Awards vs. Labels: Incentivizing Investments in Environmental Quality*

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Abstract

Although consumers often care about environmental quality, limited attention impairs consumers' perception of environmental quality. Environmental awards and labels make environmental quality salient and attract consumers' attention. We analyze how awards and labels affect firms' investments in environmental quality and social welfare. We show that, with an award, all firms invest in environmental quality; with a label, only one firm invests. In general, investments are weakly increasing in salience. A welfare-maximizing regulator prefers awards over labels if and only if marginal damage is sufficiently high or salience is sufficiently low. In addition, we identify a range of situations where awards, respectively labels, outperform emission taxes.

Keywords: awards, environmental quality, labels, limited attention, salience.

JEL Code: D91, L13, L15, Q52, Q58

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1 Introduction

Although consumers often care about the environmental quality of the goods they consume,[1] limited attention impairs consumers' perception of environmental quality.[2] To increase the salience and thereby draw consumers' attention to environmental quality, firms often employ environmental labels. Prominent labels include, for example, *Blue Angel*, *EU Ecolabel*, *Energy Star*, *FSC*, *Green Button*, or *WaterSense*.[3] Increasingly, firms that won an environmental award also advertise this award on their products to make their environmental quality salient and attract consumers' attention. Environmental awards include, for example, the *Champions of the Earth*, the *German Environmental Award*, the *German Sustainability Award*, the *Earthshot Prize*, the *EU Organic Awards*, or the *UN Global Climate Action Award*.[4]

In this article, we analyze the effects of environmental awards and environmental labels on firms' investments in environmental quality. We discuss how awards and labels differ in incentivizing investments and investigate the implications of awards and labels on social welfare. In particular, we analyze under which circumstances a regulator with the objective to maximize social welfare should implement an environmental award and under which circumstances such a regulator should implement an environmental label.

We consider a model with two firms, a regulator with the objective to maximize social welfare, and a unit mass of consumers. The regulator chooses between implementing an environmental award and implementing an environmental label. If the regulator implements an environmental award, the regulator additionally chooses a monetary prize.

[1] See, e.g., Ward et al. (2011), Löschel et al. (2013), Kuhn & Uler (2019), Hulshof & Mulder (2020), Morone et al. (2021), Bartling et al. (2024), European Commission—Directorate-General for Communication (n.d.), Ruggeri et al. (2024).

[2] See, e.g., Allcott & Taubinsky (2015), Sexton (2015), Tiefenbeck et al. (2018), Wang et al. (2018), Andor et al. (2020), Boogen et al. (2022), Sejas-Portillo et al. (2025).

[3] The *Blue Angel* is a label for environmentally friendly products in Germany (RAL gGmbH n.d.). The *EU Ecolabel* is a label for environmentally friendly products in the EU (RAL gGmbH 2024). The *Energy Star* is a label for energy efficiency in the US (Energy Star n.d.). The *FSC* is a label for a sustainable management of forests (Forest Stewardship Council n.d.). The *Green Button* is a label for sustainable textiles in Germany (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH n.d.). *WaterSense* is a label for water efficiency in the US (Environmental Protection Agency - United States 2025).

[4] For most awards, a contest is organized once a year. The *Champions of the Earth award* of the UN Environment Program recognizes individuals and organizations for innovative and transformative actions fighting against climate change, biodiversity loss, and pollution and waste (United Nations Environment Programme n.d.). The *German Environmental Award* is endowed with 500 000 euros and acknowledges individuals for research or goods that are in line with environmental protection (Deutsche Bundesstiftung Umwelt n.d.). The *German Sustainability Award* rewards companies, municipalities, and research institutions for their ecological and social engagement (Stiftung Deutscher Nachhaltigkeitspreis n.d.). The *Earthshot Prize* is endowed with 1 million pound and is awarded to innovative solutions for repairing the planet (The Earthshot Prize 2025). The *EU Organic Awards* are non-financial awards that recognize actors for their organic projects (Directorate-General for Agriculture and Rural Development n.d.). The *UN Global Climate Action Award* highlights projects and any initiatives by people, businesses, governments, and industries that focus both on climate change and broader economic, social, and environmental challenges (UNFCCC n.d.).

Then, the firms compete in a lottery contest for the award. That means, a firm's probability of winning the award is given by the firm's relative investments in environmental quality and is thus increasing in the firm's absolute investments in environmental quality. If the regulator implements an environmental label, the regulator additionally chooses a labeling threshold. Then, firms invest in environmental quality. A firm receives the label if its investments in environmental quality exceed the labeling threshold.

We assume that consumers do not pay attention to the environmental quality of a good unless an environmental award or an environmental label makes the environmental quality of the good salient. That means, we focus on the attention-generating effect of awards and labels.[5] Nevertheless, awards and labels do not always ensure that consumers perceive the true environmental quality of the good. Depending on the designs of the award and the label, consumers may perceive the environmental qualities perfectly or imperfectly. If consumers pay only limited attention to environmental quality, the perception of consumers may be biased. We capture this limited attention by including a salience parameter that may distort the perception of environmental quality.[6] The higher the salience of a good's environmental quality, the more consumers take environmental quality into account.[7]

Our article highlights that environmental awards and labels affect firms' investments in environmental quality differently. With an award, both firms invest in environmental quality. With a label, at most one firm invests in environmental quality. In general, firms have an incentive to differentiate in environmental quality to generate market power. With the award, consumers only perceive the environmental quality of the award winner. Therefore, even if both firms invest an equal amount into environmental quality, consumers perceive a difference in environmental quality between the winner and the loser of the contest. In contrast, with the label, if both firms invest an equal amount into environmental quality, consumers would perceive the goods as identical. This would yield intense price competition and prices equal to marginal costs. Therefore, firms differentiate with one firm investing enough to receive the label and one firm not investing enough to receive the label.

We show that, with the award, firms' investments are weakly increasing in the salience that the award generates. An increase in salience increases consumers' perception of the environmental quality of the award winner. That means, consumers perceive the goods as more differentiated, which allows both firms, but especially the award winner, to charge

[5]Some awards explicitly highlight that their awards generate visibility to the award winner and that their award guides consumers to sustainable products (e.g., Directorate-General for Agriculture and Rural Development n.d., Stiftung Deutscher Nachhaltigkeitspreis n.d.).

[6]Empirical evidence shows that environmental advertisement and labels may induce consumers to perceive environmental quality as lower than it actually is (e.g., Andor et al. 2019).

[7]In particular, we assume that consumers perceive the environmental quality of a good as the weighted average of not perceiving any environmental quality and perceiving the true environmental quality, where the weight is given by salience. See DellaVigna (2009) and Gabaix (2019) for similar approaches.

higher prices. Consequently, a higher salience incentivizes firms to invest more in environmental quality to increase their probability of winning the award. Furthermore, in line with the anecdotal evidence that some environmental awards include a monetary prize (e.g., the German Environmental Award or the Earthshot Prize) and some environmental awards do not include any monetary prize (e.g., the EU Organic Awards), we find both types of environmental awards and identify under which circumstances including a positive monetary prize is optimal. The monetary prize and the salience of the award both incentivize investments in environmental quality. The monetary prize directly increases the profit of the winning firm. Salience increases profits through a shift in market share: If a firm wins the award and, therefore, its environmental quality becomes salient, the award ensures that the firm captures a higher market share and is able to charge higher prices compared to its competitor. The optimal monetary prize depends on salience that awards and labels generate and on marginal damage caused by the emissions that occur during production or use of the good: If the salience is sufficiently high and the marginal damage is sufficiently low, a monetary prize is unnecessary. The attention-generating effect of the award is sufficient to incentivize adequate investments in environmental quality. In contrast, if the salience is sufficiently low or if the marginal damage is high enough, a positive monetary prize is necessary to incentivize additional investments.

With the label, the investments in environmental quality depend on the labeling threshold. We show that investments are weakly increasing in the labeling threshold as long as the labeling threshold is sufficiently low. In general, firms have an incentive to differentiate in environmental quality with one firm investing enough to receive the label and the other firm not investing anything. If the labeling threshold increases, the firm that invests has an incentive to increase its investments to ensure that its investments exceed the labeling threshold and the good still receives the label. If the labeling threshold is too high such that investing enough to receive the label is extremely costly, neither firm invests in environmental quality. The regulator sets the labeling threshold to maximize social welfare. The optimal labeling threshold is weakly increasing in the salience that the label generates. As salience increases, the perceived product differentiation between labeled and unlabeled goods increases and firms are able to charge higher prices. Although investments are costly, the increase in revenue due to higher salience ensures that revenues exceed costs also for higher labeling thresholds, which allows the regulator to increase the labeling threshold.

Whether an environmental award or an environmental label results in higher social welfare depends on the salience that the award and the label generate as well as on the marginal damage caused by emissions. We show that the award results in higher welfare than the label if and only if marginal damage is sufficiently high or salience is sufficiently low. In contrast, the label results in higher welfare than the award if and only if marginal damage is sufficiently low and salience is sufficiently high. If marginal damage and salience

are sufficiently low, implementing the award leads to lower environmental damages and larger benefits to consumers. Given low salience, these positive effects outweigh the higher costs that firms face under the award. If salience increases, investments with the label (weakly) increase. The investment advantage of the award vanishes such that the regulator introduces the label. If marginal damage is high, emissions receive a higher weight in the social welfare function. As with the award both firms invest into environmental quality, emissions are lower with the award. Therefore, if the marginal damage is sufficiently high, the regulator prefers the award for all salience levels although investment costs are higher with the award compared to the label.

To confirm the robustness of our main result, we discuss three variations. First, due to environmental advertising and environmental labels, consumers may overestimate the environmental quality of goods (e.g., Houde 2018, Sejas-Portillo et al. 2025). Therefore, we allow the salience parameter to take on values that capture overestimation of environmental quality. We show that, although the exact conditions under which the award outperforms the label change, our results are qualitatively robust to this extension. Second, we assume that the existence of an environmental award draws consumers' attention to environmental quality in general. Therefore, the environmental quality of both goods, awarded and non-awarded, becomes salient. However, the salience of the awarded good is higher than the salience of the non-awarded good. This extension has no effect on our main result. Third, environmental awards and labels might not draw consumers' attention to the environmental quality of goods in the same way. Therefore, we extend the main model by allowing the salience generated by the environmental award and the salience generated by the environmental label to differ. This extension does not qualitatively change our results.

In addition to these three robustness checks, we explore two further extensions. First, as environmental awards and labels are often introduced by NGOs, we discuss whether an NGO with the objective to minimize total damages and policy expenditures introduces an environmental award or an environmental label. We show that, in line with our main result, an NGO implements an award if and only if the marginal damage is sufficiently high or the salience is sufficiently low. In contrast, the NGO implements a label if and only if marginal damage is sufficiently low and salience is sufficiently high. Nevertheless, in contrast to our main model, if an NGO chooses between an award and a label, the range of values for which the label outperforms the award increases significantly. In contrast to the label, the award may be costly because the award regime might require a positive monetary prize to incentivize firms to invest in environmental quality, and thus labels become more attractive.

Second, we explore whether emission taxes outperform both environmental awards and environmental labels. Although there is often political resistance to emission taxes, emission taxes receive a lot of attention in policy debates and in economic research.

Given the focus of the literature on emission taxes, we compare taxes, awards, and labels to alleviate the concern that emission taxes outperform awards as well as labels. We show that if the marginal damage is high, emission taxes indeed outperform awards and labels. Yet, if the marginal damage is sufficiently low, a considerable range of circumstances exists where awards, respectively labels, result in higher welfare. The regulator implements the award if salience and marginal damage are sufficiently low. The regulator implements the label if salience is sufficiently high and marginal damage is sufficiently low.

The remainder of the article is structured as follows: In Section 2, we discuss our contributions to the related literature. Section 3 introduces our model. In Section 4, we analyze the regulator's decision between implementing an environmental award and implementing an environmental label, the firms' equilibrium investments in environmental quality, and the equilibrium prices. In Section 5, we discuss extensions to the main model to confirm the robustness of our results. In Section 6, we analyze the decision of an NGO and whether emission taxes outperform environmental awards and environmental labels. Section 7 concludes.

2 Related literature

Environmental awards and environmental labels make firms' environmental performance visible to consumers. In this article, we analyze the effects of environmental awards and environmental labels on firms' investments in environmental quality and on social welfare. Therefore, we contribute primarily to two strands of the environmental economics literature.

First, we contribute to the literature on environmental labels. A large part of this literature analyzes under which conditions introducing an environmental label increases welfare or reduces environmental externalities. Previous research finds that the labeling design, firms' relative investment costs, and costs for labeling influence the effectiveness of environmental labels (e.g., Amacher et al. 2004, Ibanez & Grolleau 2008, Li & van't Veld 2015, Fischer & Lyon 2019). Nevertheless, several articles also highlight that labels can reduce welfare: For example, labels can have negative welfare effects if there is potential for fraud in green markets (Hamilton & Zilberman 2006), if the certification process is noisy (Mason 2011), if consumers are confused about the labeling standards (Harbaugh et al. 2011), or if consumers need to acquire information about the labeling standards to understand the meaning of a particular label (Heyes et al. 2020). In addition, firms can have incentives to increase investments in brown technologies before labels are adopted which increases overall externalities (Dosi & Moretto 2001). If labeling criteria are endogenously determined to maximize total surplus, labels may, for example, have a negative effect on consumer surplus through higher prices such that it is optimal not to

implement any label (Ben Youssef & Lahmandi-Ayed 2008).[8]

The existing literature mostly assumes that consumers can directly infer the environmental quality of a good from its label. However, labels do not always ensure that consumers perceive the true environmental quality of the goods. Consumers' perception of environmental quality depends on the salience of the label. We contribute to the environmental labeling literature by accounting for salience effects. This extension to the existing literature further allows us to capture biases in consumer perception. We highlight the importance of accounting for salience by showing that salience affects firms' investments in environmental quality, prices, and welfare as well as the optimal labeling threshold that the regulator implements.

Second, we contribute to the literature on environmental awards. In contrast to the labeling literature, only little research analyzes the effects of environmental awards on investments in environmental quality and on welfare. We model the environmental award as a contest.[9] The previous literature on contests in environmental economics concentrates on the effects of monetary prizes on the provision of a public good, on countries' efforts to reduce emissions, or on firms' environmental investments when subsidies are allocated via a contest (e.g., Morgan 2000, Bos et al. 2016, Osorio & Zhang 2022). In contrast, we analyze the effects of a monetary prize on firms' investments in environmental quality and focus on the effects of winning an award on consumers' willingness to pay and on the resulting changes in demand. Thereby, we provide insights into how environmental contests affect consumer behavior. Heidelmeier & Sahm (2025) also account for effects of environmental awards on consumers' perceptions of the awarded good. However, they focus on the analysis of the optimal environmental award and highlight that implementing an environmental award may harm consumers. In contrast, we focus on how investments in environmental quality depend on different levels of salience, specify the optimal monetary prize, and identify the circumstances that require a positive monetary prize.

Our main contribution is to show that environmental awards and environmental labels have different effects on firms' incentives to invest in environmental quality. Thereby, we combine the two strands of the literature on environmental labels and on environmental awards. Our analysis provides a better understanding of the circumstances under which a welfare-maximizing regulator should implement an environmental award and under which circumstances a welfare-maximizing regulator should implement an environmental label. In addition, we contribute to each of the two strands separately by analyzing how consumers' limited attention affects firms' investments in environmental quality.

We draw on the limited attention literature and assume that awards and labels attract consumers' attention to the environmental quality by making environmental quality

[8]For an overview of the environmental labeling literature see van't Veld (2020).

[9]For an overview on contest theory see Konrad (2009).

salient. In modeling salience, we build on DellaVigna (2009) and Gabaix (2019).[10] Other articles that incorporate limited attention into models with environmental externalities, for example, show that optimal taxes should depend on consumers' attention (Allcott et al. 2014, Houde & Myers 2019, Farhi & Gabaix 2020, Gilbert & Graff Zivin 2020, Gerster & Kramm 2024, van der Ploeg 2025). Heyes et al. (2018) analyze firms' competition with an NGO about making externalities salient. In contrast to these articles, we focus on how policy interventions affect firms' investments in environmental quality. In contrast to Schmitt (2025), who analyzes the effects of taxes, subsidies, information campaigns, and mandatory disclosure on firms' investments and on welfare, we focus on awards vs. labels and compare the effectiveness of these policy instruments.[11]

3 Model

We consider a market where two firms, firm 1 and firm 2, compete for a unit mass of consumers. The firms produce goods with identical base value $v \in \mathbb{R}_0^+$ to consumers. The production of the goods causes emissions. To reduce the per-unit emissions e, firms can invest in environmental quality $q_i \in \mathbb{R}_0^+$ with $i \in \{1, 2\}$.[12] Then, the per-unit net emissions of firm i are $e - q_i$.[13] Investing in environmental quality is costly. We assume that firms have identical cost functions $C(q_i) = cq_i^2$ with $c > 0$. In addition, we assume that all other production costs are identical and set them to zero.

Each consumer buys exactly one unit of the good. A consumer who buys one unit of the good from firm $i \in \{1, 2\}$ receives utility

$$u_\theta(i) = v + \theta q_i - p_i, \tag{1}$$

where p_i is the price of the good of firm i and θ is the consumer's marginal willingness to pay for environmental quality. We assume that θ is uniformly distributed on $[0, 1]$ and that v is large enough such that, in equilibrium, the market is covered.

Although consumers value the environmental quality of goods, consumers do not automatically pay attention to the environmental quality of goods. In particular, we assume

[10] Articles modeling markets for a good with salient attributes and limited consumer attention include, for example, Eliaz & Spiegler (2011), Bordalo et al. (2016), Hefti (2018), Hefti & Liu (2020), Apffelstaedt & Mechtenberg (2021), Carroni et al. (2023). For an overview of the literature on limited attention see Gabaix (2019). Alternatively, awards and labels can be seen as instruments of social signaling (e.g., Butera et al. 2022).

