Environmental Awards in a Duopoly with Green Consumers

Lisa Heidelmeier and Marco Sahm

Working Paper No. 207

May 2025

BERG Working Paper Series

Bamberg Economic Research Group
Bamberg University
Feldkirchenstraße 21
D-96052 Bamberg
Telephone: (0951) 863 2687
felix.stuebben@uni-bamberg.de
http://www.uni-bamberg.de/vwl/forschung/berg/

https://doi.org/10.20378/irb-

Redaktion:
Dr. Felix Stübben*

* felix.stuebben@uni-bamberg.de

Environmental Awards in a Duopoly with Green Consumers*

Lisa Heidelmeier† Marco Sahm**

This version: May 9, 2025

Abstract

We investigate the impact of an environmental award in a Bertrand duopoly with green consumers considering a three-stage game. First, the regulator designs the environmental contest. Second, firms choose their green investments, and the winner of the contest is awarded. Third, firms compete in prices, and consumption takes place. We illustrate that the award not only incentivizes green investments and may thus reduce environmental externalities. As consumers perceive the product of the awarded firm to be of superior quality, it also gives rise to vertical product differentiation. This induces market power, and thus anti-competitive effects: Rents shift from consumers to producers, and consumer surplus may decrease, particularly if marginal investment costs in green technologies are high compared to the strength of environmental damage.

Keywords: Bertrand Competition; Contests; Environmental Award; Green Consumer; Product Differentiation

JEL classification: D43, H23, L13, L51, Q52, Q58

*We are grateful to Fabian Dietz, Stephan Eitel, Stefanie Schmitt, and participants at the 16th RGS Doctoral Conference in Economics, the 22nd Bavarian Micro Day, the 50th Annual Conference of the European Association for Research in Industrial Economics, the Annual Conference of the Verein für Socialpolitik 2023, the Innsbruck Winter School on Credence Goods, Incentives and Behavior, the 29th Annual Conference of the European Association of Environmental and Resource Economists, the ifo Public Economics Workshop 2024, and research seminars at the University of Bamberg for valuable comments and suggestions. Lisa Heidelmeier gratefully acknowledges financial support from the Hans-Böckler-Stiftung. A former version of this paper circulated under the title 'A Vertically Differentiated Duopoly Model with Environmental Awards'.

†University of Bamberg, Department of Economics, Feldkirchenstraße 21, 96052 Bamberg, Germany.

**Corresponding author: University of Bamberg, Department of Economics, Feldkirchenstraße 21, 96052 Bamberg, Germany; and CESifo, Poschingerstraße 5, 81679 Munich, Germany. E-mail: marco.sahm@uni-bamberg.de, Telephone: +49–951–863–2728.

1 Introduction

Traditional responses to climate change, such as emission trading or taxation, are partly reaching their limits. The IPCC Sixth Assessment Report warns that global net carbon emissions need to decline by 45% of 2010 levels by 2030 to reach net zero by around 2050 (IPCC, 2022). The OECD (2017) underscores that promoting policy packages to mobilize investment in carbon neutral infrastructure and technologies is one of the key steps to combat global warming.

This paper analyzes an alternative incentive and internalization measure that has hardly been studied so far: environmental awards. Here, individuals, firms, or organizations decide to participate in an environmental contest. Each participant applies with his environmental effort. Then the contest takes place, and one contest winner is assigned based on his environmental performance. Environmental awards are increasingly used, as the *Champions of the Earth award*, the *UN Global Climate Action Award* or the *German Sustainability Award* show. However, theoretical support is lacking.

Further, we see that a growing fraction of consumers prefers to buy products from firms that use environmentally-friendly production technologies and accepts to pay a higher price for green goods.[1] This trend opens up the possibility for firms to use green investments as strategic variables to differentiate from their competitors and to relax price competition.

In this article, we elaborate on the two observations named above: dealing with current challenges of environmental policy by means of a contest while observing consumers with an increasing willingness to pay for green products. In order to shape firms' incentives, we use a model of vertical product differentiation. Vertical preferences imply that consumers prefer the good of higher perceived environmental quality and are willing to pay a higher price for this good.

