersection between the curves $\mathcal{PP}$ and $\mathcal{LL}$ is in $\bar{c} = c^A$ and $c^e_D = c_D = c_D(c^A)$.

Case 2: $q < N/M$. The equilibrium values of c_D and $\bar{c}$ are simply given by the crossing points between the curves described by equations (20) and (21), respectively. Through (21), c_D^e is linearly increasing in $\bar{c}$, whereas through (20), $\bar{c}$, is a step function equals to c^B when $c_D^e < \tilde{c}_D$, $q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B$ when $c_D \in (\tilde{c}_D, c'_D)$ and c^A when $c_D^e > c'_D$. In addition, it can take any values between c^B and $q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B$ (resp. $q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B$ and c^A) when $c_D^e = \tilde{c}_D$ (resp. $c_D^e = c'_D$). Moreover, according to Assumption 3, $c_D(c^B)$ is below c'_D and $c_D(c^A)$ is above $\tilde{c}_D$. Hence, the only possible intersection, between the curves $\mathcal{PP}$ and $\mathcal{LL}$, is in $\bar{c} = q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B$ and $c_D^e = c_D = c_D\left(q\frac{M}{N}c^A + (1 - q\frac{M}{N})c^B\right)$.

D Proof of Proposition 3

For $q \leq q^*$, A is linearly increasing while when $q \geq N/M$, A is constant (see equation (26)). Let us focus on the case where $q \in (q^*, N/M)$. In that case, we know from Proposition 2 that $\bar{c} = q\frac{M}{N}c^A + \left(1 - q\frac{M}{N}\right)c^B$. Plugging this equilibrium value of $\bar{c}$ into expression (7) and then (9) we can express the equilibrium value $\Delta\pi$ as the following function of q:

$$\Delta\pi(q) = \frac{L\Delta c}{2\gamma}\left[\frac{2\beta\gamma}{2\gamma + \eta N} + \frac{\eta N}{2\gamma + \eta N}\left(c^B - q\frac{M}{N}\Delta c\right) - \frac{c^B + c^A}{2}\right] \tag{D.1}$$

Then, from (26), we have $A = \Psi(q)$ with $\Psi(q) = qM\phi^{-1}(\Delta\pi(q))$. The differentiation of $\Psi(q)$ with respect to q yields:

$$\Psi'(q) = M\left[\phi^{-1}(\cdot) + q\frac{\partial\phi^{-1}(\cdot)}{\partial\Delta\pi}\frac{\partial\Delta\pi(\cdot)}{\partial q}\right] \tag{D.2}$$

Since $\frac{\partial\Delta\pi}{\partial q} < 0$, $\Psi'(q)$ is positive if and only if:

$$\frac{\partial\phi^{-1}(\cdot)}{\partial\Delta\pi}\frac{\Delta\pi(\cdot)}{\phi^{-1}(\cdot)} < -\frac{\frac{\Delta\pi(\cdot)}{q}}{\frac{\partial\Delta\pi(\cdot)}{\partial q}} \qquad \Leftrightarrow \qquad -\varepsilon_{\Delta\pi,q} < \frac{1}{\varepsilon_{\phi^{-1},\Delta\pi}} \tag{D.3}$$

By the properties of the inverse function and since $\varepsilon_{\Delta\pi,q} < 0$, whereas $\varepsilon_{\phi,a} > 0$, the latter condition may be rewritten as:

$$-\varepsilon_{\Delta\pi,q} < \varepsilon_{\phi,a} \tag{D.4}$$

By (D.1) we have

$$\Psi''(q) = M\left[2\frac{\partial\phi^{-1}(\cdot)}{\partial\Delta\pi}\frac{\partial\Delta\pi(\cdot)}{\partial\rho} + q\frac{\partial^2\phi^{-1}(\cdot)}{\partial\Delta\pi^2}\left(\frac{\partial\Delta\pi(\cdot)}{\partial\rho}\right)^2\right] \tag{D.5}$$

which is negative because $\phi^{-1}(\cdot)$ is increasing and concave in $\Delta\pi$, whereas $\Delta\pi$ is linearly decreasing in q. Hence, on the interval $[0, N/M)$, A is either always increasing or, firstly increasing and then, decreasing. The former case occurs if, and only if, the inequality (D.4) is satisfied in $q = N/M$. Putting these elements together, we obtain the results stated in Proposition 3.

Finally, let us show some parametric configurations compatible with Assumptions 1-3 and the condition $\varepsilon_{\phi,a} < -\varepsilon_{\Delta\pi,q}$ at the point $q = N/M$. To that end, let us consider the following functional forms: $\phi(a) = \varphi a$ and $v(e^H, a) = e^H a^\mu$ with $\varphi \geq 0$ and $\mu \in (0,1)$, such that $a^* = (\mu e^H/\varphi)^{\frac{1}{1-\mu}}$, $\phi^* = (\mu e^H/\varphi^\mu)^{\frac{1}{1-\mu}}$, $\tilde{\phi} = \varphi$ and Assumption 2 is satisfied for

$$e^H \in \left(\frac{\varphi}{\mu}, \frac{\varphi}{\mu^{1/\mu}}\right) \tag{D.6}$$

In this configuration, the condition $\varepsilon_{\phi,a} < -\varepsilon_{\Delta\pi,q}$ at the point $q = N/M$ rewrites as $4\beta\gamma < 2\gamma(c^A + c^B) + 3N\eta\Delta c$, which is compatible with Assumption 1 if

$$\beta \in \left[c^B + \frac{\eta N\Delta c}{2\gamma}, \frac{3\eta N\Delta c}{4\gamma} + \frac{c^A + c^B}{2}\right) \tag{D.7}$$

To obtain some ranges of β compatible with the latter condition, it is sufficient to have $N > \frac{2\gamma}{\eta}$. Finally, it is easy to find some sets of parameters compatible with conditions (D.6), (D.7) and Assumption 3. Indeed, the gaps between $\tilde{c}_D$ and c^* and between c^* and c'_D may be arbitrarily large for arbitrarily low values of μ while L can be used to ensure that c^* stands in between $c_D(c^B)$ and $c_D(c^A)$.

E Proof of Proposition 4

Using equation (26) and since $q > q^*$, the aggregate abatement may be rewritten as the following function of N:

$$A = \begin{cases} N\tilde{a} & \text{if} \quad N \leq qM \\ qM\phi^{-1}(\Delta\pi) & \text{if} \quad N > qM \end{cases}$$

When $N \leq qM$, A is linearly increasing in N. When N reaches qM, the value of A switches from $qM\tilde{a}$ to $qM\phi^{-1}(\Delta\pi)$ where $\Delta\pi$ is given by (D.1) with $q = N/M$. Moreover, because $c_D(c^A) > \tilde{c}_D$ (Assumption 3), this value of $\Delta\pi$ is higher than $\tilde{\phi}$ such that A is upward shifted in $N = qM$. Finally, differentiating (D.1) with respect to N yields

$$\frac{\partial \Delta\pi}{\partial N} = \frac{L\eta\Delta c}{(2\gamma + N\eta)^2}\left[\eta qM\Delta c - 2\gamma(\beta - c^B)\right] \tag{E.1}$$

which is negative if

$$q < \frac{2\gamma(\beta - c^B)}{\eta M\Delta c} \tag{E.2}$$

while, since $c^B < c_D(c^A)$ (Assumption 3), $\frac{2\gamma(\beta - c^B)}{\eta M\Delta c} > \frac{N}{M}$. Thus the inequality (E.2) is satisfied for all values of $q < N/M$ such that A is decreasing in N when $N > qM$.

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