[11] Given the underlying vertical product differentiation model, the mechanism behind our label and the perception threshold in Schmitt (2025) are similar. However, our results on investments under an environmental award differ significantly.

[12] We assume that environmental quality is one-dimensional, measurable, and comparable. Often, environmental quality includes multiple dimensions (e.g., emissions caused during production, use, and transportation). We assume that this multi-dimensionality is reduced to one dimension by creating an index of environmental quality.

[13] We assume that e is large enough such that, in equilibrium, firms' net emissions are always positive.

that consumers do not consider the environmental quality of goods that carry neither an award nor a label, i.e., consumers are naive. In contrast, awards and labels make the environmental quality salient and draw consumers' attention to the environmental quality of the awarded/labeled good. Thus consumers consider the environmental quality of goods that carry an award or a label. We assume that consumers' perception of the environmental quality of an awarded or a labeled good depends on the salience $\sigma \in [0,1]$ that awards and labels generate. Consequently, the perceived environmental quality of good i is[14]

$$\hat{q}_i = \begin{cases} \sigma q_i & \text{if good } i \text{ has received an award / a label,} \\ 0 & \text{otherwise.} \end{cases} \tag{2}$$

With the award, only one firm wins the award. If firm i wins the award, the perceived environmental quality is $\hat{q}_i = \sigma q_i$. If firm i does not win the award, the perceived environmental quality is $\hat{q}_i = 0$. With the label, both firms may receive the label. If firm i receives the label, the perceived environmental quality is $\hat{q}_i = \sigma q_i$. If firm i does not receive the label, the perceived environmental quality is $\hat{q}_i = 0$. As the perceived environmental quality depends on the true environmental quality, if both firms receive the label but differ in their environmental qualities, consumers perceive a difference in environmental quality. If $\sigma = 1$, consumers perceive the environmental quality of awarded/labeled goods perfectly. If $\sigma < 1$, the perceived environmental quality of awarded/labeled goods is lower than the true environmental quality.

In their consumption decision, consumers take the perceived environmental quality $\hat{q}_i$ into account. Therefore, we distinguish between the experienced utility in (1) and the decision utility

$$\hat{u}_\theta(i) = v + \theta \hat{q}_i - p_i.$$

We denote by h the firm with the higher perceived environmental quality and by l the firm with the lower perceived environmental quality, i.e., $\hat{q}_h \geq \hat{q}_l$. Consumers buy the good of the firm with the higher perceived environmental quality if their decision utility from buying the good with the higher perceived environmental quality exceeds the decision utility from buying the good with the lower perceived environmental quality:

$$\hat{u}_\theta(h) \geq \hat{u}_\theta(l) \;\Leftrightarrow\; \theta \geq \bar{\theta} \equiv \frac{p_h - p_l}{\hat{q}_h - \hat{q}_l}.$$

[14] Without further information, consumers do not pay attention to the environmental quality of goods which results in a perceived environmental quality of $\hat{q}_i = 0$. If a firm makes its environmental quality salient, consumers update towards the true environmental quality, i.e., $\hat{q}_i = (1-\sigma)\cdot 0 + \sigma \cdot q_i = \sigma q_i$. See DellaVigna (2009) and Gabaix (2019) for similar approaches. In Section 5.1, to capture evidence that labels (and awards) can lead to overestimation of environmental quality (e.g. Houde 2018, Sejas-Portillo et al. 2025), we allow for $\sigma > 1$.

$\bar{\theta}$ describes the indifferent consumer. Therefore, the demand for the good of the firm with the higher and the demand for the good with the lower perceived environmental quality are $x_h^D(p_h, p_l, \hat{q}_h, \hat{q}_l) = 1 - \bar{\theta}$ and $x_l^D(p_h, p_l, \hat{q}_h, \hat{q}_l) = \bar{\theta}$.

The regulator can implement either an award or a label. If the regulator implements an award, the regulator determines the monetary prize $\phi \in \mathbb{R}_0^+$ that the winning firm receives. Firms compete for the award in a lottery contest. Then, firm i's probability of winning the environmental award is given by the following contest success function:

$$\alpha_i(q_i, q_j) = \begin{cases} \frac{1}{2} & \text{if } q_i = q_j \\ \frac{q_i}{q_i + q_j} & \text{otherwise,} \end{cases}$$

for $i, j \in \{1, 2\}$ and $i \neq j$ (Tullock 1980). The lottery contest incorporates some noise: A firm can (ceteris paribus) increase its probability of winning the award by increasing its investments, but the firm with the highest investments does not win with certainty. This contest success function captures that a regulator cannot always perfectly ensure that the firm with the higher investments receives the award.

If the regulator implements a label, the regulator determines the labeling threshold $\bar{q}$. Goods with environmental quality $q_i \geq \bar{q}$ receive the label and goods with environmental quality $q_i < \bar{q}$ do not receive the label. If the regulator implements the award, only one firm can receive the award, but if the regulator implements the label, both firms can receive the label.

The regulator decides between either implementing an award or implementing a label to maximize social welfare, i.e., the sum of consumer surplus (CS)[15] and producer surplus (PS, the sum of firms' profits), minus the damages caused by emissions $D(E)$ and, if the regulator implements an award, the monetary prize ϕ: $W = CS + PS - D(E) - \mathbb{I}_A \phi$, where $\mathbb{I}_A$ is an indicator function that is 1 if the regulator implements an award. We assume the following damage function: $D(E) = \delta E$ with $\delta \in \mathbb{R}_0^+$ representing marginal damage and where $E = (e - q_1)x_1^D(p_1, p_2, \hat{q}_1, \hat{q}_2) + (e - q_2)x_2^D(p_1, p_2, \hat{q}_1, \hat{q}_2)$ are the total net emissions in the market.

We consider the following three-stage game (see Figure 1): In the first stage, the regulator decides whether to implement either an award with monetary prize ϕ or a label with threshold $\bar{q}$.[16] In the second stage, firms observe the decision of the regulator and simultaneously invest in environmental quality. In the third stage, if the regulator

[15] We assume that consumer surplus depends on the true environmental qualities of the goods and not on the perceived environmental qualities. This captures that consumers over time might learn the true environmental qualities or benefit from higher environmental quality when environmental quality implies monetary benefits to consumers (e.g., appliances with high energy efficiency also benefit consumers financially). With this assumption we refrain from capturing "warm glow."

[16] In Section 6.1, we discuss how our results change if, instead of a regulator, an NGO with the objective to minimize total damages and total expenditures decides between introducing an award or introducing a label. In Section 6.2, we allow the regulator to choose between an emission tax, an award, and a label.

has implemented an award, the regulator awards the contest winner and firms observe the environmental quality of their competitor and which firm received the award. Then, firms simultaneously choose their prices. In contrast, if the regulator has implemented a label, the regulator labels the goods that exceed the labeling threshold and firms observe the environmental quality of their competitor and which goods are labeled. Then, firms simultaneously choose their prices. Afterwards, consumers make their consumption decision. We solve the game by backward-induction for the subgame-perfect equilibria in pure strategies.

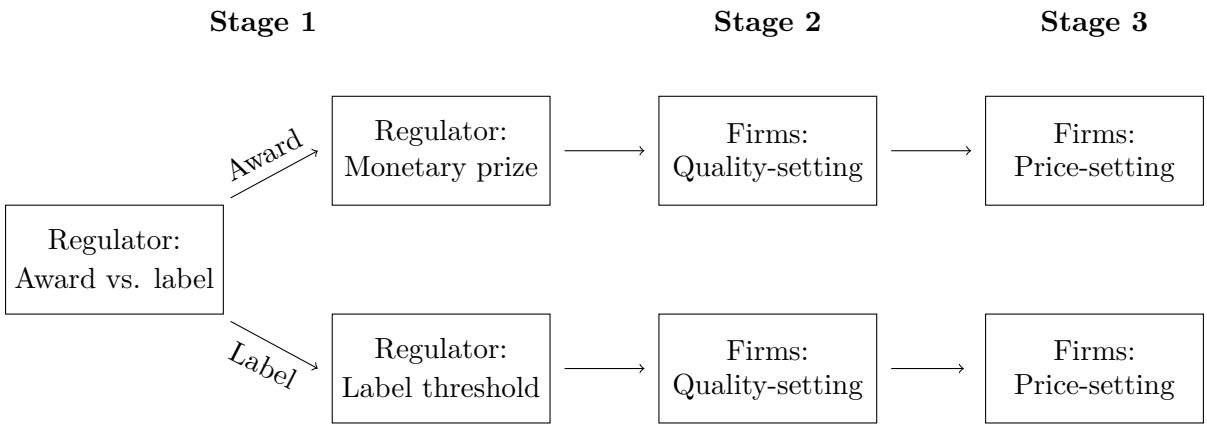

Figure 1: Timeline.

In general, we denote the environmental quality and the price of firm i by q_i and p_i. However, to facilitate comparison between awards and labels, we add subscripts A for award and L for label for the equilibrium environmental qualities and prices, i.e., $q^*_{i,A}$, $p^*_{i,A}$, $q^*_{i,L}$, and $p^*_{i,L}$.

4 Awards vs. labels

In this section, we derive and compare the equilibrium outcomes under awards and labels.

4.1 Price-setting stage

In the third stage of the game, firms choose their market prices to maximize their profits given the investments in environmental quality from the previous stage. The profits of the firms depend on the perceived environmental qualities. Consequently, the price-setting stage is identical for the subgames where the regulator has implemented an award and for the subgames where the regulator has implemented a label. Firms simultaneously choose their prices to maximize their profits

$$\pi_h(p_h, p_l, \hat{q}_h, \hat{q}_l) = p_h \cdot x_h^D(p_h, p_l, \hat{q}_h, \hat{q}_l) + \mathbb{I}_A\phi - cq_h^2 = p_h(1-\bar{\theta}) + \mathbb{I}_A\phi - cq_h^2$$
$$\pi_l(p_h, p_l, \hat{q}_h, \hat{q}_l) = p_l \cdot x_l^D(p_h, p_l, \hat{q}_h, \hat{q}_l) - cq_l^2 = p_l\bar{\theta} - cq_l^2,$$

where $\mathbb{I}_A$ is an indicator function that is 1 if the regulator implements an award.[17] Consequently, equilibrium prices are

$$p_h = \frac{2}{3}(\hat{q}_h - \hat{q}_l) \quad \text{and} \quad p_l = \frac{1}{3}(\hat{q}_h - \hat{q}_l). \tag{3}$$

Prices are increasing in the perceived difference in environmental qualities. The firm with the higher perceived environmental quality chooses a higher price in equilibrium. The indifferent consumer is located at $\bar{\theta} = 1/3$ such that the demand for the good with the higher perceived environmental quality is $x_h^D = 2/3$ and the demand for the good with the lower perceived environmental quality is $x_l^D = 1/3$.

4.2 Quality-setting stage and optimal policies

In the second stage of the game, firms invest in environmental quality anticipating the market prices. We need to distinguish two cases. First, we analyze firms' investments in environmental quality if the regulator has implemented an environmental award. In addition, we derive the optimal monetary prize. Second, we analyze firms' investments in environmental quality if the regulator has implemented an environmental label. In addition, we derive the optimal labeling threshold.

4.2.1 Environmental award

If the regulator has implemented an award, consumers' perceived environmental quality of a good depends on whether the good received an award. Firms' investments in environmental quality determine (i) the probability with which each firm wins the award and (ii) the profits that the firms receive if they win and if they lose the contest.

The firm that wins the contest is always the firm with the higher perceived environmental quality, i.e., firm h, whereas the firm that loses the contest is always the firm with the lower perceived environmental quality, i.e., firm l. If firm i wins the award, the perceived environmental qualities of firms $i, j \in \{1, 2\}$ with $i \neq j$ are $\hat{q}_i = \hat{q}_h = \sigma q_i$ and $\hat{q}_j = \hat{q}_l = 0$. The corresponding profit of firm i is $\pi_h(\hat{q}_h = \sigma q_i, \hat{q}_l = 0)$. If firm i loses and firm j wins the award, the perceived environmental qualities of the firms are $\hat{q}_i = \hat{q}_l = 0$ and $\hat{q}_j = \hat{q}_h = \sigma q_j$. The corresponding profit of firm i is $\pi_l(\hat{q}_h = \sigma q_j, \hat{q}_l = 0)$.

Consequently, the expected profit of firm i is

$$\begin{aligned}\mathbb{E}[\pi_i] &= \alpha_i(q_i, q_j) \cdot \pi_h(\hat{q}_h = \sigma q_i, \hat{q}_l = 0) + \Big(1 - \alpha_i(q_i, q_j)\Big) \cdot \pi_l(\hat{q}_h = \sigma q_j, \hat{q}_l = 0) \\ &= \frac{q_i}{q_i + q_j}\left(\frac{4}{9}\sigma q_i + \phi\right) + \left(1 - \frac{q_i}{q_i + q_j}\right)\frac{1}{9}\sigma q_j - c q_i^2.\end{aligned}$$

[17] If the regulator implements an award, the winning firm, i.e., the firm with the higher perceived environmental quality, additionally receives the monetary prize ϕ.

Firms choose their environmental qualities simultaneously to maximize their expected profits. Firms face the following trade-off: On the one hand, as higher investments translate into a higher probability of winning the contest, the firms have an incentive to invest in environmental quality. On the other hand, as higher investments result in higher costs, the firms have an incentive to invest less in environmental quality. In equilibrium, firms choose investments in environmental quality to balance these two effects. Lemma 1 summarizes the equilibrium.

Lemma 1 *Let $i \in \{1, 2\}$ and denote by h (l) the firm that wins (loses) the contest and thus has a higher (lower) perceived environmental quality. If the regulator implements an award, in the subgame-perfect equilibrium, environmental qualities and prices are $q^*_{i,A} = (11\sigma + \sqrt{121\sigma^2 + 2592c\phi})/(144c)$, $p^*_{h,A} = 2\sigma q^*_{i,A}/3$, and $p^*_{l,A} = \sigma q^*_{i,A}/3$.*

The proof is in Appendix A.1.

Lemma 1 shows that, in equilibrium, both firms invest the same amount into environmental quality. Therefore, both firms are equally likely to win the award. In general, if the consumers perceive the goods as having the same environmental quality, intense price competition drives down prices to marginal costs. In contrast, if the consumers perceive the goods to be differentiated in environmental quality, firms have market power to charge prices above marginal costs. Therefore, firms have an incentive to be perceived as differentiated. With the award, even if firms invest the same amount into environmental quality, as only one firm wins the award, goods appear differentiated. Consumers perceive the environmental quality of the firm that wins the contest as higher than the environmental quality of the firm that loses the contest. Therefore, the firm that wins the award is able to charge a higher price, i.e., $p^*_{h,A} > p^*_{l,A}$. Nevertheless, both firms charge positive prices.

Firms' investments in environmental quality are increasing in the monetary prize ϕ and in the salience σ that the award generates, but are decreasing in the cost parameter c. A higher monetary prize increases the profit of the winning firm directly. An increase in salience implies that consumers perceive the goods as more differentiated which allows both firms, but especially the award winner, to charge higher prices. Consequently, if the monetary prize or the salience that the award generates increase, firms increase their investments to increase their probability of winning the award. In contrast, if the cost parameter c increases, investing becomes more costly. Consequently, firms reduce their investments if c increases.

In the first stage, the regulator chooses the monetary prize ϕ to maximize social welfare. Proposition 1 summarizes the optimal award and the corresponding equilibrium environmental qualities and prices.

Proposition 1 (Award) *Let $i \in \{1,2\}$ and denote by h (l) the firm that wins (loses) the contest and thus has a higher (lower) perceived environmental quality. If the regulator implements an award, the optimal monetary prize is*

$$\phi^* = max\Big\{0, \frac{(1+2\delta)(9+18\delta-11\sigma)}{72c}\Big\}.$$

The corresponding environmental qualities and prices in equilibrium are $q^*_{i,A} = max\{(11\sigma)/(72c), (1+2\delta)/(8c)\}$, $p^*_{h,A} = 2\sigma q^*_{i,A}/3$, *and* $p^*_{l,A} = \sigma q^*_{i,A}/3$.

The proof is in Appendix A.2. The regulator anticipates investments and chooses the monetary prize to maximize social welfare. An increase in the monetary prize ϕ increases firms' investments in environmental quality (see Lemma 1) and thus affects social welfare in three ways. First, as consumers receive utility from higher environmental quality, an increase in investments benefits consumers and thus increases social welfare. Second, higher investments reduce emissions and thus increase social welfare. Third, higher investments increase firms' costs and thus reduce social welfare.[18] If the marginal damage δ is sufficiently low, i.e., $\delta \leq (11\sigma-9)/18$, the third effect dominates such that the regulator chooses an award without any monetary prize: $\phi^* = 0$. In this case, generating additional investments would be too costly while environmental damage plays a minor role in the social welfare function.

If the marginal damage is sufficiently high, i.e., $\delta > (11\sigma - 9)/18$, the weight of the emissions in the social welfare is sufficiently high such that the positive effects of the monetary prize outweigh the negative effects. The regulator sets a strictly positive monetary prize to further incentivize investments. Then, the monetary prize is increasing in marginal environmental damage δ and decreasing in salience σ and cost parameter c. First, an increase in the marginal damage δ increases the weight of the emissions in the social welfare. Then, a higher monetary prize which incentivizes higher investments is beneficial. Second, salience and the monetary prize are strategic substitutes for the regulator. An increase in salience as well as an increase in the monetary prize ensure higher profits of the winning firm and thus incentivize investments in environmental quality. Consequently, an increase in salience reduces the need of the regulator to incentivize investments via the monetary prize, such that the regulator reduces the monetary prize. Third, if the cost parameter c increases, the negative effects of the monetary prize on the welfare increase. To dampen this effect, the regulator reduces the monetary prize.