More specifically, to examine the effectiveness of an environmental contest, we consider a Bertrand duopoly where the firms' products differ in the perceived level of environmental quality. We analyze competition between the two firms in the framework of a game with three stages: In the first stage, the regulator designs the environmental award, that is, the salience of the winner's product. In the second stage, firms decide simultaneously how much to invest in environmentally-friendly technologies. After observing the investment efforts, the contest winner is awarded. The environmental award reveals to consumers which product is (perceived to be) the greener one. In the third stage, firms simultaneously set their market prices. Thereafter, consumers make their consumption decisions.

Our baseline model concentrates on a covered market with unit demand: Each consumer buys exactly one unit of the product. Moreover, the contest is organized as an all-pay auction. This reflects the assumption that the contest designer can perfectly observe firms' investment levels and thus awards the firm with the highest investment level. We distinguish between two different objectives of environmental policy: The regulator maximizes either welfare (total surplus) or consumer surplus.

For both objectives, we find that the regulator implements the contest as long as the firms' marginal green investment costs are not too high in relation to the marginal strength of environmental damage. The welfare maximizing award, however, will raise consumer surplus if and only if the marginal green investment costs are sufficiently low compared

[1] See, e.g., Ward et al. (2011), Berger (2019), Kuhn and Uler (2019), Hulshof and Mulder (2020), Gomes et al. (2023), European Commission—Directorate-General for Communication. (2024), Ruggeri et al. (2024).

to the marginal strength of environmental damage. Otherwise, the welfare maximizing contest will be detrimental to consumers. Intuitively, using an environmental contest induces the following trade-off: On the one hand, the award motivates firms to invest in green technologies and, thereby, to internalize part of the environmental externality. Consequently, consumers profit from reduced environmental damage. However, on the other hand, the award implies product differentiation that confers market power on firms. This leads to higher prices and shifts rents from consumers to producers. Compared to a welfare maximizing regulator, a regulator who maximizes consumer surplus thus chooses a lower environmental award and accepts higher environmental damage.

The main results also hold for two variants of the baseline model. In the extension section, we first relax the assumption of a covered market. If some consumers stop buying if the environmental contest is installed, additional quantity effects will arise as consumption levels decrease. Secondly, we relax the assumption that the contest designer can perfectly observe investment levels. To allow for some noise, the environmental contest is modeled as a lottery: A firm can (ceteris paribus) increase its probability of winning the award by increasing its investment, but the firm with the higher investment does not win for sure.

The remainder of the article is organized as follows: Section 2 reviews the related literature. Section 3 introduces the baseline model and Section 4 presents the main results. In Section 5, we discuss the two extensions of the baseline model. Section 6 concludes.

2 Related Literature

Our paper contributes to two strands of the literature: specifically, models that adopt a contest to internalize externalities, and, more generally, articles that highlight measures to make firms' environmental performance visible.

To create an incentive scheme for green investment, we develop a theoretical model based on contest theory.[2] Related studies are found in the public goods literature, as protecting the quality of the environment can be interpreted as a public good. Previous work on contests in the public goods literature focuses mainly on the effects of monetary prizes and player heterogeneity, as well as on correcting distortions in consumption due to taxation (see, e.g., Morgan, 2000; Giebe and Schweinzer, 2014; Kolmar and Sisak, 2014).[3]

Another, as yet small, field of research combines market-based environmental policy with contest theory. MacKenzie et al. (2009) develop a mechanism that distributes emission permits to firms based on a rank-order contest. Bos et al. (2016) implement a contest to incentivize the formation of international environmental agreements, ensuring that harmful emissions are reduced to the socially efficient level without sacrificing productive efficiency.

Similarly to our approach, two recent papers by Osorio and Zhang incentivize green investment by applying a contest mechanism. In Osorio and Zhang (2022a), firms compete for an environmental subsidy. The authors compare two subsidy mechanisms: Firms compete by investing in green product features or by investing in emission abatement. The

[2] For an overview, see Konrad (2009).

[3] Another branch of the contest literature uses political contests to model the process of environmental regulation under lobbying, see, e.g., Heyes (1997), Liston-Heyes (2001), Dijkstra (2007), Ansink and Weikard (2025).

article suggests the green product feature design in industries with relatively high emission levels and the abatement design in industries with relatively low emission levels. In their second paper, Osorio and Zhang (2022b) examine different contest designs to determine emission taxes endogenously. They find that the optimal tax mechanism depends on the level of environmental damage in the respective industry.