4.2.2 Environmental label

If the regulator has implemented an environmental label with threshold $\bar{q}$, consumers' perceived environmental quality of a good depends on whether the good receives the

[18] Prices are a reallocation of welfare from consumers to firms and the monetary prize is a reallocation of welfare from the regulator to the award winner.

label. If the good of firm $i \in \{1,2\}$ does not receive the label, i.e., if $q_i < \bar{q}$, consumers perceive the environmental quality of the good as $\hat{q}_i = 0$. If the good of firm i receives the label, i.e., if $q_i \geq \bar{q}$, consumers perceive the environmental quality of the good as $\hat{q}_i = \sigma q_i$. The profit of firm i depends on (i) whether firm i receives the label, (ii) whether firm $j \in \{1,2\}$ with $i \neq j$ receives the label, and (iii) whether firm i is the firm with the higher perceived environmental quality.

If $q_j \geq \bar{q}$, firm j receives the label and the profit of firm i is

$$\pi_i(q_i, q_j) = \begin{cases} \frac{4}{9}(\sigma q_i - \sigma q_j) - c q_i^2 & \text{if } q_i \geq q_j \\ \frac{1}{9}(\sigma q_j - \sigma q_i) - c q_i^2 & \text{if } \bar{q} \leq q_i < q_j \\ \frac{1}{9}\sigma q_j - c q_i^2 & \text{if } q_i < \bar{q}. \end{cases} \tag{4}$$

If firm j receives the label, the profit of firm i depends on whether firm i also receives the label or whether firm i does not receive the label. If firm i also receives the label, i.e., $q_i \geq \bar{q}$, the perceived environmental qualities of the firms are $\hat{q}_i = \sigma q_i$ and $\hat{q}_j = \sigma q_j$. Then, the prices and the resulting revenues depend on which firm has the higher environmental quality. If firm i chooses a higher environmental quality than firm j, i.e., $q_i \geq q_j$ (first case of (4)), firm i is the firm with the higher perceived environmental quality, sets a higher price in the price-setting stage, and thus receives a higher revenue than firm j. In contrast, if firm i chooses a lower environmental quality than firm j, i.e., $q_i < q_j$ (second case of (4)), firm i is the firm with the lower perceived environmental quality, sets a lower price in the price-setting stage, and thus receives a lower revenue than firm j. The third case of (4) illustrates the situation where firm i chooses a quality below the labeling threshold and thus does not receive the label. As the prices depend on the difference in perceived environmental qualities, in this case, the prices depend only on firm j's environmental quality: $\hat{q}_j - \hat{q}_i = \sigma q_j - 0$.

If $q_j < \bar{q}$, firm j does not receive the label and the profit of firm i is

$$\pi_i(q_i, q_j) = \begin{cases} \frac{4}{9}\sigma q_i - c q_i^2 & \text{if } q_i \geq \bar{q} \\ -c q_i^2 & \text{if } q_i < \bar{q}. \end{cases} \tag{5}$$

If firm j does not receive the label, the profit of firm i only depends on whether firm i receives the label. If firm i chooses an environmental quality above the labeling threshold, i.e., $q_i \geq \bar{q}$ (first case of (5)), firm i is always the firm with the higher perceived environmental quality and thus chooses a higher price than firm j in the price-setting stage. If firm i chooses an environmental quality below the labeling threshold, i.e., $q_i < \bar{q}$ (second case of (5)), consumers do not perceive any difference in environmental quality between the goods. The intense price competition drives down prices to marginal costs of zero and both firms make zero revenue.

Firms simultaneously choose their environmental qualities to maximize their profits.[19] The optimal environmental qualities depend on the labeling threshold $\bar{q}$. In general, firms have an incentive to differentiate in their environmental qualities and to ensure that consumers perceive this difference. If firms choose goods with identical environmental quality, the goods only differ in prices. This leads to intense price competition and thus to prices equal to marginal costs of zero. In contrast, a perceived difference in environmental quality gives firms market power to charge prices above marginal costs and the optimal prices depend on the difference in perceived environmental qualities (see Section 4.1). Consequently, in the benchmark where the regulator labels all goods, i.e., $\bar{q} = 0$, two asymmetric equilibria result where firms differentiate with one firm choosing a positive environmental quality and the other firm choosing zero environmental quality: $q^*_{i,L} = (2\sigma)/(9c)$ and $q^*_{j,L} = 0$ for all $i, j \in \{1, 2\}$ and $i \neq j$. This benchmark equilibrium is maintained as long as the labeling threshold is sufficiently low, i.e., for $\bar{q} \leq (2\sigma)/(9c)$.

If the regulator chooses a labeling threshold $\bar{q} > (2\sigma)/(9c)$, the firm with the higher environmental quality needs to increase its investments in environmental quality. With an environmental quality of $q_{i,L} = (2\sigma)/(9c)$, firm i would no longer receive the label. Then, consumers would perceive both goods as having identical environmental quality $\hat{q}_i = \hat{q}_j = 0$ and intense price competition ensures zero revenues. To avoid this case, firm i increases its investments to produce goods where the environmental quality is high enough to receive the label: $q^*_{i,L} = \bar{q}$. Then, consumers perceive a product differentiation and both firms are able to choose prices above marginal costs and make positive revenues. With increasing labeling threshold, firm i needs to increase its investments which increases the costs. For $\bar{q} > (4\sigma)/(9c)$, the costs exceed the revenues such that the firm prefers to produce goods that do not satisfy the labeling criteria. Then, as consumers do not perceive the environmental quality of the goods and are not willing to pay for positive environmental quality, but positive investments are costly, the firms do not invest in environmental quality.

Lemma 2 summarizes the equilibria.

Lemma 2 *Let $i, j \in \{1, 2\}$ with $i \neq j$. If the regulator implements a label with labeling threshold $\bar{q}$, the equilibria depend on the labeling threshold:*

(i) If $\bar{q} \leq (4\sigma)/(9c)$, two asymmetric equilibria exist where environmental qualities and prices are $q^*_{i,L} = max\{(2\sigma)/(9c), \bar{q}\}$, $q^*_{j,L} = 0$, $p^*_{i,L} = 2\sigma q^*_{i,L}/3$, and $p^*_{j,L} = \sigma q^*_{i,L}/3$.

(ii) If $\bar{q} > (4\sigma)/(9c)$, one symmetric equilibrium exists where environmental qualities and prices are $q^*_{i,L} = q^*_{j,L} = 0$, $p^*_{i,L} = p^*_{j,L} = 0$.

[19] We make the following tie-breaking assumption: If firm i is indifferent between an environmental quality $q_i < \bar{q}$ and an environmental quality $q_i \geq \bar{q}$, firm i chooses quality $q_i \geq \bar{q}$ and implements the label.

The proof is in Appendix B.1.

Lemma 2 shows that firms' investments in environmental quality depend on the labeling threshold that the regulator chooses. As long as the labeling threshold is sufficiently low, i.e., $\bar{q} \leq (4\sigma)/(9c)$, investments in environmental quality are weakly increasing in the labeling threshold. In addition, an increase in the salience σ increases the range for which one firm chooses a positive level of investments and (weakly) increases these investments.

The regulator anticipates investments and chooses the labeling threshold optimally to maximize social welfare.[20] As increasing prices imply a pure reallocation of welfare from consumers to firms, the regulator only takes into account the effects of the labeling threshold on the equilibrium environmental qualities and on firms' costs. A labeling threshold that increases investments in environmental quality is beneficial to consumers as consumers receive a higher utility from consuming the goods and higher investments additionally reduce damages. Yet, a labeling threshold that increases investments in environmental quality is harmful to firms because it increases firms' costs. The optimal labeling threshold takes this trade-off into account.

According to Lemma 2, equilibrium environmental qualities depend on the salience σ. If σ increases, the investments weakly increase. Consequently, the optimal labeling threshold depends on the salience σ: First, as long as the salience is sufficiently low (relative to the marginal damage), i.e., if $\sigma \leq (2+3\delta)/4$, the positive effects outweigh the negative effects and the regulator chooses the labeling threshold that maximizes (average) investments in environmental quality: $\bar{q}^* = (4\sigma)/(9c)$. Second, for greater salience, i.e., if $\sigma > (2+3\delta)/4$,[21] such a labeling threshold would imply high costs for the firms. To reduce this negative effect, the regulator chooses a lower labeling threshold such that one firm still invests more into environmental quality than in the benchmark, but without being excessively costly. Proposition 2 summarizes the results.

Proposition 2 (Label) *Let $i, j \in \{1, 2\}$ with $i \neq j$. If the regulator implements a label, the optimal labeling threshold depends on the salience σ:*

(i) If $\sigma \leq (2+3\delta)/4$, the optimal labeling threshold is $\bar{q}^* = (4\sigma)/(9c)$ and firms' equilibrium environmental qualities and prices are $q^*_{i,L} = \bar{q}$, $q^*_{j,L} = 0$, $p^*_{i,L} = 2\sigma q^*_{i,L}/3$, and $p^*_{j,L} = \sigma q^*_{i,L}/3$.

(ii) If $\sigma > (2+3\delta)/4$, the optimal labeling threshold is $\bar{q}^* = (2+3\delta)/(9c)$ and firms' equilibrium environmental qualities and prices are $q^*_{i,L} = \bar{q}$, $q^*_{j,L} = 0$, $p^*_{i,L} = 2\sigma q^*_{i,L}/3$, and $p^*_{j,L} = \sigma q^*_{i,L}/3$.

The proof is in Appendix B.2.

[20] We make the following tie-breaking assumption: If the regulator is indifferent between two labeling thresholds, the regulator chooses the threshold that induces higher investments.

[21] As $\sigma \in [0, 1]$, this case only exists if $\delta < 2/3$.

4.3 Regulator: awards vs. labels

In the first stage of the game, the regulator chooses between implementing an award and implementing a label. The regulator can also choose not to implement any policy (no policy case, denoted by N). However, without any policy intervention, consumers cannot distinguish between the environmental qualities of the goods. Then, perceived environmental qualities are $\hat{q}_{i,N} = 0$ for $i \in \{1, 2\}$. The game reduces to homogeneous Bertrand competition where prices are set equal to marginal costs. That means, independent of their actual investments in environmental quality, firms receive zero revenue. In addition, any positive investment in environmental quality is costly. Consequently, without any policy intervention, both firms do not invest in environmental quality: $q^*_{i,N} = 0$ for $i \in \{1, 2\}$. The social welfare is $W_N = v - \delta e$. As shown in Appendix B.2, welfare under labeling is weakly higher than welfare without any policy. Therefore, we only focus on awards vs. labels.

One major difference between awards and labels is that, in equilibrium, with the award both firms invest in environmental quality, whereas, with the label only one firm invests in environmental quality. Consequently, with the award all consumers buy a good with strictly positive environmental quality, whereas with the label, only 2/3 of consumers buy a good with strictly positive environmental quality.

The regulator implements the policy which generates the higher social welfare. A policy that incentivizes investments in environmental quality has positive and negative effects on social welfare. Consumers benefit from goods with higher environmental quality which increases social welfare. In addition, higher environmental quality reduces damages which also increases social welfare. However, producing goods with environmental quality is costly. Therefore, a higher environmental quality also has negative effects on social welfare.

Proposition 3 summarizes under which circumstances the regulator implements the label and under which circumstances the regulator implements the award.

Proposition 3 (Award vs. Label) *Whether the regulator implements the environmental award or the environmental label depends on the marginal damage δ and the salience σ that awards and labels generate: The regulator implements the label if and only if the marginal damage is sufficiently low and the salience is sufficiently high, i.e., if and only if $\delta \leq (37 + 8\sqrt{10})/54$ and $(2 + 3\delta)/4 - \sqrt{47 + 60\delta - 36\delta^2}/(16\sqrt{2}) \leq \sigma \leq 1$. Otherwise, the regulator implements the award.*

The proof is in Appendix C. Figure 2 illustrates Proposition 3 graphically. If the marginal damage is sufficiently low, i.e., $\delta \leq (37 + 8\sqrt{10})/54$, the regulator implements the award if salience is sufficiently low relative to the marginal damage and the label if salience is sufficiently high relative to the marginal damage. In general, for low levels

of salience (relative to marginal damage), investments with the award are constant in salience and investments with the label are weakly increasing in salience. If the salience is sufficiently low, i.e., $\sigma < (2+3\delta)/4 - \sqrt{47+60\delta-36\delta^2}/(16\sqrt{2})$, the positive effects of the award (lower damages and higher utility from environmental quality) dominate the negative effect that costs are higher with the award. As the salience increases, the investments with the label increase. Consequently, the environmental damages with the label decrease and the utility from environmental quality with the label increases such that, for $\sigma \geq (2+3\delta)/4 - \sqrt{47+60\delta-36\delta^2}/(16\sqrt{2})$, it becomes optimal to implement the label.

If the marginal damage is sufficiently high, i.e., $\delta > (37+8\sqrt{10})/54$, the regulator implements the award for all $\sigma \in [0,1]$. If the marginal damage is sufficiently high, the emissions receive a higher weight in the social welfare. Then, with the award, the regulator (weakly) increases the monetary prize which incentivizes firms to invest more in environmental quality. In contrast, with the label, investments do not depend on the marginal damage. As with the award, in contrast to the label, both firms invest in environmental quality and thus all consumers buy a good with positive environmental quality, damages are lower and utility from environmental quality is higher with the award; costs are lower with the label. As the marginal damage is sufficiently high, the positive effects of the award outweigh the negative effect.

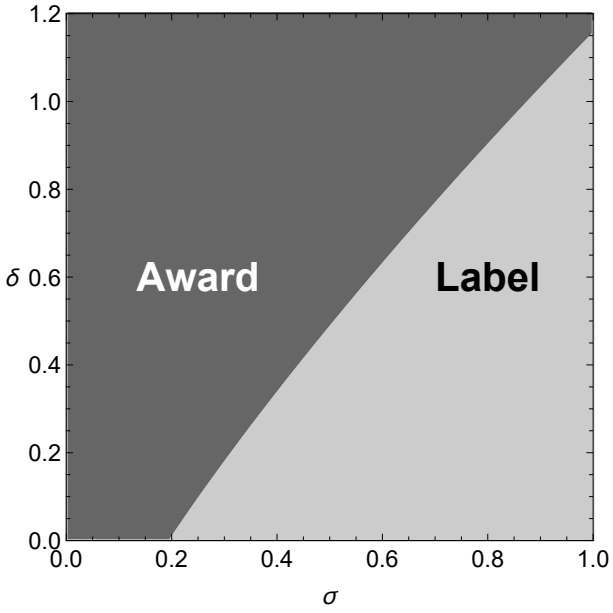

Figure 2: Policy decision dependent on salience σ and marginal damage δ. In the dark gray area, the regulator implements the award. In the light gray area, the regulator implements the label.

5 Discussion

In this section, we explore three extensions to test the robustness of our results.

5.1 Overestimation of environmental quality

Empirical evidence shows that environmental advertisement and labels may induce consumers to perceive environmental performance as higher than it actually is (e.g., Houde 2018, Sejas-Portillo et al. 2025). In this section, we capture overestimation of environmental quality by allowing salience to take on values greater than one, i.e., we assume $\sigma \in \mathbb{R}_0^+$.

We solve the game by backward induction. In the third stage, firms face the same pricing game as described in Section 4.1. In the second stage, firms invest in environmental quality q_i. We need to distinguish between the label and the award case. For the award, the equilibrium monetary prize, environmental qualities, and market prices from Proposition 1 hold.

For the label, equilibrium environmental qualities and prices depend on the labeling threshold as described in Lemma 2. However, allowing for $\sigma \in \mathbb{R}_0^+$ changes the optimal labeling threshold for $\sigma > 1$. Lemma 3 summarizes the results.

Lemma 3 *Let $i, j \in \{1, 2\}$ with $i \neq j$ and $\sigma \in \mathbb{R}_0^+$. If the regulator implements a label, the optimal labeling threshold depends on the salience σ:*

(i) If $\sigma \leq (2 + 3\delta)/4$, the optimal labeling threshold is $\bar{q}^* = (4\sigma)/(9c)$ and firms' equilibrium environmental qualities and prices are $q_{i,L}^* = \bar{q}$, $q_{j,L}^* = 0$, $p_{i,L}^* = 2\sigma q_{i,L}^*/3$, and $p_{j,L}^* = \sigma q_{i,L}^*/3$.

(ii) If $(2 + 3\delta)/4 < \sigma < (2 + 3\delta)/2$, the optimal labeling threshold is $\bar{q}^* = (2 + 3\delta)/(9c)$ and firms' equilibrium environmental qualities and prices are $q_{i,L}^* = \bar{q}$, $q_{j,L}^* = 0$, $p_{i,L}^* = 2\sigma q_{i,L}^*/3$, and $p_{j,L}^* = \sigma q_{i,L}^*/3$.

(iii) If $(2+3\delta)/2 \leq \sigma \leq 2+3\delta$, the optimal labeling threshold is any $\bar{q}^* \in [0, 2\sigma/(9c)]$ and firms' equilibrium environmental qualities and prices are $q_{i,L}^* = (2\sigma)/(9c)$, $q_{j,L}^* = 0$, $p_{i,L}^* = 2\sigma q_{i,L}^*/3$, and $p_{j,L}^* = \sigma q_{i,L}^*/3$.

(iv) If $\sigma > 2 + 3\delta$, the optimal labeling threshold is any $\bar{q}^* \in ((4\sigma)/(9c), \infty)$ and firms' equilibrium environmental qualities and prices are $q_{i,L}^* = q_{j,L}^* = 0$ and $p_{i,L}^* = p_{j,L}^* = 0$.

The proof is in Appendix D.1. First, as long as salience is sufficiently low, i.e., if $\sigma \leq (2 + 3\delta)/4$ (cf. Lemma 2), the positive effects of higher investments outweigh the negative effects and the regulator chooses the labeling threshold that maximizes (average) investments in environmental quality: $\bar{q}^* = (4\sigma)/(9c)$. Second, for greater salience, i.e., if $(2 + 3\delta)/4 < \sigma < (2 + 3\delta)/2$ (cf. Lemma 2), such a labeling threshold would imply

high costs for the firms. To reduce this negative effect, the regulator chooses a lower labeling threshold such that one firm still invests more into environmental quality than in the benchmark, but without being excessively costly. Third, if σ increases further, i.e., if $(2+3\delta)/2 \leq \sigma \leq 2+3\delta$, it becomes optimal to choose a labeling threshold such that the benchmark equilibrium results. Fourth, if $\sigma > 2+3\delta$, setting the labeling threshold such that one firm invests any positive amount into environmental quality implies high costs for the firm. This negative effect outweighs any positive effects.

As long as $\sigma < (2+3\delta)/2$, the results and the intuition from Section 4 hold. For $\sigma \geq (2+3\delta)/2$, the optimal labeling threshold differs compared to Section 4 which affects the comparison awards vs. labels. However, the main intuition still holds. For $(2+3\delta)/2 \leq \sigma \leq 2+3\delta$, the optimal labeling threshold is sufficiently low such that investment costs necessary to receive the label remain sufficiently low. Nevertheless, damages are lower with the award; benefits to consumers and costs are higher with the award. Consequently, if the marginal damage is sufficiently high such that the emissions receive more weight in the social welfare, the award outperforms the label.

If $\sigma > 2+3\delta$, the optimal labeling threshold is so high that neither firm invests in environmental quality under the label. Consequently, investments are higher with the award. If the marginal damage is sufficiently high such that the emissions receive a sufficiently high weight in the social welfare, implementing an award is optimal, because the award leads to lower emissions. In contrast, if the marginal damage is sufficiently low, implementing a label, which leads to lower costs for firms, is optimal.

Proposition 4 summarizes the results.

Proposition 4 (Award vs. Label: $\sigma \in \mathbb{R}_0^+$) *Whether the regulator implements an environmental award or an environmental label depends on the marginal damage δ and the salience σ that awards and labels generate: The regulator implements the label if and only if the marginal damage is sufficiently low and the salience is sufficiently high. Otherwise, the regulator implements the award.*

The exact conditions and the proof are in Appendix D.2. Figure 3 illustrates Proposition 4 graphically. As Proposition 4 and Figure 3 show, our results are qualitatively robust to extending the salience from $\sigma \in [0,1]$ to $\sigma \in \mathbb{R}_0^+$. The award always gives a higher welfare than the label if salience σ is sufficiently low, i.e., $0 < \sigma \leq (16-\sqrt{94})/32$. In contrast, if $\sigma > (16-\sqrt{94})/32$, there always exists a range of values for marginal damage for which the label outperforms the award: The label outperforms the award if the marginal damage is sufficiently low.

As our main result is qualitatively robust to allowing for overestimation of environmental quality ($\sigma \in \mathbb{R}_0^+$), in the following, we restrict salience to $\sigma \in [0,1]$.

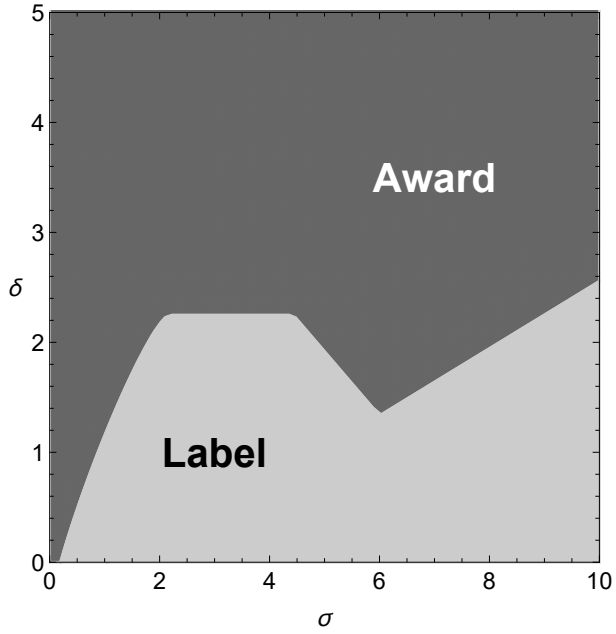

Figure 3: Policy decision dependent on salience σ and marginal damage δ. In the dark gray area, the regulator implements the award. In the light gray area, the regulator implements the label.

5.2 Environmental award with different degrees of salience

In the main model, we assume that consumers' perception of the environmental quality of the non-awarded good is zero, see (2). Yet, the firm losing the contest may also promote its environmental performance and thereby generate visibility. Nevertheless, compared to the visibility of the awarded firm, the visibility of the non-awarded firm should be lower. In the following, we allow for the environmental quality of the non-awarded good to be at least partially perceived by the consumers. In particular, we assume that the perceived environmental quality of good i in the award regime is

$$\hat{q}_i = \begin{cases} \sigma q_i & \text{if good } i \text{ has received an award} \\ s\sigma q_i & \text{otherwise,} \end{cases}$$

where $s \in [0, 3/5]$.[22]

We solve the game by backward induction. In the third stage, firms choose their prices. The new assumption has no effect on the price-setting. Consequently, the analysis in Section 4.1 still holds. In the second stage, firms invest in environmental quality q_i. We need to distinguish between the label and the award case. The assumption does not affect the label case. Consequently, for the label, equilibrium environmental qualities and prices are given in Proposition 2. In contrast, the new assumption changes the quality-setting stage if the regulator has implemented an award. The firm that wins the contest

[22]This assumption on s ensures that the symmetric solution of the first-order condition is a maximum.

is always the firm with the higher perceived environmental quality, i.e., firm h, whereas, the firm that loses the contest is always the firm with the lower perceived environmental quality, i.e., firm l. If firm i wins the award, the perceived environmental qualities of firms $i, j \in \{1, 2\}$ with $i \neq j$ are $\hat{q}_i = \sigma q_i$ and $\hat{q}_j = s\sigma q_j$. The corresponding profit of firm i is $\pi_h(\hat{q}_h = \sigma q_i, \hat{q}_l = s\sigma q_j)$. If firm i loses and firm j wins the award, the perceived environmental qualities of the firms are $\hat{q}_i = s\sigma q_i$ and $\hat{q}_j = \sigma q_j$. The corresponding profit of firm i is $\pi_l(\hat{q}_h = \sigma q_j, \hat{q}_l = s\sigma q_i)$. As in the main model, firms maximize their expected profits from winning and losing the contest. To distinguish the results of the main model from the results of this extension, we call the main model *award with one degree of salience*, denoted by A, and this extension *award with two degrees of salience*, denoted by $A2$. To be able to compare the results to the award with one degree of salience, we focus only on the equilibrium with symmetric environmental quality investments.

Lemma 4 summarizes the equilibrium outcomes.

Lemma 4 *Let $i \in \{1, 2\}$ and denote by h (l) the firm that wins (loses) the contest and thus has a higher (lower) perceived environmental quality. If the regulator implements an award with two degrees of salience, the optimal monetary prize for the winning firm is*

$$\phi^*_{A2} = max\left\{0, \frac{(1+2\delta)(9+18\delta-11\sigma+5s\sigma)}{72c}\right\}.$$

The corresponding symmetric subgame-perfect equilibrium environmental qualities and prices are $q^*_{i,A2} = max\{(1+2\delta)/(8c), (11-5s)\sigma/(72c)\}$, $p^*_{h,A2} = 2(1-s)\sigma q^*_{i,A2}/3$, and $p^*_{l,A2} = (1-s)\sigma q^*_{i,A2}/3$.

The proof is in Appendix E.1. The model with two degrees of salience converges to the main model with one degree of salience if $s \to 0$. Decreasing the salience share s has three effects: First, a decrease in the salience share s of the firm losing the contest leads to a weak increase in equilibrium quality investments of both firms. Consequently, a decrease in the salience share s results in lower damages. Second, a decrease in the salience share s implies a higher degree of perceived product differentiation, resulting in higher equilibrium prices and more market power for the firms. Third, a decrease in the salience share s decreases the optimal monetary prize. As with a decrease in the salience share s firms receive monetary compensation through a higher degree of perceived product differentiation, a lower level of the monetary prize is required to achieve the same investment levels.

When comparing the award with two degrees of salience to the award with one degree of salience, the welfare is always weakly larger with the award with two degrees of salience. With one degree of salience, the investments in environmental quality and thus the benefits to consumers and the costs for firms are weakly higher and damages are weakly lower. However, with two degrees of salience, the monetary prize is weakly higher. Consequently,

for a large range of values, i.e., if $\sigma \leq (9+18\delta)/11$, the award with one degree of salience and the award with two degrees of salience yield the same welfare. Otherwise, the award with two degrees of salience yields a higher welfare. Lemma 5 summarizes the comparison of the award with two degrees of salience and the award with one degree of salience.

Lemma 5 *The award with two degrees of salience yields a weakly higher welfare than the award with one degree of salience.*

The proof is in Appendix E.2. As for $\sigma \leq (9+18\delta)/11$, the award with one and the award with two degrees of salience yield identical welfare, for $\sigma \leq (9+18\delta)/11$, the results from Proposition 3 hold.

If $(9+18\delta)/11 < \sigma \leq 1$, the marginal damage δ and thus the weight of the emissions in the social welfare function is comparatively small (otherwise, this range would not exist). Therefore, the effect of the emissions in the comparison of the policies plays a minor role. For $(9+18\delta)/11 < \sigma \leq 1$, the label yields larger benefits to consumers but higher costs to firms. Nevertheless, the label outperforms the award.

Proposition 5 summarizes the results.

Proposition 5 *Let the salience of an awarded good be σ and the salience of a non-awarded good be $s \cdot \sigma$ with $s \in [0, 3/5]$. The regulator implements the label if and only if the marginal damage is sufficiently low and the salience is sufficiently high relative to the marginal damage, i.e., if and only if $\delta \leq (37+8\sqrt{10})/54$ and $(2+3\delta)/4 - \sqrt{47+60\delta-36\delta^2}/(16\sqrt{2}) \leq \sigma \leq 1$. Otherwise, the regulator implements the award with two degrees of salience.*

The proof is in Appendix E.3. Whether consumers only perceive the winning firm's environmental quality (Section 4) or whether consumers perceive both firms' environmental qualities does not affect our results on awards vs. labels. With two degrees of salience, the regulator adjusts the monetary prize sufficiently such that our main result still holds.

5.3 Distinguishing award salience and label salience

Consumers may have a different perception of environmental quality depending on whether a good has received an award or a label. For example, awards and labels may differ in their visibility or their popularity. Therefore, in this section, we allow for different salience parameters depending on the policy instrument: σ_A denotes award salience and σ_L denotes label salience. Price-setting and quality-investments are analogous to Sections 4.1 and 4.2.1 for the award and Sections 4.1 and 4.2.2 for the label.

Proposition 6 summarizes the comparison of awards vs. labels.

Proposition 6 *Let the salience of the award be σ_A and the salience of the label be σ_L. Then, the regulator implements the label if and only if the marginal damage is sufficiently low and the salience of the label is sufficiently high:*

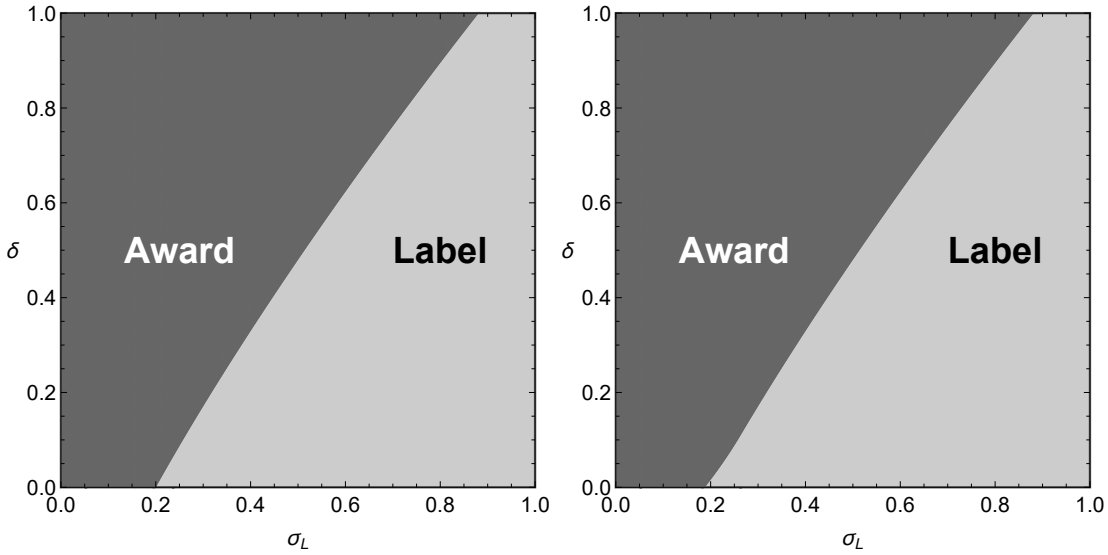

Figure 4: Policy decision dependent on label salience σ_L and marginal damage δ. In the dark gray area, the regulator implements the award. In the light gray area, the regulator implements the label. In the left panel, $\sigma_A = 9/11$ which illustrates the condition $\sigma_A \leq (9 + 18\delta)/11$. In the right panel, $\sigma_A = 1$ which illustrates the condition $\sigma_A > (9 + 18\delta)/11$.

(a) $\sigma_A \leq min\{(9 + 18\delta)/11, 1\}$, $\delta \leq (37 + 8\sqrt{10})/54$, *and*
$(2 + 3\delta)/4 - \sqrt{47 + 60\delta - 36\delta^2}/(16\sqrt{2}) \leq \sigma_L \leq 1$, *or*

(b) $\sigma_A > (9 + 18\delta)/11$, $\delta \leq 1/9$, *and*
$(2 + 3\delta)/4 - \sqrt{288\delta^2 - 396\delta\sigma_A + 384\delta + 121\sigma_A^2 - 198\sigma_A + 128}/(16\sqrt{2}) \leq \sigma_L \leq 1$.

Otherwise, the regulator implements the award.

The proof is in Appendix F. For $\sigma_A \leq \min\{(9 + 18\delta)/11, 1\}$, the condition for which the label outperforms the award is identical to the condition in Section 4. For $\sigma_A \leq (9 + 18\delta)/11$, the social welfare with the award is independent of the salience. Consequently, distinguishing award salience and label salience has no effect on the comparison of awards and labels. The left panel of Figure 4 illustrates this: Compared to Figure 2, the conditions do not change. For $\sigma_A > (9 + 18\delta)/11$ (right panel of Figure 4) , the condition for which the label outperforms the award changes slightly. However, qualitatively, the condition remains the same (compare right panel and left panel of Figure 4). In general, the label outperforms the award if and only if marginal damage is sufficiently low and label salience is sufficiently high.

6 Extensions

In this section, we explore two extensions. First, we analyze the decision between awards and labels of an NGO with the objective to minimize environmental damages and total

expenditures. Second, we analyze whether a classical emission tax outperforms environmental awards and environmental labels.

6.1 NGO

Not all awards or labels are implemented by a regulator with the objective to maximize social welfare. Often, awards or labels are introduced by an NGO with the objective to minimize total environmental damages and policy expenditures: $D(E)+\mathbb{I}_A\phi$, where $D(E)$ are damages and $\mathbb{I}_A$ is an indicator function that is one if the NGO implements an award with monetary prize ϕ.[23] In this section, we analyze whether an NGO implements an environmental award or a label.

First, if the NGO implements an environmental award, firms face the same pricing and quality-investment choices as described in Sections 4.1 and 4.2.1. However, an NGO chooses a different monetary prize. A larger monetary prize reduces damages, but increases policy expenditures for the NGO. The NGO chooses the monetary prize to balance these two effects, i.e., to minimize

$$D(E_A) + \phi = \delta \left(e - \frac{11\sigma + \sqrt{121\sigma^2 + 2592c\phi}}{144c} \right) + \phi.$$

As

$$\frac{\partial D(E_A) + \phi}{\partial \phi} \geq 0 \Leftrightarrow -\frac{9\delta}{\sqrt{121\sigma^2 + 2592c\phi}} + 1 \geq 0 \Leftrightarrow \phi \geq \frac{81\delta^2 - 121\sigma^2}{2592c}$$

and as by assumption $\phi \geq 0$, the optimal monetary prize is

$$\phi^*_{NGO} = max\left\{0, \frac{81\delta^2 - 121\sigma^2}{2592c}\right\}.$$

Consequently, the firms' investments in environmental quality in equilibrium are $q^*_{i,A} = max\{(11\sigma)/(72c), (9\delta + 11\sigma)/(144c)\}$.

Second, if the NGO implements an environmental label, firms face the same pricing and quality-investment choices as described in Sections 4.1 and 4.2.2. However, an NGO with the objective to minimize total damages chooses a different labeling threshold than a regulator with the objective to maximize social welfare. Given the investments in environmental quality dependent on the labeling threshold (cf. Lemma 2), the damages

[23] We assume that the NGO does not have any expenditures for the label.

dependent on the labeling threshold $\bar{q}$ are

$$D(E_L) = \begin{cases} \delta\left(e - \frac{4\sigma}{27c}\right) & \text{if } \bar{q} < \frac{2\sigma}{9c} \\ \delta\left(e - \frac{2\bar{q}}{3}\right) & \text{if } \frac{2\sigma}{9c} \leq \bar{q} \leq \frac{4\sigma}{9c} \\ \delta e & \text{if } \bar{q} > \frac{4\sigma}{9c}. \end{cases} \tag{6}$$

Thus damages are lowest for the labeling threshold $\bar{q} = (4\sigma)/(9c)$, resulting in environmental qualities of $q^*_{i,L} = (4\sigma)/(9c)$ and $q^*_{j,L} = 0$ (cf. Lemma 2).