The studies surveyed above emphasize the welfare-enhancing effects of contests. In contrast, our approach reveals that using a contest may also have anti-competitive effects which, to our knowledge, have not been taken into account in previous research. Our main contribution is to provide a theoretical framework for an environmental award based on contest theory and a comprehensive analysis of how environmental awards affect consumer behavior.

Firms need to promote their environmentally-friendly image to attract consumers for their green products. One way for firms to reveal their environmental efforts is by participating in an environmental contest. Another, more prevalent way, is to adopt an eco-label. There is extensive literature on eco-labeling.[4] Current eco-labeling literature stresses that the labeling design, firms' cost structures, abatement technologies, and costs for eco-labeling determine the effectiveness of eco-labels (see, e.g., Amacher et al., 2004; Ibanez and Grolleau, 2008; Li and van't Veld, 2015; Fischer and Lyon, 2019). On the consumer side, environmental consciousness, information structures, consumer informedness, and altruism play a crucial role (see, e.g., Brécard, 2017; Heyes et al., 2020; Ghazzai and Lahmandi-Ayed, 2021). Ben Youssef and Lahmandi-Ayed (2008) endogenously determine the labeling criteria that maximize total welfare. Similarly to our paper, but for labels, Ben Youssef and Lahmandi-Ayed (2008) show that introducing an eco-label may induce anti-competitive effects resulting in price increases that harm consumers. Bringing together the literature on environmental awards and eco-labels, Heidelmeier and Schmitt (2025) compare awards and labels as two instruments that allow firms to draw consumers' attention to the environmental quality of their products. In particular, the paper discusses the impact of awards and labels on firms' investments in environmental quality and on social welfare. Heidelmeier and Schmitt (2025) show that a social welfare maximizing regulator implements an environmental award if and only if marginal damage and salience of the environmental quality are sufficiently high such that consumers overestimate the environmental quality of the awarded and labeled goods.

Our contest approach stands out against traditional environmental regulatory instruments (such as emission taxation or trading systems) in terms of its positive investment incentives: The environmental contest allows firms to differentiate their products from those of their competitors with respect to environmental quality. As products get differentiated, firms can generate higher profits. Thus, the environmental award incentivizes firms to participate voluntarily in the contest. Firms invest in green technologies and, thereby, contribute to internalizing the environmental externality. While traditional instruments mainly concentrate on emission regulation and sanctions based on negative incentives, the contest mechanism sets positive investment incentives - similar to the use of eco-labels. Many studies examine eco-labeling as an incentive mechanism for green technology investment, whereas the literature on environmental awards is scarce. Yet, Lai et al. (2022) and Li et al. (2024) provide empirical evidence that environmental awards can indeed be a significant driver of green technology innovation. Besides these posi-

[4] For an overview, see Yokessa and Marette (2019) or van't Veld (2020).

tive consequences, however, our model also highlights that an environmental award may induce anti-competitive effects and harm consumers.

3 Model

We examine a duopoly model of price competition on a market with an environmental externality and green consumers. In principle, differences in the intensities of the consumers' preferences for environmental quality give rise to vertical product differentiation (Shaked and Sutton, 1982; Motta, 1993). We assume, however, that a firm can (credibly) signal the (superior) environmental quality of its product only by winning an environmental award. Designing the respective environmental contest is the only (remaining) policy tool of a benevolent regulator who aims to internalize the environmental externality in order to maximize social welfare or, alternatively, consumer surplus.

3.1 Firms

We consider a market with price competition between two firms. Each Firm $i \in \{1, 2\}$ produces one version of a product with (perceived) environmental quality μ_i and sells it at price p_i per unit. For simplicity, we assume the (constant) marginal costs of production to be zero (Motta, 1993). The production of each unit of the good causes an environmental externality equal to $1 - x_i$, where x_i denotes Firm i's investment into environmental quality. The marginal costs of green investments are constant and equal to $c > 0$. We assume, however, that neither the firms' investments nor the resulting environmental qualities are directly observable by consumers.[5] Without any (further) information on Firm i's investment, consumers perceive the firm's environmental quality as μ_ℓ, which we interpret as the minimum standard quality.