The NGO implements the policy that yields the lowest damages and expenditures:

$$\begin{aligned} & D(E_L) \leq D(E_A) + \phi \\ \Leftrightarrow\ & \delta\left(e - \frac{8\sigma}{27c}\right) \leq \delta\left(e - max\left\{\frac{11\sigma}{72c}, \frac{9\delta + 11\sigma}{144c}\right\}\right) + max\left\{0, \frac{81\delta^2 - 121\sigma^2}{2592c}\right\} \\ \Leftrightarrow\ & \sigma \geq \frac{(285 - 48\sqrt{31})\delta}{121}. \end{aligned}$$

Note that $(285 - 48\sqrt{31})\delta/121 \leq 1 \Leftrightarrow \delta \leq 121/(285 - 48\sqrt{31})$. Proposition 7 summarizes the result.

Proposition 7 (NGO: Award vs. Label) *An NGO with the incentive to minimize total damages and policy expenditures implements a label with labeling threshold* $\bar{q}^*_{NGO} = (4\sigma)/(9c)$ *if and only if* $\delta \leq 121/(285 - 48\sqrt{31})$ *and* $(285 - 48\sqrt{31})\delta/121 \leq \sigma \leq 1$. *Otherwise, the NGO implements an award with monetary prize* $\phi^*_{NGO} = max\{0, (81\delta^2 - 121\sigma^2)/(2592c)\}$.

Figure 5 illustrates Proposition 7 graphically. In contrast to a regulator with the objective to maximize social welfare, an NGO implements a label for a larger range of values. Nevertheless, the general result from the main model that for sufficiently high marginal damage δ or for sufficiently low salience σ, the regulator implements an award, is robust. If $\delta < (11\sigma)/9$, with the award, the NGO finds it optimal to implement the award without any monetary prize. Then, optimal investments are $q^*_{i,A} = (11\sigma)/(72c) < (4\sigma)/(9c) = q^*_{i,L}$. With the label, 2/3 of the consumers buy from the high-quality firm with environmental quality $(4\sigma)/(9c)$, whereas 1/3 of the consumers buy from the low-quality firm with environmental quality of zero. With the award, all consumers buy a good with environmental quality of $(11\sigma)/(72c)$. Nevertheless, the damages are lower with the label. As neither the award nor the label includes any monetary prize and, in contrast to the regulator, the NGO neglects the effect of the policy on firms' costs and on consumers' utility, the NGO implements the label for $\delta < (11\sigma)/9$.

If $\delta \geq (11\sigma)/9$, with the award, the NGO finds it optimal to include a positive monetary prize to induce higher investments. For $\delta < (95\sigma)/27$, the damages with the label are lower. For $\delta \geq (95\sigma)/27$, the damages with the award are lower. However, due to the posi-

tive monetary prize, the award is costly. Therefore, the NGO prefers the award if and only if $\sigma < (285 - 48\sqrt{31})\delta/121$. Otherwise, i.e., if and only if $(285 - 48\sqrt{31})\delta/121 \leq \sigma \leq 1$, the NGO implements the label.

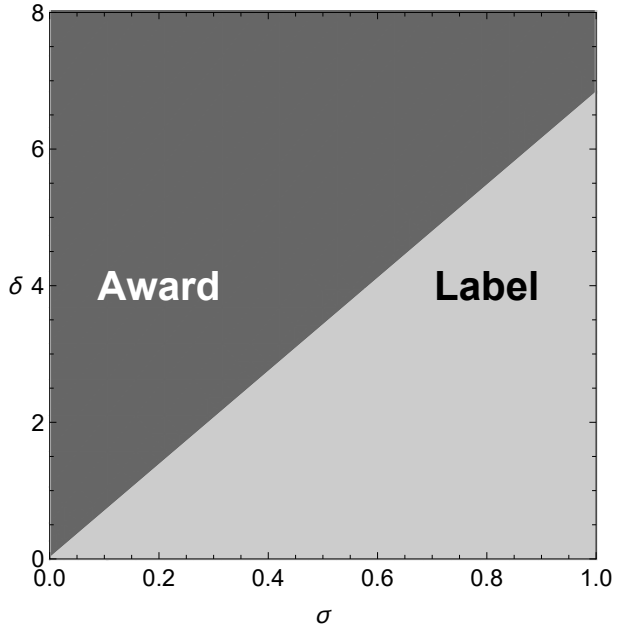

Figure 5: Policy decision of the NGO dependent on salience σ and marginal damage δ. In the dark gray area, the NGO implements the award. In the light gray area, the NGO implements the label.

6.2 Emission tax

In the main model, we allow the regulator to decide between implementing an environmental award and an environmental label. Although environmental awards and environmental labels exist and are implemented in reality, the most prominent environmental policy in the literature and in policy debates is emission taxation. Consequently, in this section, we analyze whether an emission tax outperforms awards and labels or whether circumstances exist where environmental awards and labels yield higher social welfare than emission taxes.

We assume that, in the first stage, the regulator chooses between implementing an environmental award, an environmental label, and an emission tax, i.e., a per-unit tax $t(e - q_i)$, where $t \in [0, \delta]$ is the tax rate. If the regulator implements a per-unit tax $t(e - q_i)$, the profit of firm $i, j \in \{1, 2\}$ with $i \neq j$ becomes

$$\pi_i(p_i, p_j, \hat{q}_i, \hat{q}_j) = \Big(p_i - t(e - q_i)\Big) \cdot x_i^D(p_i, p_j, \hat{q}_i, \hat{q}_j) - cq_i^2.$$

We limit the tax rate to $t \leq \delta$, to capture that a tax rate $t = \delta$ would ensure that each firm has marginal costs equal to the size of its marginal damage. We keep the structure

of the game. Consequently, the price-setting stage, the quality-setting stage, the optimal monetary prize, and the optimal labeling threshold are identical to the main model if the regulator implements an environmental award and if the regulator implements an environmental label.

If the regulator implements an emission tax, consumers do not perceive any environmental quality, i.e., $\hat{q}_i = 0$. Consequently, consumers buy from the firm with the lower price.[24] This leads to intense price competition between the firms that drives down prices to the marginal costs of the firm with the higher marginal costs: $p_i = \max\{t(e - q_i), t(e - q_j)\}$ where $i, j \in \{1, 2\}$ and $i \neq j$. Then, the profit of firm i is

$$\pi_i(q_i, q_j) = \begin{cases} t(e - q_j) - t(e - q_i) - cq_i^2 & \text{if } q_i \geq q_j \\ -cq_i^2 & \text{if } q_i < q_j. \end{cases}$$

In the quality-setting stage, firms simultaneously choose their environmental qualities to maximize their profits. The resulting equilibrium environmental qualities are $q_h^* = t/(2c)$ and $q_l^* = 0$, where firm h (l) is the firm with the higher (lower) investments in environmental quality.[25] All consumers buy from the firm with the higher environmental quality and the firm with the lower environmental quality is not active in the market.

The regulator chooses the tax rate t to maximize social welfare, see Lemma 6.

Lemma 6 *If the regulator implements a per-unit tax $t(e - q_i)$, the optimal tax rate is $t^* = \delta$.*

The proof is in Appendix G.1. In general, as taxes and prices are a reallocation of welfare, the regulator takes into account the effect of the tax rate on firms' costs, benefits of consumers from consuming a good with higher environmental quality, and damages. An increase in the tax rate t increases investments in environmental quality to reduce marginal cost, i.e., tax payments. Consequently, an increase in the tax rate t benefits consumers and reduces damages but harms firms through higher cost. In sum, for all $t \in [0, \delta]$, the positive effects outweigh the negative effects such that the optimal tax rate is the boundary $t^* = \delta$.

In the first stage of the game, the regulator chooses between implementing an environmental award, an environmental label, and an emission tax. Proposition 8 shows under which conditions the regulator chooses an emission tax.

Proposition 8 (Award vs. Label vs. Emission tax) *A regulator with the decision between an environmental award, an environmental label, and an emission tax and with*

[24] We impose the following tie-breaking rule: If prices are identical, consumers buy from the firm with the higher environmental quality. Any other tie-breaking rule would ensure that the firm with the higher environmental quality chooses a marginally lower price, but would not otherwise change our results.

[25] There are two equilibria: One equilibrium in which firm 1 invests $t/(2c)$ and firm 2 invests zero and one equilibrium in which firm 2 invests $t/(2c)$ and firm 1 invests zero.

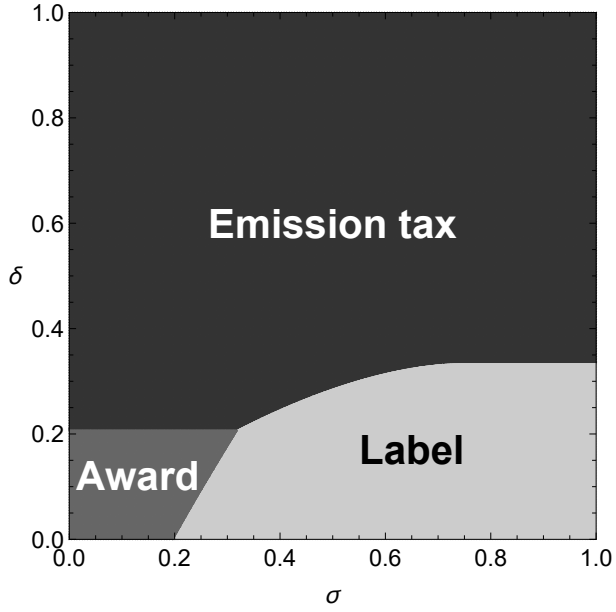

Figure 6: Policy decision dependent on salience σ and marginal damage δ. In the dark gray area, the regulator implements the award. In the light gray area, the regulator implements the label. In the black area, the regulator implements the emission tax.

the objective to maximize social welfare chooses the emission tax if and only if the marginal damage is sufficiently high.

The exact conditions for which the emission tax outperforms awards and labels and the proof are in Appendix G.2. Figure 6 illustrates Proposition 8 graphically.

With the emission tax, all consumers buy from the firm that invests more in environmental quality. Thereby, higher investments reduce marginal cost by reducing per-unit emissions and thus increase the profit of the firm capturing the entire market and ensure that only the high-quality firm is active in the market.

If $\delta \leq (37 + 8\sqrt{10})/54$ with $\sigma < (2 + 3\delta)/4 - \sqrt{47 + 60\delta - 36\delta^2}/(16\sqrt{2})$ or $\delta > (37 + 8\sqrt{10})/54$, the environmental award yields higher welfare than the environmental label (see Proposition 3). Then, the regulator either implements the environmental award or the emission tax. With the tax as well as with the award, all consumers buy a good with identical strictly positive environmental quality. The individual investments with the award are higher than with the emission tax if and only if the marginal damage is low enough, i.e., $\delta < 1/2$. Consequently, if and only if $\delta < 1/2$, the award yields higher benefits to consumers and lower damages. Yet, higher investments also ensure higher costs to firms: As long as $\delta < 1/2(1 + \sqrt{2})$, costs are higher with the award. Balancing costs and benefits, the award outperforms the emission tax if and only if the marginal damage is sufficiently low, i.e., $\delta \leq (\sqrt{2} - 1)/2$. In contrast, if and only if $\delta > (\sqrt{2} - 1)/2$, the emission tax yields higher social welfare than the environmental award.

If $\delta \leq (37 + 8\sqrt{10})/54$ with $\sigma \geq (2 + 3\delta)/4 - \sqrt{47 + 60\delta - 36\delta^2}/(16\sqrt{2})$, the environmental label yields higher welfare than the environmental award (see Proposition 3).

Then, the regulator either implements the environmental label or the emission tax. Similarly to the award vs. tax analysis, as long as the marginal damage is sufficiently low, the label yields higher benefits to consumers and lower damages, but also has higher costs. The regulator balances the costs and benefits: The label outperforms the emission tax if and only if the marginal damage is sufficiently low.

In sum, the emission tax outperforms environmental awards and labels for a range of parameters. However, a range of situations still exists, where it is optimal to implement an environmental award, and, in addition, a range of situations still exists, where it is optimal to implement an environmental label. Furthermore, if an emission tax that fully internalizes the damages caused by emissions is politically not feasible, i.e., if $t \leq \beta\delta$ with $\beta \in [0, 1]$, the range of values for which awards or labels outperform emission taxes increases in β.

7 Conclusion

In this article, we analyze how environmental awards and environmental labels affect firms' investments in environmental quality and social welfare. We show that firms use the award and the label to differentiate their products and to generate market power. However, awards and labels provide different incentives to firms. With an award, both firms invest in environmental quality, but only one firm receives the award. With a label, at most one firm invests in environmental quality. We show that whether the award or the label maximizes social welfare depends on the salience that the award and the label generate and on the marginal damage. The award results in higher welfare than the label if marginal damage is sufficiently high or if salience is sufficiently low. Otherwise, i.e., if marginal damage is sufficiently low and salience is sufficiently high, the label generates higher social welfare.

In addition, we also explore the robustness of our main result. First, we analyze how our results change if consumers overestimate the environmental quality of goods that won an environmental award or received a label. We show that although the exact conditions for which the label outperforms the award change, qualitatively our results hold. Second, we analyze the effects on social welfare if the environmental quality of the awarded and of the non-awarded good become salient, but to different extents. We show that this extension neither qualitatively nor quantitatively changes our main result. Third, we assume that environmental awards and labels affect consumers' attention differently; we allow award salience and label salience to differ. Although the conditions whether to implement an award or a label change slightly, the main result is qualitatively the same as in the main model.

Furthermore, we discuss two extensions. First, we investigate the policy choice of an NGO aiming to minimize total damages and total policy expenditures. We find that,

although the conditions for which the label outperforms the award changes, qualitatively our results are robust to this extension. Second, we discuss whether an emission tax outperforms environmental awards and labels or whether circumstances exist under which awards, respectively labels, are optimal. We show that if the marginal damage is sufficiently high, the regulator should implement an emission tax. However, a significant range of situations exists where environmental awards, respectively environmental labels, outperform emission taxes.

In our model, we focus on investments in environmental quality, on environmental awards, and on environmental labels. Nevertheless, by setting the marginal damage to zero, our model captures awards and labels for any type of credence goods, i.e., goods where consumers are unable to observe the quality of the goods directly, or more broadly for goods where consumers are inattentive to quality unless made salient through an award or a label.

To keep the model tractable, we make some assumptions that limit the scope of the analysis. First, to keep the model tractable, we only consider a covered duopoly market and neglect any possible quantity effects. Second, we do not address the coordination problem that arises under labeling, i.e., how firms decide which firm invests and which firm does not invest. Third, we do not consider that the regulator simultaneously implements an environmental award and an environmental label. In the main model, we assume that awards as well as labels affect the salience of environmental quality in the same way. As it is not straightforward how implementing simultaneously an award and a label would affect salience, we refrain from exploring joint policies further. We leave these issues to further research.

A Environmental award

A.1 Proof of Lemma 1

Firm $i \in \{1,2\}$ with $j \in \{1,2\}$ and $i \neq j$ maximizes its expected profit:

$$\begin{aligned}\mathbb{E}[\pi_i] &= \alpha_i(q_i,q_j)\cdot\pi_h(\hat{q}_h=\sigma q_i,\hat{q}_l=0)+\Big(1-\alpha_i(q_i,q_j)\Big)\cdot\pi_l(\hat{q}_h=\sigma q_j,\hat{q}_l=0)\\ &= \frac{q_i}{q_i+q_j}\left(\frac{4}{9}\sigma q_i+\phi\right)+\left(1-\frac{q_i}{q_i+q_j}\right)\frac{1}{9}\sigma q_j - cq_i^2.\end{aligned}$$

The first-order condition simplifies to

$$\frac{4q_i^2\sigma+q_j(9\phi+8q_i\sigma-q_j\sigma)}{9(q_i+q_j)^2}-2cq_i=0.$$

Solving the first-order conditions simultaneously and checking the second-order conditions yields the following equilibrium environmental qualities:

$$q_{i,A}^{*}=\frac{11\sigma+\sqrt{121\sigma^2+2592c\phi}}{144c} \tag{7}$$

for $i \in \{1,\,2\}$.

A.2 Proof of Proposition 1

If the regulator implements an award, the social welfare is $W_A = CS_A + PS_A - D(E_A) - \phi$, i.e., the sum of consumer surplus (CS_A) and producer surplus (PS_A, the sum of the profits), minus the damages caused by emissions and the monetary prize. We assume the following damage function: $D(E_A) = \delta E_A$ with $\delta \in \mathbb{R}_0^+$. The consumer surplus, producer surplus, emissions, and thus the social welfare are

$$\begin{aligned}CS_A &= \int_0^{\bar{\theta}}(v+\theta q_l-p_l)d\theta+\int_{\bar{\theta}}^{1}(v+\theta q_h-p_h)d\theta\\ &= v+\frac{(9-10\sigma)\left(11\sigma+\sqrt{121\sigma^2+2592c\phi}\right)}{2592c}\\ PS_A &= \pi_i+\pi_j=\frac{\sigma\left(11\sigma+\sqrt{121\sigma^2+2592c\phi}\right)}{576c}+\frac{3\phi}{4}\\ E_A &= e-\frac{11\sigma+\sqrt{121\sigma^2+2592c\phi}}{144c}\\ W_A &= v-\frac{1}{4}\phi+\frac{(18-11\sigma)(11\sigma+\sqrt{121\sigma^2+2592c\phi})}{5184c}\\ &\quad-\delta\left(e-\frac{11\sigma+\sqrt{121\sigma^2+2592c\phi}}{144c}\right).\end{aligned}$$

The regulator chooses the monetary prize ϕ to maximize social welfare:

$$\frac{\partial W_A}{\partial \phi} \geq 0 \Leftrightarrow \frac{18 + 36\delta - 11\sigma - \sqrt{121\sigma^2 + 2592c\phi}}{4\sqrt{121\sigma^2 + 2592c\phi}} \geq 0$$
$$\Leftrightarrow \phi \leq \frac{(1 + 2\delta)(9 + 18\delta - 11\sigma)}{72c}.$$

As $\phi \geq 0$ by assumption, the optimal monetary prize is

$$\phi^* = max\left\{0, \frac{(1 + 2\delta)(9 + 18\delta - 11\sigma)}{72c}\right\}.$$

B Environmental label

B.1 Proof of Lemma 2

The profit of firm i depends on whether firm j receives the label: The profit of firm i is given in (4) if $q_j \geq \bar{q}$ and in (5) if $q_j < \bar{q}$.

(i) Assume $q_j \geq \bar{q}$. If $q_i < q_j$, the profit of firm i is decreasing in $q_i \in [0, q_j)$. Consequently, the candidate for best reply in $[0, q_j)$ is $q_i = 0$. If $q_i \geq q_j$,

$$\frac{\partial \pi_i(q_i, q_j)}{\partial q_i} = \frac{4}{9}\sigma - 2cq_i = 0 \Leftrightarrow q_i = \frac{2\sigma}{9c}.$$

Consequently, the candidate for best reply on the interval $[q_j, \infty)$ is this inner solution or the boundary:

$$q_i(q_j) = \begin{cases} \frac{2\sigma}{9c} & \text{if } q_j \leq \frac{2\sigma}{9c} \\ q_j & \text{if } q_j > \frac{2\sigma}{9c}. \end{cases}$$

Note that

$$\pi_i\left(q_i = 0, q_j \geq \bar{q}\right) \geq \pi_i\left(q_i = \frac{2\sigma}{9c}, q_j \geq \bar{q}\right) \Leftrightarrow \frac{1}{9}\sigma q_j \geq \frac{4}{9}\left(\sigma\frac{2\sigma}{9c} - \sigma q_j\right) - c\left(\frac{2\sigma}{9c}\right)^2$$
$$\Leftrightarrow q_j \geq \frac{4\sigma}{45c}$$

and

$$\pi_i\left(q_i = 0, q_j \geq \bar{q}\right) \geq \pi_i\left(q_i = q_j, q_j \geq \bar{q}\right) \forall q_j > \frac{2\sigma}{9c}.$$

(ii) Assume $q_j < \bar{q}$. If $q_i < \bar{q}$, the profit of firm i is decreasing in $q_i \in [0, \bar{q})$. Consequently, the candidate for best reply in $[0, \bar{q})$ is $q_i = 0$. If $q_i \geq \bar{q}$,

$$\frac{\partial \pi_i(q_i, q_j)}{\partial q_i} = \frac{4}{9}\sigma - 2cq_i = 0 \Leftrightarrow q_i = \frac{2\sigma}{9c}.$$

Consequently, the candidate for best reply on the interval $[\bar{q}, \infty)$ is this inner solution or the boundary:

$$q_i(q_j) = \begin{cases} \frac{2\sigma}{9c} & \text{if } \bar{q} \leq \frac{2\sigma}{9c} \\ \bar{q} & \text{if } \bar{q} > \frac{2\sigma}{9c}. \end{cases}$$

Note that

$$\pi_i\left(q_i = \frac{2\sigma}{9c}, q_j < \bar{q}\right) \geq \pi_i\left(q_i = 0, q_j < \bar{q}\right) \Leftrightarrow \frac{4\sigma^2}{81c} \geq 0 \Leftrightarrow \sigma \geq 0, c \geq 0$$

and

$$\pi_i\left(q_i = 0, q_j < \bar{q}\right) > \pi_i\left(q_i = \bar{q}, q_j < \bar{q}\right) \Leftrightarrow 0 > \frac{4}{9}\sigma\bar{q} - c\bar{q}^2 \Leftrightarrow \bar{q} > \frac{4\sigma}{9c}.$$

Bringing (i) and (ii) together gives the best reply of firm i: If $\bar{q} \leq (4\sigma)/(45c)$, the best reply of firm i is

$$q_i^*(q_j) = \begin{cases} \frac{2\sigma}{9c} & \text{if } q_j \leq \frac{4\sigma}{45c} \\ 0 & \text{if } q_j > \frac{4\sigma}{45c}. \end{cases}$$

If $(4\sigma)/(45c) < \bar{q} \leq (2\sigma)/(9c)$, the best reply of firm i is

$$q_i^*(q_j) = \begin{cases} \frac{2\sigma}{9c} & \text{if } q_j < \bar{q} \\ 0 & \text{if } q_j \geq \bar{q}. \end{cases}$$

If $(2\sigma)/(9c) < \bar{q} \leq (4\sigma)/(9c)$, the best reply of firm i is

$$q_i^*(q_j) = \begin{cases} \bar{q} & \text{if } q_j < \bar{q} \\ 0 & \text{if } q_j \geq \bar{q}. \end{cases}$$

If $\bar{q} > (4\sigma)/(9c)$, the best reply of firm i is

$$q_i^*(q_j) = 0.$$

Consequently, the equilibrium qualities also depend on the labeling threshold:

(i) If $\bar{q} < (2\sigma)/(9c)$, two asymmetric equilibria exist where $q_{i,L}^* = (2\sigma)/(9c)$, $q_{j,L}^* = 0$, $p_{i,L}^* = 2\sigma q_{i,L}^*/3$, and $p_{j,L}^* = \sigma q_{i,L}^*/3$.

(ii) If $(2\sigma)/(9c) \leq \bar{q} \leq (4\sigma)/(9c)$, two asymmetric equilibria exist where $q_{i,L}^* = \bar{q}$, $q_{j,L}^* = 0$, $p_{i,L}^* = 2\sigma q_{i,L}^*/3$, and $p_{j,L}^* = \sigma q_{i,L}^*/3$.

(iii) If $\bar{q} > (4\sigma)/(9c)$, one symmetric equilibrium exists where $q_{i,L}^* = q_{j,L}^* = 0$, $p_{i,L}^* = p_{j,L}^* = 0$.

B.2 Proof of Proposition 2

If the regulator implements a label, the social welfare is $W_L = CS_L + PS_L - D(E_L)$, i.e., the sum of consumer surplus (CS_L) and producer surplus (PS_L, the sum of the profits), minus the damages caused by emissions. We assume the following damage function: $D(E_L) = \delta E_L$ with $\delta \in \mathbb{R}_0^+$. As the subgame-perfect equilibria depend on the labeling

threshold, consumer surplus, producer surplus, and social welfare also depend on the labeling threshold.

(i) If $\bar{q} < (2\sigma)/(9c)$, two asymmetric equilibria exist where $q^*_{i,L} = (2\sigma)/(9c)$, $q^*_{j,L} = 0$, $p^*_{i,L} = 2\sigma q^*_{i,L}/3$, and $p^*_{j,L} = \sigma q^*_{i,L}/3$. Consequently, consumer surplus, producer surplus, and welfare are

$$\begin{aligned} CS_L &= \int_0^{\bar{\theta}} (v + \theta q_j - p_j) d\theta + \int_{\bar{\theta}}^1 (v + \theta q_i - p_i) d\theta = v + \frac{8\sigma - 10\sigma^2}{81c} \\ PS_L &= \pi_i + \pi_j = \frac{2\sigma^2}{27c} \\ W_L &= v + \frac{8\sigma - 4\sigma^2}{81c} - \delta \left(e - \frac{4\sigma}{27c} \right). \end{aligned}$$

(ii) If $(2\sigma)/(9c) \leq \bar{q} \leq (4\sigma)/(9c)$, two asymmetric equilibria exist where $q^*_{i,L} = \bar{q}$, $q^*_{j,L} = 0$, $p^*_{i,L} = 2\sigma q^*_{i,L}/3$, and $p^*_{j,L} = \sigma q^*_{i,L}/3$. Consequently, consumer surplus, producer surplus, and welfare are

$$\begin{aligned} CS_L &= \int_0^{\bar{\theta}} (v + \theta q_j - p_j) d\theta + \int_{\bar{\theta}}^1 (v + \theta q_i - p_i) d\theta = v + \frac{1}{9}\bar{q}(4 - 5\sigma) \\ PS_L &= \pi_i + \pi_j = \frac{5\bar{q}\sigma}{9} - c\bar{q}^2 \\ W_L &= v - c\bar{q}^2 + \frac{4\bar{q}}{9} - \delta \left(e - \frac{2\bar{q}}{3} \right). \end{aligned}$$

(iii) If $(4\sigma)/(9c) < \bar{q}$, one symmetric equilibrium exists where $q^*_{i,L} = q^*_{j,L} = 0$, $p^*_{i,L} = p^*_{j,L} = 0$. Consequently, consumer surplus, producer surplus, and welfare are

$$\begin{aligned} CS_L &= v \\ PS_L &= \pi_i + \pi_j = 0 \\ W_L &= v - \delta e. \end{aligned}$$

Optimal labeling threshold: Welfare is constant in $\bar{q} \in [0, (2\sigma)/(9c))$ and in $\bar{q} \in ((4\sigma)/(9c), \infty)$. If $(2 + 3\delta)/(9c) < (4\sigma)/(9c)$, welfare is increasing for all $\bar{q} \in [(2\sigma)/(9c), (2 + 3\delta)/(9c))$ and decreasing for all $\bar{q} \in ((2 + 3\delta)/(9c), (4\sigma)/(9c)]$. If $(2 + 3\delta)/(9c) \geq (4\sigma)/(9c)$, welfare is increasing for all $\bar{q} \in [(2\sigma)/(9c), (4\sigma)/(9c)]$. In addition,

- if $(2 + 3\delta)/(9c) < (4\sigma)/(9c) \Leftrightarrow \sigma > (2 + 3\delta)/4$,

$$W_L \left(\bar{q} = \frac{2 + 3\delta}{9c} \right) \geq W_L \left(\bar{q} < \frac{2\sigma}{9c} \right) \text{ and } W_L \left(\bar{q} = \frac{2 + 3\delta}{9c} \right) > W_L \left(\bar{q} > \frac{4\sigma}{9c} \right).$$

- if $(2 + 3\delta)/(9c) \geq (4\sigma)/(9c) \Leftrightarrow \sigma \leq (2 + 3\delta)/4$,

$$W_L \left(\bar{q} = \frac{4\sigma}{9c} \right) \geq W_L \left(\bar{q} < \frac{2\sigma}{9c} \right) \text{ and } W_L \left(\bar{q} = \frac{4\sigma}{9c} \right) \geq W_L \left(\bar{q} > \frac{4\sigma}{9c} \right).$$

Consequently, the optimal labeling threshold depends on the salience σ and the marginal damage δ:

(i) If $\sigma \leq (2+3\delta)/4$, $\bar{q}^* = (4\sigma)/(9c)$.

(ii) If $\sigma > (2+3\delta)/4$, $\bar{q}^* = (2+3\delta)/(9c)$.[26]

[26] As $\sigma \in [0,1]$, this case only exists if $\delta < 2/3$.

C Proof of Proposition 3

If the regulator implements the award, social welfare given the optimal monetary prize is[27]

$$W_A(\phi^*) = \begin{cases} v + \frac{(1+2\delta)^2}{32c} - \delta e & \text{if } \sigma \leq \frac{9+18\delta}{11} \\ v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right) & \text{if } \sigma > \frac{9+18\delta}{11}. \end{cases}$$

If the regulator implements the label, social welfare given the optimal labeling threshold is

$$W_L(\bar{q}^*) = \begin{cases} v + \frac{16(\sigma-\sigma^2)}{81c} - \delta\left(e - \frac{8\sigma}{27c}\right) & \text{if } \sigma \leq \frac{2+3\delta}{4} \\ v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) & \text{if } \sigma > \frac{2+3\delta}{4}. \end{cases}$$

The regulator implements the policy that maximizes social welfare. We assume that, if indifferent, the regulator implements the label. As the social welfare of the award depends on the monetary prize and the social welfare of the label depends on the optimal labeling threshold, we need to distinguish three cases:

(i) If $\sigma \leq (2+3\delta)/4$,

$$\begin{aligned} & W_L(\bar{q}^*) \geq W_A(\phi^*) \\ \Leftrightarrow\ & v + \frac{16(\sigma-\sigma^2)}{81c} - \delta\left(e - \frac{8\sigma}{27c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\ \Leftrightarrow\ & \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \sigma \leq \frac{1}{4}(2+3\delta) + \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \wedge \\ & \delta \leq \frac{1}{6}\left(5+6\sqrt{2}\right). \end{aligned}$$

Note that by assumption $\sigma \in [0,1]$ and

$$\begin{aligned} & \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \frac{2+3\delta}{4}, \\ & \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq 1 \Leftrightarrow \delta \leq \frac{1}{54}\left(37+8\sqrt{10}\right), \\ & \frac{1}{54}\left(37+8\sqrt{10}\right) < \frac{1}{6}\left(5+6\sqrt{2}\right), \end{aligned}$$

and

$$\frac{1}{4}(2+3\delta) + \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \geq \frac{2+3\delta}{4}.$$

[27] The optimal monetary prize is $\phi^* = \max\left\{0, (1+2\delta)(9+18\delta-11\sigma)/(72c)\right\}$. That means, if $\sigma > (9+18\delta)/11$, the optimal monetary prize is zero. Otherwise, the monetary prize is $(1+2\delta)(9+18\delta-11\sigma)/(72c)$.

Consequently, in the range $\sigma \leq (2+3\delta)/4$, the regulator implements the label if and only if

$$\delta \leq \frac{1}{54}\left(37+8\sqrt{10}\right) \text{ and } \sigma \geq \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}}.$$

Otherwise, the regulator implements the award.

(ii) If $(2+3\delta)/4 < \sigma \leq (9+18\delta)/11$,

$$\begin{aligned} & W_L(\bar{q}^*) \geq W_A(\phi^*) \\ \Leftrightarrow\ & v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\ \Leftrightarrow\ & \delta \leq \frac{(5+6\sqrt{2})}{6}. \end{aligned}$$

Note that by assumption $\sigma \in [0,1]$. Therefore, the range $(2+3\delta)/4 < \sigma \leq (9+18\delta)/11$ only exists if $(2+3\delta)/4 < 1 \Leftrightarrow \delta < 2/3$. As $2/3 < (5+6\sqrt{2})/6$, in the range $(2+3\delta)/4 < \sigma \leq (9+18\delta)/11$, the regulator always implements the label.

(iii) If $\sigma > (9+18\delta)/11$,

$$\begin{aligned} & W_L(\bar{q}^*) \geq W_A(\phi^*) \\ & \Leftrightarrow v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) \geq v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right). \end{aligned} \tag{8}$$

Note that, for $\sigma \in [0,1]$, inequality (8) is always fulfilled. Consequently, in the range $\sigma > (9+18\delta)/11$, the regulator always implements the label.

Combining (i)-(iii), the regulator implements the label if and only if

$$\delta \leq \frac{1}{54}(37+8\sqrt{10}) \text{ and } \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \sigma \leq 1$$

Otherwise, the regulator implements the award. In particular, if $\delta > \left(37+8\sqrt{10}\right)/54$, then $(2+3\delta)/4 - \sqrt{47+60\delta-36\delta^2}/(16\sqrt{2}) > 1$ and the regulator always implements the award.

D Overestimation of environmental quality

D.1 Proof of Lemma 3

As the subgame-perfect equilibria depend on the labeling threshold (cf. Lemma 2), consumer surplus, producer surplus, and social welfare also depend on the labeling threshold. Following Appendix B.2, the welfare given the labeling threshold $\bar{q}$ is

$$W_L(\bar{q}) = \begin{cases} v + \frac{8\sigma - 4\sigma^2}{81c} - \delta\left(e - \frac{4\sigma}{27c}\right) & \text{if } \bar{q} < \frac{2\sigma}{9c} \\ v - c\bar{q}^2 + \frac{4\bar{q}}{9} - \delta\left(e - \frac{2\bar{q}}{3}\right) & \text{if } \frac{2\sigma}{9c} \leq \bar{q} \leq \frac{4\sigma}{9c} \\ v - \delta e & \text{if } \bar{q} > \frac{4\sigma}{9c}. \end{cases}$$

Optimal labeling threshold: Welfare is constant in $\bar{q} \in [0, (2\sigma)/(9c))$ and in $\bar{q} \in ((4\sigma)/(9c), \infty)$. If $(2 + 3\delta)/(9c) \leq (2\sigma)/(9c)$, welfare is decreasing for all $\bar{q} \in [(2\sigma)/(9c), (4\sigma)/(9c)]$. If $(2\sigma)/(9c) < (2 + 3\delta)/(9c) < (4\sigma)/(9c)$, welfare is increasing for all $\bar{q} \in [(2\sigma)/(9c), (2 + 3\delta)/(9c))$ and decreasing for all $\bar{q} \in ((2 + 3\delta)/(9c), (4\sigma)/(9c)]$. If $(2 + 3\delta)/(9c) \geq (4\sigma)/(9c)$, welfare is increasing for all $\bar{q} \in [(2\sigma)/(9c), (4\sigma)/(9c)]$. In addition,[28]

- if $(2 + 3\delta)/(9c) \leq (2\sigma)/(9c) \Leftrightarrow \sigma \geq (2 + 3\delta)/2$,

$$W_L\left(\bar{q} = \frac{2\sigma}{9c}\right) = W_L\left(\bar{q} < \frac{2\sigma}{9c}\right) \text{ and } W_L\left(\bar{q} = \frac{2\sigma}{9c}\right) \geq W_L\left(\bar{q} > \frac{4\sigma}{9c}\right) \Leftrightarrow \sigma \leq 2 + 3\delta.$$

- if $(2\sigma)/(9c) < (2 + 3\delta)/(9c) < (4\sigma)/(9c) \Leftrightarrow (2 + 3\delta)/4 < \sigma < (2 + 3\delta)/2$,

$$W_L\left(\bar{q} = \frac{2 + 3\delta}{9c}\right) > W_L\left(\bar{q} < \frac{2\sigma}{9c}\right) \text{ and } W_L\left(\bar{q} = \frac{2 + 3\delta}{9c}\right) > W_L\left(\bar{q} > \frac{4\sigma}{9c}\right).$$

- if $(2 + 3\delta)/(9c) \geq (4\sigma)/(9c) \Leftrightarrow \sigma \leq (2 + 3\delta)/4$,

$$W_L\left(\bar{q} = \frac{4\sigma}{9c}\right) \geq W_L\left(\bar{q} < \frac{2\sigma}{9c}\right) \text{ and } W_L\left(\bar{q} = \frac{4\sigma}{9c}\right) \geq W_L\left(\bar{q} > \frac{4\sigma}{9c}\right).$$

Consequently, the optimal labeling threshold depends on the salience σ and the marginal damage δ:

(i) If $\sigma \leq (2 + 3\delta)/4$, $\bar{q}^* = (4\sigma)/(9c)$.