3.2 Consumers

We consider a continuum of consumers indexed by θ. The parameter θ represents the consumer's marginal valuation of environmental quality. For the sake of concreteness, we assume that θ is uniformly distributed on the interval $[0, 1]$. We assume discrete choice and unit demand: Each consumer has the same reservation price r for a good with environmental quality 0 and buys either none or exactly one unit of the good, either from Firm 1 or from Firm 2. For sufficiently large income y, the preferences of consumer θ can be described by the following (indirect) utility function (Mussa and Rosen, 1978):[6] $U(y, p, \mu) = \max\{0, \max_{i\in\{1,2\}} u_i(y, p, \mu)\}$, where

$$u_i(y, p, \mu) = r + \theta\mu_i - p_i. \tag{1}$$

In our baseline model, we assume that the reservation price r is high enough to ensure that the market is covered, i.e., each consumer buys exactly one unit of the good, either from Firm 1 or from Firm 2.[7]

[5] Firms' environmental quality and the underlying green investments satisfy the criteria characterizing a credence good: While goods are often differentiated by their environmental quality, e.g., low-emission electricity, consumers may be unable to observe these differences, even after consumption. Therefore, consumers have to rely on instruments, as an award, to make firms' environmental performance visible.

[6] Peitz (1995) provides a thorough foundation for this kind of modeling.

[7] In Section 5, we relax this assumption allowing for an uncovered market, where some consumers do not buy any of the two versions of the good.

3.3 Regulator

We consider a benevolent regulator who is able to observe the firms' environmental investments. As the only (remaining) instrument for providing investment incentives and, thereby, reducing the environmental externality, the regulator designs an environmental contest. In the baseline model, the contest is organized as an all-pay auction:[8] The firm with the higher environmental investment wins the contest and receives the award. While consumers perceive the loser's environmental quality as the minimum standard quality μ_ℓ, they perceive the winner's environmental quality as μ_w. We assume that the regulator can freely choose the winner's perceived environmental quality $\mu_w \geq \mu_\ell$, and refer to it as the environmental award. The award μ_w can be interpreted as the attention-generating effect of the contest that may, e.g., depend on the regulator's publicity campaign regarding the contest.[9] We ignore the cost of the contest program, which is a reasonable assumption as long as it is small compared to the environmental externality and investments.

Below, we consider two alternative objectives the regulator may have: the maximization of either total welfare (as the sum of producer surplus and net consumer surplus) or net consumer surplus only. We define net consumer surplus as the difference between consumer surplus net of consumers' environmental concerns[10] and the social loss caused by the environmental externality. For the sake of concreteness, we assume a quadratic loss function, $L = \delta\varepsilon^2$, where the parameter $\delta \geq 0$ scales the damage associated with the aggregate externality ε.

3.4 Timing of events

We model the interdependent decisions as a game with three stages. In the first stage, the regulator decides upon the award for the winner of the environmental contest, μ_w. In the second stage, firms choose simultaneously their investments in environmental quality x_i, $i \in \{1, 2\}$, the contest takes place, and the winner's product is awarded. In the last stage, firms choose simultaneously the prices p_i, $i \in \{1, 2\}$, for their so differentiated products, and consumers make their consumption decisions.

4 Analysis and Results

Before we describe the decisions on the three stages in more detail and solve the game by backward induction for its subgame-perfect equilibrium, we briefly discuss the unregulated market (laissez-faire economy) as a benchmark.

[8] In Section 5, we consider a lottery contest as an alternative choice of modeling.

[9] The assumption that the regulator has full control over the perceived environmental qualities is a simplification. Implicitly, it rests upon a behavioral assumption on consumers, e.g., limited attention or awareness: Consumers recognize only the winner's environmental effort, all the more the more salient the award is. See, e.g., Eliaz and Spiegler (2011), Bordalo et al. (2016), Hefti and Liu (2020), Carroni et al. (2023).

[10] I.e., aggregating individual utilities, the regulator includes only the net utility from consumption, $r - p_i$, but not the extra surplus from environmental quality, $\theta\mu_i$. The reason for this assumption is that an unbiased regulator should take into account only the real consequences of environmental quality (i.e., the environmental externality) but not the perceived ones (i.e., the consumers' different green consciousness). Moreover, this keeps our model free from additional incentives for the regulator to raise μ_w in order to increase consumer surplus directly (besides stimulating green investments).

4.1 The laissez-faire economy

In absence of the regulator, i.e., without the environmental contest, Firm $i \in \{1,2\}$ has no possibility to (credibly) signal the (superior) environmental quality of its product and, thus, no incentive to invest into environmental quality, $x_i = 0$. In this case, our model boils down to a standard Bertrand duopoly with homogeneous goods. Both firms produce goods of perceived environmental quality μ_ℓ. Price competition yields equilibrium prices equal to marginal costs of production, $p_i = 0$. Consequently, gross profits (not accounting for fixed or sunk costs) are zero as well, $\pi_i = 0$, and total welfare equals net consumer surplus. On the covered market, each consumer buys exactly one unit of the product. This yields the externality $\varepsilon = 1$ and net consumer surplus $CS = r - \delta$. The first column of Table 1 summarizes the results.

4.2 Stage 3: Price game

In the third stage of the game, the awarded firm, w, and the non-awarded firm, ℓ, simultaneously choose their prices p_w and p_ℓ. Under the assumption of a covered market, consumers decide whether to buy the good produced by the firm having lost the contest with perceived environmental quality μ_ℓ or to buy the good produced by the firm having won the contest with perceived environmental quality μ_w. Consumer θ prefers the awarded good to the non-awarded good whenever $u_w(y,p,\mu) \geq u_\ell(y,p,\mu)$ or, equivalently, $r + \theta\mu_w - p_w \geq r + \theta\mu_\ell - p_\ell$. The marginal consumer being indifferent between the two quality levels is thus defined by

$$\tilde{\theta} \equiv \frac{p_w - p_\ell}{\mu_w - \mu_\ell}.$$

Consequently, the non-awarded firm faces a demand of $D_\ell = \tilde{\theta}$ and the awarded firm faces a demand of $D_w = 1 - \tilde{\theta}$. Firm $i \in \{\ell, w\}$ thus chooses the price p_i in order to maximize its profit $\pi_i = p_i \cdot D_i$. We derive the firms' best response functions from the first-order conditions for solutions of these maximization problems and use them to compute the equilibrium. Lemma 1 summarizes the results.

Lemma 1. *Assume that the market is covered. Denote by w (ℓ) the firm that wins (loses) the contest and offers the perceived environmental quality μ_w (μ_ℓ). Then, third-stage equilibrium prices, market shares, and profits are $p_w^* = (2/3)(\mu_w - \mu_\ell)$, $p_\ell^* = (1/3)(\mu_w - \mu_\ell)$, $D_w^* = 2/3$, $D_\ell^* = 1/3$, $\pi_w^* = (4/9)(\mu_w - \mu_\ell)$, and $\pi_\ell^* = (1/9)(\mu_w - \mu_\ell)$.*

Lemma 1 shows that the market prices and profits are increasing in the difference in perceived environmental qualities. Moreover, the winner of the contest charges a higher price and makes higher profits than the loser.

4.3 Stage 2: Investment game

In the second stage, the firms anticipate these profits and decide simultaneously on their green investments x_i, $i \in \{1, 2\}$. The investment levels determine their success in the environmental contest, which is organized as an all-pay auction under complete information.

Thus, Firm i's probability of winning is

$$\alpha_i(x_i, x_j) = \begin{cases} 1 & \text{if } x_i > x_j, \\ \frac{1}{2} & \text{if } x_i = x_j, \\ 0 & \text{if } x_i < x_j, \end{cases}$$

for $i, j \in \{1, 2\}$ and $i \neq j$. The all-pay auction structure implies that the firm with the highest investment level (effort) wins the award with certainty.

Firms maximize their expected profits from participating in the contest while taking investment costs into account. The all-pay auction has a unique Nash-equilibrium, which is in mixed strategies (Baye et al., 1996). It can be derived from the property that the cumulative distribution function F_j, which describes the mixed strategy of Firm j, must leave Firm i indifferent between all its pure strategies (played with positive density), where $i, j \in \{1, 2\}$ and $i \neq j$. This implies, in particular, that Firm i's expected profit from choosing any investment level $x_i > 0$ (with positive density) equals the expected profit from choosing an investment level of $x_i = 0$ and losing the contest almost surely:

$$E[\pi_i] = \pi_w \cdot F_j(x_i) + \pi_\ell \cdot (1 - F_j(x_i)) - cx_i = \pi_\ell$$

for $i, j \in \{1, 2\}$ and $i \neq j$. In combination with Lemma 1, this yields

$$F_i^*(x_i) = \frac{cx_i}{\pi_w - \pi_\ell} = \frac{3cx_i}{\mu_w - \mu_\ell}$$

as the mixed equilibrium strategy of Firm $i \in \{1, 2\}$. Based on these cumulative distribution functions, we can compute the equilibrium values. As the firms are symmetric ex ante, i.e., before the contest takes place, their expected green investments coincide and they have the same equilibrium winning probabilities. Conditional on the outcome of the contest, however, the winner's expected green investment is higher than the loser's one. Lemma 2 summarizes the results.