(ii) If $(2 + 3\delta)/4 < \sigma < (2 + 3\delta)/2$, $\bar{q}^* = (2 + 3\delta)/(9c)$.

(iii) If $(2 + 3\delta)/2 \leq \sigma \leq 2 + 3\delta$, $\bar{q}^* \in [0, 2\sigma/(9c)]$.

(iv) If $\sigma > 2 + 3\delta$, $\bar{q}^* \in ((4\sigma)/(9c), \infty)$.

[28] We assume that if the regulator is indifferent between two labeling thresholds, the regulator chooses the threshold that leads to higher investments.

D.2 Proof of Proposition 4

If the regulator implements the award, social welfare given the optimal monetary prize is

$$W_A(\phi^*) = \begin{cases} v + \frac{(1+2\delta)^2}{32c} - \delta e & \text{if } \sigma \leq \frac{9+18\delta}{11} \\ v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right) & \text{if } \sigma > \frac{9+18\delta}{11}. \end{cases}$$

If the regulator implements the label, social welfare given the optimal labeling threshold is

$$W_L(\bar{q}^*) = \begin{cases} v + \frac{16(\sigma-\sigma^2)}{81c} - \delta\left(e - \frac{8\sigma}{27c}\right) & \text{if } \sigma \leq \frac{2+3\delta}{4} \\ v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) & \text{if } \frac{2+3\delta}{4} < \sigma < \frac{2+3\delta}{2} \\ v + \frac{8\sigma-4\sigma^2}{81c} - \delta\left(e - \frac{4\sigma}{27c}\right) & \text{if } \frac{2+3\delta}{2} \leq \sigma \leq 2+3\delta \\ v - \delta e & \text{if } \sigma > 2+3\delta. \end{cases}$$

The regulator implements the policy that maximizes social welfare. We assume that, if indifferent, the regulator implements the label. As the social welfare of the award depends on the monetary prize and the social welfare of the label depends on the optimal labeling threshold, we need to distinguish six cases. Note that

$$\frac{2+3\delta}{2} \leq \frac{9+18\delta}{11} \Leftrightarrow \delta \geq \frac{4}{3}.$$

(i) If $\sigma \leq (2+3\delta)/4$,

$$\begin{aligned} & W_L(\bar{q}^*) \geq W_A(\phi^*) \\ \Leftrightarrow\ & v + \frac{16(\sigma-\sigma^2)}{81c} - \delta\left(e - \frac{8\sigma}{27c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\ \Leftrightarrow\ & \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \sigma \leq \frac{1}{4}(2+3\delta) + \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \\ & \wedge\ \delta \leq \frac{1}{6}\left(5+6\sqrt{2}\right). \end{aligned}$$

Note that

$$\frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \frac{2+3\delta}{4}$$

and

$$\frac{1}{4}(2+3\delta) + \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \geq \frac{2+3\delta}{4}.$$

Consequently, in the range $\sigma \leq (2+3\delta)/4$, the regulator implements the label if

and only if

$$\delta \leq \frac{1}{6}\left(5+6\sqrt{2}\right) \text{ and } \sigma \geq \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}}.$$

Otherwise, the regulator implements the award.

(ii) If $(2+3\delta)/4 < \sigma \leq \min\{(9+18\delta)/11, (2+3\delta)/2\}$,

$$\begin{aligned}
& W_L(\bar{q}^*) \geq W_A(\phi^*) \\
\Leftrightarrow\ & v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\
\Leftrightarrow\ & \delta \leq \frac{1}{6}\left(5+6\sqrt{2}\right).
\end{aligned}$$

Consequently, in the range $(2+3\delta)/4 < \sigma \leq \min\{(9+18\delta)/11, (2+3\delta)/2\}$, the regulator implements the label if and only if $\delta \leq (5+6\sqrt{2})/6$. Otherwise, the regulator implements the award.

(iii) If $\delta < 4/3$ and $(9+18\delta)/11 < \sigma < (2+3\delta)/2$,

$$\begin{aligned}
& W_L(\bar{q}^*) \geq W_A(\phi^*) \\
\Leftrightarrow\ & v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) \geq v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right) \\
\Leftrightarrow\ & \frac{128+384\delta+288\delta^2-198\sigma-396\delta\sigma+121\sigma^2}{2592c} \geq 0 \\
\Leftrightarrow\ & (9+18\delta-11\sigma)^2 \geq 36\delta^2 - 47 - 60\delta,
\end{aligned}$$

which is always fulfilled for $\delta < 4/3$.

Consequently, in the range $\delta < 4/3$ and $(9+18\delta)/11 < \sigma < (2+3\delta)/2$, the regulator always implements the label.

(iv) If $\delta \geq 4/3$ and $(2+3\delta)/2 \leq \sigma \leq (9+18\delta)/11$,

$$\begin{aligned}
& W_L(\bar{q}^*) \geq W_A(\phi^*) \\
\Leftrightarrow\ & v + \frac{8\sigma-4\sigma^2}{81c} - \delta\left(e - \frac{4\sigma}{27c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\
\Leftrightarrow\ & \frac{2+3\delta}{2} - \frac{\sqrt{47+60\delta-36\delta^2}}{8\sqrt{2}} \leq \sigma \leq \frac{2+3\delta}{2} + \frac{\sqrt{47+60\delta-36\delta^2}}{8\sqrt{2}} \wedge \\
& \delta \leq \frac{1}{6}\left(5+6\sqrt{2}\right).
\end{aligned}$$

Note that

$$\begin{aligned}
&\frac{2+3\delta}{2} - \frac{\sqrt{47+60\delta-36\delta^2}}{8\sqrt{2}} \leq \frac{2+3\delta}{2},\\
&\frac{2+3\delta}{2} + \frac{\sqrt{47+60\delta-36\delta^2}}{8\sqrt{2}} \geq \frac{2+3\delta}{2},\\
&\frac{2+3\delta}{2} + \frac{\sqrt{47+60\delta-36\delta^2}}{8\sqrt{2}} \leq \frac{9+18\delta}{11} \Leftrightarrow \delta \geq \frac{575}{258}.
\end{aligned}$$

Consequently, in the range $\delta \geq 4/3$ and $(2+3\delta)/2 \leq \sigma \leq (9+18\delta)/11$, the regulator implements the label if and only if $\delta \leq 575/258$ or $575/258 < \delta \leq (5+6\sqrt{2})/6$ with $\sigma \leq (2+3\delta)/2 + (\sqrt{47+60\delta-36\delta^2})/(8\sqrt{2})$. Otherwise, the regulator implements the award.

(v) If $\max\{(9+18\delta)/11, (2+3\delta)/2\} \leq \sigma \leq 2+3\delta$,

$$\begin{aligned}
&W_L(\bar{q}^*) \geq W_A(\phi^*)\\
\Leftrightarrow\ & v + \frac{8\sigma-4\sigma^2}{81c} - \delta\left(e - \frac{4\sigma}{27c}\right) \geq v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right)\\
\Leftrightarrow\ & \sigma \leq \frac{58-12\delta}{7}.
\end{aligned}$$

Note that

$$\begin{aligned}
&\frac{58-12\delta}{7} \geq 0 \Leftrightarrow \delta \leq \frac{29}{6},\\
&\frac{9+18\delta}{11} < \frac{58-12\delta}{7} \Leftrightarrow \delta < \frac{575}{258},\\
&\frac{58-12\delta}{7} \leq 2+3\delta \Leftrightarrow \delta \geq \frac{4}{3}.
\end{aligned}$$

Consequently, in the range $\max\{(9+18\delta)/11, (2+3\delta)/2\} \leq \sigma \leq 2+3\delta$, the regulator implements the label if and only if $\delta < 4/3$ or $4/3 \leq \delta < 575/258$ with $\sigma \leq (58-12\delta)/7$. Otherwise, the regulator implements the award.

(vi) If $\sigma > 2+3\delta$,

$$\begin{aligned}
&W_L(\bar{q}^*) \geq W_A(\phi^*)\\
\Leftrightarrow\ & v - \delta e \geq v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right)\\
\Leftrightarrow\ & \sigma \geq \frac{1}{11}(18+36\delta).
\end{aligned}$$

Note that

$$\frac{1}{11}(18+36\delta) > 2+3\delta \Leftrightarrow \delta > \frac{4}{3}.$$

Consequently, in the range $\sigma > 2+3\delta$, the regulator implements the label if and only if $\delta \leq 4/3$ or $\delta > 4/3$ with $\sigma \geq (18+36\delta)/11$. Otherwise, the regulator implements the award.

Combining (i)-(vi), the regulator implements the label if and only if

- $(16-\sqrt{94})/32 < \sigma < (9+6\sqrt{2})/8$ with $\delta \leq (64\sigma-27)/54+(4\sqrt{2}\sqrt{9\sigma-4\sigma^2})/27$ or
- $(9+6\sqrt{2})/8 \leq \sigma \leq (9+6\sqrt{2})/4$ with $\delta \leq (5+6\sqrt{2})/6$ or
- $(9+6\sqrt{2})/4 < \sigma \leq 192/43$ with $\delta \leq (32\sigma-27)/54+(4\sqrt{9\sigma-2\sigma^2})/27$ or
- $\sigma > 192/43$ with $\delta \leq \max\{(58-7\sigma)/12, (11\sigma-18)/36\}$.

Otherwise, the regulator implements the award.

E Environmental award with different degrees of salience

E.1 Proof of Lemma 4

Firms $i, j \in \{1, 2\}$ with $i \neq j$ maximize their expected profits from winning and losing the contest:

$$\begin{aligned}\mathbb{E}[\pi_i] &= \alpha_i(q_i, q_j) \cdot \pi_h(\hat{q}_h = \sigma q_i, \hat{q}_l = s\sigma q_j) + \Big(1 - \alpha_i(q_i, q_j)\Big) \cdot \pi_l(\hat{q}_h = \sigma q_j, \hat{q}_l = s\sigma q_i) \\ &= \frac{q_i}{q_i + q_j}\left(\frac{4}{9}(\sigma q_i - s\sigma q_j) + \phi\right) + \left(1 - \frac{q_i}{q_i + q_j}\right)\frac{1}{9}(\sigma q_j - s\sigma q_i) - cq_i^2.\end{aligned}$$

The first-order condition simplifies to

$$\frac{\Big(4q_i^2 + 8q_iq_j - q_j^2(1+5s)\Big)\sigma + 9\phi q_j}{9(q_i+q_j)^2} - 2cq_i = 0.$$

By symmetry $q_i = q_j$, checking the second-order conditions, and noting that by assumption $\phi \geq 0$ in equilibrium:

$$q^*_{i,A2} = \frac{11\sigma - 5s\sigma + \sqrt{(11\sigma - 5s\sigma)^2 + 2592c\phi}}{144c} \tag{9}$$

for $i \in \{1, 2\}$. Then, consumer surplus, producer surplus, emissions, and welfare are

$$\begin{aligned}CS_{A2} &= \int_0^{\bar{\theta}} (v + \theta q_l - p_l)\, d\theta + \int_{\bar{\theta}}^1 (v + \theta q_h - p_h)\, d\theta \\ &= v + \frac{(9 + 10s\sigma - 10\sigma)\left(11\sigma - 5s\sigma + \sqrt{(11\sigma - 5s\sigma)^2 + 2592c\phi}\right)}{2592c} \\ PS_{A2} &= \pi_{l,A2} + \pi_{h,A2} = \frac{3\phi}{4} + \frac{(3\sigma - 5s\sigma)\left(11\sigma - 5s\sigma + \sqrt{(11\sigma - 5s\sigma)^2 + 2592c\phi}\right)}{1728c} \\ E_{A2} &= e - \frac{11\sigma - 5s\sigma + \sqrt{(11\sigma - 5s\sigma)^2 + 2592c\phi}}{144c} \\ W_{A2} &= v + \frac{(5s\sigma - 11\sigma + 18)\left(11\sigma - 5s\sigma + \sqrt{(11\sigma - 5s\sigma)^2 + 2592c\phi}\right)}{5184c} - \frac{\phi}{4} \\ &\quad - \delta\left(e - \frac{11\sigma - 5s\sigma + \sqrt{(11\sigma - 5s\sigma)^2 + 2592c\phi}}{144c}\right).\end{aligned}$$

As

$$\frac{\partial W_{A2}}{\partial \phi} = \frac{36\delta + 5s\sigma - 11\sigma + 18}{4\sqrt{(11\sigma - 5s\sigma)^2 + 2592c\phi}} - \frac{1}{4} \geq 0 \Leftrightarrow \phi \leq \frac{(1+2\delta)(9 + 18\delta - 11\sigma + 5s\sigma)}{72c}$$

and as by assumption $\phi \geq 0$, the optimal monetary prize is

$$\phi^*_{A2} = \max\left\{0, \frac{(1+2\delta)(9+18\delta-11\sigma+5s\sigma)}{72c}\right\}.$$

E.2 Proof of Lemma 5

The welfare with one degree of salience given the optimal monetary prize is

$$W_A(\phi^*) = \begin{cases} v + \frac{(1+2\delta)^2}{32c} - \delta e & \text{if } \sigma \leq \frac{9+18\delta}{11} \\ v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right) & \text{if } \sigma > \frac{9+18\delta}{11}. \end{cases}$$

The welfare with two degrees of salience given the optimal monetary prize is

$$W_{A2}(\phi^*_{A2}) = \begin{cases} v + \frac{(1+2\delta)^2}{32c} - \delta e & \text{if } \sigma \leq \frac{9+18\delta}{11-5s} \\ v + \frac{(11-5s)\sigma(36\delta+5s\sigma-11\sigma+18)}{2592c} - \delta e & \text{if } \sigma > \frac{9+18\delta}{11-5s}. \end{cases}$$

Comparing equilibrium welfare of an award with one degree of salience and an award with two degrees of salience yields:

(i) If $\sigma \leq (9+18\delta)/11$,

$$W_A(\phi^*) = W_{A2}(\phi^*_{A2}) \Leftrightarrow\ v + \frac{(1+2\delta)^2}{32c} - \delta e = v + \frac{(1+2\delta)^2}{32c} - \delta e.$$

For $0 < \sigma \leq (9+18\delta)/11$ and $0 \leq s \leq 3/5$, the award with one degree of salience and the award with two degrees of salience yield the same welfare.

(ii) If $(9+18\delta)/11 < \sigma \leq (9+18\delta)/(11-5s)$, as

$$\begin{aligned} & W_A(\phi^*) < W_{A2}(\phi^*_{A2}) \\ \Leftrightarrow\ & v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right) < v + \frac{(1+2\delta)^2}{32c} - \delta e \\ \Leftrightarrow\ & -\frac{(18\delta-11\sigma+9)^2}{2592c} < 0, \end{aligned}$$

for $(9+18\delta)/11 < \sigma \leq (9+18\delta)/(11-5s)$ and $0 \leq s \leq 3/5$, the award with two degrees of salience yields a higher welfare than the award with one degree of salience.

(iii) If $\sigma > (9+18\delta)/(11-5s)$, as

$$\begin{aligned}
&W_A(\phi^*) \leq W_{A2}(\phi^*_{A2}) \\
\Leftrightarrow\ & v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right) \leq v + \frac{(11-5s)\sigma(36\delta+5s\sigma-11\sigma+18)}{2592c} - \delta e \\
\Leftrightarrow\ & \frac{5s\sigma(18+36\delta+(5s-22)\sigma)}{2592c} \leq 0,
\end{aligned}$$

for $\sigma > (9+18\delta)/(11-5s)$ and $0 \leq s \leq 3/5$, the award with two degrees of salience yields a higher welfare than the award with one degree of salience.

Combining (i)-(iii), the award with two degrees of salience yields a weakly higher welfare than the award with one degree of salience.

E.3 Proof of Proposition 5

If the regulator implements the award with two degrees of salience, social welfare given the optimal monetary prize is

$$W_{A2}(\phi^*_{A2}) = \begin{cases} v + \frac{(1+2\delta)^2}{32c} - \delta e & \text{if } \sigma \leq \frac{9+18\delta}{11-5s} \\ v + \frac{(11-5s)\sigma(36\delta+5s\sigma-11\sigma+18)}{2592c} - \delta e & \text{if } \sigma > \frac{9+18\delta}{11-5s}. \end{cases}$$

If the regulator implements the label, social welfare given the optimal labeling threshold is

$$W_L(\bar{q}^*) = \begin{cases} v + \frac{16(\sigma-\sigma^2)}{81c} - \delta\left(e - \frac{8\sigma}{27c}\right) & \text{if } \sigma \leq \frac{2+3\delta}{4} \\ v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) & \text{if } \sigma > \frac{2+3\delta}{4}. \end{cases}$$

The regulator implements the policy that maximizes social welfare. We assume that, if indifferent, the regulator implements the label. As the social welfare of the award depends on the monetary prize and the social welfare of the label depends on the optimal labeling threshold, we need to distinguish three cases:

(i) If $\sigma \leq (2+3\delta)/4$,

$$\begin{aligned}
&W_L(\bar{q}^*) \geq W_{A2}(\phi^*_{A2}) \\
\Leftrightarrow\ & v + \frac{16(\sigma-\sigma^2)}{81c} - \delta\left(e - \frac{8\sigma}{27c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\
\Leftrightarrow\ & \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \sigma \leq \frac{1}{4}(2+3\delta) + \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \wedge \\
& \delta \leq \frac{1}{6}\left(5+6\sqrt{2}\right).
\end{aligned}$$

Note that by assumption $\sigma \in [0,1]$ and

$$\begin{aligned}
&\frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \frac{2+3\delta}{4}, \\
&\frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq 1 \Leftrightarrow \delta \leq \frac{1}{54}\left(37+8\sqrt{10}\right), \\
&\frac{1}{54}\left(37+8\sqrt{10}\right) < \frac{1}{6}\left(5+6\sqrt{2}\right)
\end{aligned}$$

and

$$\frac{1}{4}(2+3\delta) + \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} > \frac{2+3\delta}{4}.$$

Consequently, in the range $\sigma \leq (2+3\delta)/4$, the regulator implements the label if and only if

$$\delta \leq \frac{1}{54}\left(37+8\sqrt{10}\right) \text{ and } \sigma \geq \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}}.$$

Otherwise, the regulator implements the award with two degrees of salience.