Lemma 2. *Assume that the market is covered and the environmental contest is organized as an all-pay auction with an award $\mu_w > \mu_\ell$. In the second-stage equilibrium, Firm $i \in \{1, 2\}$ makes an expected green investment of $E[x_i] = (\pi_w - \pi_\ell)/(2c) = (\mu_w - \mu_\ell)/(6c)$ and has a winning probability of $\alpha_i = 1/2$. Moreover, conditional on the outcome of the contest, the expected green investment of the winner and loser, respectively, are*

$$E[x_w | x_w > x_\ell] = \frac{2}{3}\frac{(\pi_w - \pi_\ell)}{c} = 2\frac{(\mu_w - \mu_\ell)}{9c}, \tag{2}$$

$$E[x_\ell | x_\ell < x_w] = \frac{1}{3}\frac{(\pi_w - \pi_\ell)}{c} = \frac{(\mu_w - \mu_\ell)}{9c}. \tag{3}$$

Lemma 2 shows that an increase in the difference between perceived environmental qualities leads to an increase in expected green investments. This highlights the positive investment incentive provided by the contest.

4.4 Stage 1: Setting the environmental award

In the first stage, the regulator sets the level of the environmental award μ_w in order to maximize total welfare or, alternatively, net consumer surplus. We discuss the two objectives in turn and compare the results.

4.4.1 Maximization of total welfare

We use Lemmata 1 and 2 to compute total welfare:

$$
\begin{aligned}
W &= p_\ell \cdot D_\ell + p_w \cdot D_w - c \cdot (E[x_\ell | x_\ell < x_w] + E[x_w | x_w > x_\ell]) \\
&\quad + \int_0^{\tilde{\theta}} (r - p_\ell)\, d\theta + \int_{\tilde{\theta}}^1 (r - p_w)\, d\theta \\
&\quad - \delta \cdot (D_\ell \cdot (1 - E[x_\ell | x_\ell < x_w]) + D_w \cdot (1 - E[x_w | x_w > x_\ell]))^2 \\
&= r - \frac{1}{3}(\mu_w - \mu_\ell) - \delta \left(\frac{27c - 5(\mu_w - \mu_\ell)}{27c} \right)^2 .
\end{aligned} \tag{4}
$$

The first line contains the expected profit of the firms. The second line represents consumer surplus net of environmental concerns; it equals $r - (p_\ell \cdot D_\ell + p_w \cdot D_w)$. The third line captures the expected social loss caused by the environmental externality.

As the market is covered, increasing prices have no impact on total welfare: They only shift surplus from consumers to producers. Thus, when choosing the award μ_w to foster environmental investments, a welfare maximizing regulator only faces a trade-off between investment costs on the one hand and the induced reduction of the externality on the other hand. We use the first order condition $dW/d\mu_w = 0$ to compute the equilibrium value $\mu_w^* = \mu_\ell + (27c(10\delta - 9c))/(50\delta)$. It satisfies the constraint $\mu_w^* > \mu_\ell$ if and only if $0 < c/\delta < 10/9$. Therefore, it is optimal for the regulator to implement the environmental contest if and only if the marginal investment costs are sufficiently low compared to the strength of the environmental externality.

In this case, a straightforward comparative statics analysis shows that the optimal award μ_w^* increases in the strength of the environmental damage δ. Intuitively, a stronger externality requires higher green investments and, thus, stronger investment incentives. By contrast, μ_w^* is an inverted U-shaped function of the marginal investment costs c. On the one hand, higher marginal costs make green investments more expensive, which argues for a reduction of investment incentives. On the other hand, higher marginal costs require stronger investment incentives to achieve the same level of green investment and, thus, the same reduction of the environmental externality. As long as marginal investment costs are sufficiently low, the latter effect dominates the former. Proposition 1 summarizes the results.

Proposition 1. *On a covered market, a regulator who maximizes total welfare implements an environmental all-pay auction contest if and only if the marginal investment costs are sufficiently low compared to the strength of the environmental externality:* $0 < c/\delta < 10/9$. *In this case, the optimal environmental award equals* $\mu_w^* = \mu_\ell + (27c(10\delta - 9c))/(50\delta)$, *with* $d\mu_w^*/d\delta > 0$, *and* $d\mu_w^*/dc > 0$ *if and only if* $0 < c/\delta < 5/9$.

Based on the results of Lemmata 1 and 2 and Proposition 1, the second column of Table 1 summarizes the equilibrium values of the respective variables if $0 < c/\delta < 10/9$; otherwise, the regulator does not implement the contest ($\mu_w^* = \mu_\ell$) and the first column applies.

We now analyze the incidence of the welfare maximizing contest. To this end, we compare the equilibrium values of producer surplus and net consumer surplus in presence of the all-pay auction contest (*) to those in the laissez-faire equilibrium (LF). As the

Table 1: Equilibrium outcomes for a laissez-faire policy (LF), a welfare maximizing all-pay auction contest (*) for $0 < c/\delta < 10/9$ and a consumer surplus maximizing all-pay auction contest (CS) for $0 < c/\delta < 2/3$.

Laissez-faire	Welfare maximizing APA	CS maximizing APA
$\mu_w^{LF} = \mu_\ell$	$\mu_w^* = \mu_\ell + \frac{27c(10\delta-9c)}{50\delta}$	$\mu_w^{CS} = \mu_\ell + \frac{27c(2\delta-3c)}{10\delta}$
$p_w^{LF} = 0$ $p_\ell^{LF} = 0$	$p_w^* = \frac{9c(10\delta-9c)}{25\delta} = 2 \cdot p_\ell^*$ $p_\ell^* = \frac{9c(10\delta-9c)}{50\delta}$	$p_w^{CS} = \frac{9c(2\delta-3c)}{5\delta}$ $p_\ell^{CS} = \frac{9c(2\delta-3c)}{10\delta}$
$x_1^{LF} = x_2^{LF} = 0$ $\epsilon^{LF} = 1$	$E[x_1]^* = E[x_2]^* = \frac{9}{100}(10 - \frac{9c}{\delta})$ $E[x_w \vert x_w > x_\ell]^* = \frac{6}{5} - \frac{27c}{25\delta}$ $E[x_\ell \vert x_\ell < x_w]^* = \frac{3}{5} - \frac{27c}{50\delta}$ $\epsilon^* = \left(\frac{9c}{10\delta}\right)^2$	$E[x_1]^{CS} = E[x_2]^{CS} = \frac{9}{20}(2 - \frac{3c}{\delta})$ $E[x_w \vert x_w > x_\ell]^{CS} = \frac{6}{5} - \frac{9c}{5\delta}$ $E[x_\ell \vert x_\ell < x_w]^{CS} = \frac{3}{5} - \frac{9c}{10\delta}$ $\epsilon^{CS} = \left(\frac{3c}{2\delta}\right)^2$
$CS^{LF} = r - \delta$ $PS^{LF} = 0$ $W^{LF} = r - \delta$	$CS^* = r - 3c + \frac{189c^2}{100\delta}$ $PS^* = \frac{3c(10\delta-9c)}{25\delta}$ $W^* = r - \frac{9c}{5} + \frac{81c^2}{100\delta}$	$CS^{CS} = r - 3c + \frac{9c^2}{4\delta}$ $PS^{CS} = \frac{3}{2}c(2 - \frac{3c}{\delta})$ $W^{CS} = r + \frac{9c(c-4\delta)}{20\delta}$

contest maximizes total welfare and entails product differentiation, both total surplus (as the sum of producer surplus and consumer surplus) and producer surplus are always larger in the APA-equilibrium than in the LF-equilibrium. For consumers, however, the contest has two opposing effects: While they profit from a reduction of the environmental damage, they suffer from higher prices due to differentiated goods. Using Table 1, we find that the environmental contest increases net consumer surplus if and only if the marginal investment costs c are sufficiently low compared to the strength of the environmental damage δ:[11]

$$\Delta CS = CS^* - CS^{LF} = \frac{(9c - 10\delta)(21c - 10\delta)}{100\delta} > 0 \quad \Leftrightarrow \quad 0 < c/\delta < \frac{10}{21}. \tag{5}$$

Otherwise, the welfare maximizing contest is detrimental to consumers. This leads to the following Proposition.