(ii) If $(2+3\delta)/4 < \sigma \leq (9+18\delta)/(11-5s)$,

$$\begin{aligned}
&W_L(\vec{q}^*) \geq W_{A2}(\phi^*_{A2}) \\
\Leftrightarrow\ & v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\
\Leftrightarrow\ & \delta \leq \frac{1}{6}\left(5+6\sqrt{2}\right).
\end{aligned}$$

Note that by assumption $\sigma \leq 1$. Therefore, the range $(2+3\delta)/4 < \sigma \leq (9+18\delta)/(11-5s)$ only exists if $(2+3\delta)/4 < 1 \Leftrightarrow \delta < 2/3$. As $\left(5+6\sqrt{2}\right)/6 > 2/3$, the welfare of the label is always strictly larger than the welfare of the award with two degrees of salience. Consequently, for any $(2+3\delta)/4 < \sigma \leq (9+18\delta)/(11-5s)$, the regulator implements the label.

(iii) If $\sigma > (9+18\delta)/(11-5s)$,

$$\begin{aligned}
&W_L(\vec{q}^*) \geq W_{A2}(\phi^*_{A2}) \\
\Leftrightarrow\ & v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) \geq v + \frac{(11-5s)\sigma(36\delta+5s\sigma-11\sigma+18)}{2592c} - \delta e \\
\Leftrightarrow\ & \frac{32(2+3\delta)^2 - 18(1+2\delta)(11-5s)\sigma + (11\sigma-5s\sigma)^2}{2592c} \geq 0,
\end{aligned}$$

which is always fulfilled. Consequently, for any $\sigma > (9+18\delta)/(11-5s)$, the regulator implements the label.

Combining (i)-(iii), the regulator implements the label if and only if

$$\delta \leq \frac{1}{54}\left(37+8\sqrt{10}\right) \text{ and } \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \sigma \leq 1.$$

Otherwise, the regulator implements the award with two degrees of salience. In particular, if $\delta > \left(37+8\sqrt{10}\right)/54$, then $(2+3\delta)/4 - \sqrt{47+60\delta-36\delta^2}/(16\sqrt{2}) > 1$ and the regulator always implements the award with two degrees of salience.

F Distinguishing award salience and label salience: proof of Proposition 6

If the regulator implements the award, the social welfare given the optimal monetary prize is

$$W_A(\phi^*) = \begin{cases} v + \frac{(1+2\delta)^2}{32c} - \delta e & \text{if } \sigma_A \leq \frac{9+18\delta}{11} \\ v + \frac{11(18-11\sigma_A)\sigma_A}{2592c} - \delta\left(e - \frac{11\sigma_A}{72c}\right) & \text{if } \sigma_A > \frac{9+18\delta}{11}. \end{cases}$$

If the regulator implements the label, social welfare given the optimal labeling threshold is

$$W_L(\bar{q}^*) = \begin{cases} v + \frac{16(\sigma_L - \sigma_L^2)}{81c} - \delta\left(e - \frac{8\sigma_L}{27c}\right) & \text{if } \sigma_L \leq \frac{2+3\delta}{4} \\ v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) & \text{if } \sigma_L > \frac{2+3\delta}{4}. \end{cases}$$

The regulator implements the policy that maximizes social welfare. We assume that, if indifferent, the regulator implements the label. As the social welfare of the award depends on the optimal monetary prize and the social welfare of the label depends on the optimal labeling threshold, we need to distinguish four cases:

(i) If $\sigma_A \leq (9+18\delta)/11$ and $\sigma_L \leq (2+3\delta)/4$,

$$\begin{aligned} & W_L(\bar{q}^*) \geq W_A(\phi^*) \\ \Leftrightarrow\ & v + \frac{16(\sigma_L - \sigma_L^2)}{81c} - \delta\left(e - \frac{8\sigma_L}{27c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\ \Leftrightarrow\ & \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \sigma_L \leq \frac{1}{4}(2+3\delta) + \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \wedge \\ & \delta \leq \frac{1}{6}(5+6\sqrt{2}). \end{aligned}$$

As

$$\begin{aligned} & \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \frac{1}{4}(2+3\delta), \\ & \frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq 1 \Leftrightarrow \delta \leq \frac{1}{54}(37+8\sqrt{10}), \\ & \frac{1}{4}(2+3\delta) + \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \geq \frac{1}{4}(2+3\delta), \end{aligned}$$

in the range $\sigma_A \leq (9+18\delta)/11$ and $\sigma_L \leq (2+3\delta)/4$, the regulator implements the

label if and only if

$$\delta \leq \frac{1}{54}(37 + 8\sqrt{10}) \text{ and } \sigma_L \geq \frac{1}{4}(2 + 3\delta) - \frac{\sqrt{47 + 60\delta - 36\delta^2}}{16\sqrt{2}}.$$

(ii) If $\sigma_A \leq (9 + 18\delta)/11$ and $\sigma_L > (2 + 3\delta)/4$, as by assumption $\sigma_L \in [0, 1]$, this range only exists if $\delta < 2/3$.

$$\begin{aligned} & W_L(\bar{q}^*) \geq W_A(\phi^*) \\ \Leftrightarrow\ & v + \frac{4 - 9\delta^2}{81c} - \delta\left(e - \frac{4 + 6\delta}{27c}\right) \geq v + \frac{(1 + 2\delta)^2}{32c} - \delta e \\ \Leftrightarrow\ & \frac{47 + 60\delta - 36\delta^2}{2592c} \geq 0, \end{aligned}$$

is always fulfilled for $\delta < 2/3$. Consequently, in the range $\sigma_A \leq (9 + 18\delta)/11$ and $\sigma_L > (2 + 3\delta)/4$, the regulator always implements the label.

(iii) If $\sigma_A > (9 + 18\delta)/11$ and $\sigma_L \leq (2 + 3\delta)/4$,

$$\begin{aligned} & W_L(\bar{q}^*) \geq W_A(\phi^*) \\ \Leftrightarrow\ & v + \frac{16(\sigma_L - \sigma_L^2)}{81c} - \delta\left(e - \frac{8\sigma_L}{27c}\right) \geq v + \frac{11(18 - 11\sigma_A)\sigma_A}{2592c} - \delta\left(e - \frac{11\sigma_A}{72c}\right) \\ \Leftrightarrow\ & \frac{1}{4}(2 + 3\delta) - \frac{\sqrt{288\delta^2 - 396\delta\sigma_A + 384\delta + 121\sigma_A^2 - 198\sigma_A + 128}}{16\sqrt{2}} \leq \sigma_L \\ & \leq \frac{1}{4}(2 + 3\delta) + \frac{\sqrt{288\delta^2 - 396\delta\sigma_A + 384\delta + 121\sigma_A^2 - 198\sigma_A + 128}}{16\sqrt{2}}. \end{aligned}$$

As

$$\begin{aligned} \frac{1}{4}(2 + 3\delta) - \frac{\sqrt{288\delta^2 - 396\delta\sigma_A + 384\delta + 121\sigma_A^2 - 198\sigma_A + 128}}{16\sqrt{2}} &\leq \frac{1}{4}(2 + 3\delta), \\ \frac{1}{4}(2 + 3\delta) + \frac{\sqrt{288\delta^2 - 396\delta\sigma_A + 384\delta + 121\sigma_A^2 - 198\sigma_A + 128}}{16\sqrt{2}} &> \frac{1}{4}(2 + 3\delta), \end{aligned}$$

in the range $\sigma_A > (9 + 18\delta)/11$ and $\sigma_L \leq (2 + 3\delta)/4$, the regulator implements the label if and only if

$$\sigma_L \geq \frac{1}{4}(2 + 3\delta) - \frac{\sqrt{288\delta^2 - 396\delta\sigma_A + 384\delta + 121\sigma_A^2 - 198\sigma_A + 128}}{16\sqrt{2}}.$$

.

(iv) If $\sigma_A > (9+18\delta)/11$ and $\sigma_L > (2+3\delta)/4$,

$$\begin{aligned}
&W_L(\bar{q}^*) \geq W_A(\phi^*) \\
\Leftrightarrow\ & v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) \geq v + \frac{11(18-11\sigma_A)\sigma_A}{2592c} - \delta\left(e - \frac{11\sigma_A}{72c}\right) \\
\Leftrightarrow\ & \frac{288\delta^2 - 396\delta\sigma_A + 384\delta + 121\sigma_A^2 - 198\sigma_A + 128}{2592c} \geq 0,
\end{aligned}$$

is always fulfilled. Consequently, in the range $\sigma_A > (9+18\delta)/11$ and $\sigma_L > (2+3\delta)/4$, the regulator implements the label.

Note that

$$\frac{9+18\delta}{11} \leq 1 \Leftrightarrow \delta \leq \frac{1}{9}.$$

Combining (i)-(iv), the regulator implements the label if and only if

$$\begin{aligned}
&(a)\ \sigma_A \leq \min\left\{\frac{9+18\delta}{11}, 1\right\},\ \delta \leq \frac{1}{54}(37+8\sqrt{10}),\ \text{and} \\
&\frac{1}{4}(2+3\delta) - \frac{\sqrt{47+60\delta-36\delta^2}}{16\sqrt{2}} \leq \sigma_L \leq 1
\end{aligned}$$

or

$$\begin{aligned}
&(b)\ \sigma_A > \frac{9+18\delta}{11}, \delta \leq \frac{1}{9},\ \text{and} \\
&\frac{1}{4}(2+3\delta) - \frac{\sqrt{288\delta^2 - 396\delta\sigma_A + 384\delta + 121\sigma_A^2 - 198\sigma_A + 128}}{16\sqrt{2}} \leq \sigma_L \leq 1.
\end{aligned}$$

G Emission tax

In the following the index t denotes the emission tax design.

G.1 Proof of Lemma 6

If the regulator implements an emission tax $t(e - q_i)$ with $t \in [0, \delta]$ for each unit that firm i produces, the social welfare is $W_t = CS_t + PS_t - D(E_t) + T$, i.e., the sum of consumer surplus (CS_t), producer surplus (PS_t, the sum of the profits), and tax revenue (T), minus the damage caused by emissions ($D(E_t)$). The consumer surplus, producer surplus, emissions, and thus the social welfare are

$$\begin{aligned} CS_t &= \int_0^1 (v + \theta q_h - p_h) d\theta = v + \frac{t}{4c} - et \\ PS_t &= \pi_i + \pi_j = \frac{t^2}{4c} \\ E_t &= e - \frac{t}{2c} \\ T &= t\left(e - \frac{t}{2c}\right) \\ W_t &= v + \frac{t - t^2}{4c} - \delta\left(e - \frac{t}{2c}\right). \end{aligned}$$

As

$$\frac{\partial W_t}{\partial t} = \frac{1 - 2t}{4c} + \frac{\delta}{2c} \geq 0 \Leftrightarrow t \leq \frac{1 + 2\delta}{2}$$

and as

$$\frac{1 + 2\delta}{2} > \delta,$$

the optimal tax rate is $t^* = \delta$.

G.2 Proof of Proposition 8

(A) If and only if $\delta \leq (37 + 8\sqrt{10})/54$ with $\sigma < (2 + 3\delta)/4 - \sqrt{47 + 60\delta - 36\delta^2}/(16\sqrt{2})$ or $\delta > (37 + 8\sqrt{10})/54$, the environmental award yields higher welfare than the environmental label (see Proposition 3). Then, the regulator either implements the environmental award or the emission tax. The social welfare of the emission tax, given the optimal tax, is

$$W_t(t^*) = v + \frac{\delta - \delta^2}{4c} - \delta\left(e - \frac{\delta}{2c}\right).$$

If the regulator implements the award, social welfare is

$$W_A(\phi^*) = \begin{cases} v + \frac{(1+2\delta)^2}{32c} - \delta e & \text{if } \sigma \leq \frac{9+18\delta}{11} \\ v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right) & \text{if } \sigma > \frac{9+18\delta}{11}. \end{cases}$$

(i) If $\sigma \leq (9+18\delta)/11$,

$$\begin{aligned} & W_t(t^*) \geq W_A(\phi^*) \\ & \Leftrightarrow v + \frac{\delta - \delta^2}{4c} - \delta\left(e - \frac{\delta}{2c}\right) \geq v + \frac{(1+2\delta)^2}{32c} - \delta e \\ & \Leftrightarrow \delta \geq \frac{\sqrt{2}-1}{2}. \end{aligned}$$

For $\sigma \leq (9+18\delta)/11$, the regulator implements the tax if $\delta \geq (\sqrt{2}-1)/2$.

(ii) If $\sigma > (9+18\delta)/11$,

$$\begin{aligned} & W_t(t^*) \geq W_A(\phi^*) \\ \Leftrightarrow\ & v + \frac{\delta - \delta^2}{4c} - \delta\left(e - \frac{\delta}{2c}\right) \geq v + \frac{11(18-11\sigma)\sigma}{2592c} - \delta\left(e - \frac{11\sigma}{72c}\right) \\ \Leftrightarrow\ & \delta \geq \frac{1}{36}(11\sigma - 18) + \frac{1}{36}\sqrt{324 - 121\sigma^2}. \end{aligned}$$

As $\sigma > (9+18\delta)/11 \Leftrightarrow \delta < (11\sigma - 9)/18$ and

$$\frac{1}{36}(11\sigma - 18) + \frac{1}{36}\sqrt{324 - 121\sigma^2} > \frac{11\sigma - 9}{18},$$

for $\sigma > (9+18\delta)/11$, the regulator always implements the award.

(B) If and only if $\delta \leq (37+8\sqrt{10})/54$ with $\sigma \geq (2+3\delta)/4 - \sqrt{47+60\delta-36\delta^2}/(16\sqrt{2})$, the environmental label yields higher welfare than the environmental award (see Proposition 3). Then, the regulator either implements the environmental label or the emission tax. If the regulator implements the label, social welfare is

$$W_L(\bar{q}^*) = \begin{cases} v + \frac{16(\sigma-\sigma^2)}{81c} - \delta\left(e - \frac{8\sigma}{27c}\right) & \text{if } \sigma \leq \frac{2+3\delta}{4} \\ v + \frac{4-9\delta^2}{81c} - \delta\left(e - \frac{4+6\delta}{27c}\right) & \text{if } \sigma > \frac{2+3\delta}{4}. \end{cases}$$

(i) If $\sigma \leq (2+3\delta)/4$,

$$\begin{aligned} & W_t(t^*) \geq W_L(\vec{q}^*) \\ \Leftrightarrow\ & v + \frac{\delta - \delta^2}{4c} - \delta\left(e - \frac{\delta}{2c}\right) \geq v + \frac{16(\sigma - \sigma^2)}{81c} - \delta\left(e - \frac{8\sigma}{27c}\right) \\ \Leftrightarrow\ & \delta \geq \frac{1}{54}(32\sigma - 27) + \frac{1}{54}\sqrt{729 + 576\sigma - 1280\sigma^2}. \end{aligned}$$

As $\sigma \leq (2+3\delta)/4 \Leftrightarrow \delta \geq (4\sigma - 2)/3$ and

$$\frac{1}{54}(32\sigma - 27) + \frac{1}{54}\sqrt{729 + 576\sigma - 1280\sigma^2} \geq \frac{4\sigma - 2}{3} \Leftrightarrow \sigma \leq \frac{3}{4},$$

for $\sigma \leq (2+3\delta)/4$, the emission tax yields a higher welfare than the environmental label if $\sigma \leq 3/4$ and $\delta \geq (32\sigma - 27)/54 + \sqrt{729 + 576\sigma - 1280\sigma^2}/54$ or $\sigma > 3/4$.

(ii) If $\sigma > (2+3\delta)/4$,

$$\begin{aligned} & W_t(t^*) \geq W_L(\vec{q}^*) \\ \Leftrightarrow\ & v + \frac{\delta - \delta^2}{4c} - \delta\left(e - \frac{\delta}{2c}\right) \geq v + \frac{4 - 9\delta^2}{81c} - \delta\left(e - \frac{4 + 6\delta}{27c}\right) \\ \Leftrightarrow\ & \delta \geq \frac{1}{3}. \end{aligned}$$

As $\sigma > (2+3\delta)/4 \Leftrightarrow \delta < (4\sigma - 2)/3$ and

$$\frac{1}{3} < \frac{4\sigma - 2}{3} \Leftrightarrow \sigma > \frac{3}{4},$$

for $\sigma > (2+3\delta)/4$, the emission tax yields a higher welfare than the environmental label if $\sigma > 3/4$ and $\delta \geq 1/3$.

In sum, the regulator implements the emission tax if and only if (a) $\sigma \leq 3/4$ and $\delta \geq \max\Big\{(32\sigma - 27)/54 + \sqrt{729 + 576\sigma - 1280\sigma^2}/54, (\sqrt{2} - 1)/2\Big\}$ or (b) $\sigma > 3/4$ and $\delta \geq 1/3$.

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