Proposition 2. *On a covered market, implementing the welfare maximizing environmental all-pay auction contest increases net consumer surplus if and only if the marginal investment costs c are sufficiently low compared to the strength of the environmental damage δ, i.e., for* $0 < c/\delta < 10/21$.

If instead marginal investment costs are high and the externality is weak, the contest will lead to a sharp increase in prices but only a small reduction of the environmental damage so that it will harm consumers. Figure 1 illustrates the results.

4.4.2 Maximization of net consumer surplus

If the regulator maximizes consumer surplus instead of total welfare, he will face a slightly different trade-off. On the one hand, he still takes into account that the award stimulates

[11] Further calculations show that consumers profit from the contest even more than producers if and only if the marginal investment costs c are sufficiently low compared to the strength of the environmental damage δ:

$$\Delta CS - \Delta PS = \frac{(9c - 10\delta)(33c - 10\delta)}{100\delta} > 0 \quad \Leftrightarrow \quad 0 < c/\delta < \frac{10}{33}.$$

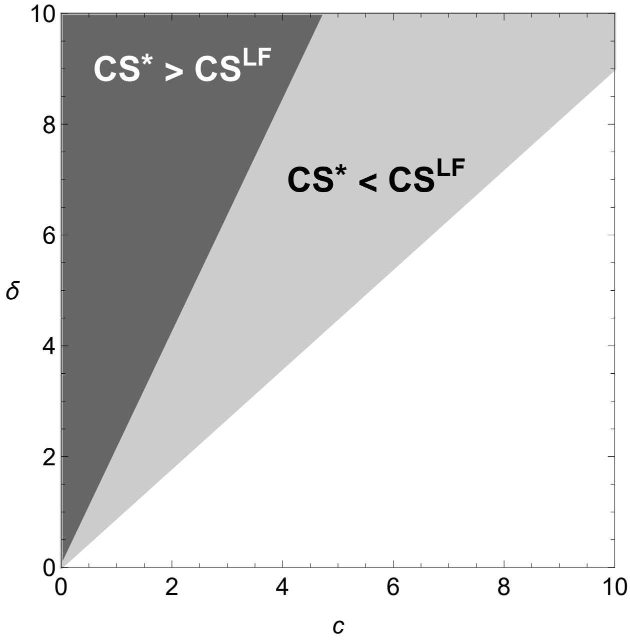


Figure 1: Consumer surplus dependent on marginal green investment cost c and marginal damages δ in a covered market. In the dark gray area, implementing the welfare maximizing all-pay auction contest yields higher consumer surplus, compared to the laissez-faire outcome. In the light gray area, implementing the laissez-faire equilibrium yields higher consumer surplus, compared to the welfare maximizing all-pay auction contest. The white area represents the constraint $0 < c/\delta < 10/9$, where the welfare maximizing regulator does not implement the contest.

green investments and, thereby, reduces the environmental externality. On the other hand, he does no longer account for investment costs directly but only indirectly by means of their impact on consumer prices. The regulator thus trades off the reduction of the environmental damage against the negative effect of higher prices due to more pronounced product differentiation. More formally, using Lemmata 1 and 2, the regulator chooses the award μ_w in order to maximize net consumer surplus

$$\begin{aligned} CS = & \int_0^{\tilde{\theta}} (r - p_\ell)\, d\theta + \int_{\tilde{\theta}}^1 (r - p_w)\, d\theta \\ & - \delta \cdot (D_\ell \cdot (1 - E[x_\ell | x_\ell < x_w]) + D_w \cdot (1 - E[x_w | x_w > x_\ell]))^2 \\ = & \, r - \frac{5}{9}(\mu_w - \mu_\ell) - \delta \left(\frac{27c - 5(\mu_w - \mu_\ell)}{27c} \right)^2 . \end{aligned}$$

We use the first order condition $dCS/d\mu_w = 0$ to compute the equilibrium value $\mu_w^{CS} = \mu_\ell + (27c(2\delta - 3c))/(10\delta)$. It satisfies the constraint $\mu_w^{CS} > \mu_\ell$ if and only if $0 < c/\delta < 2/3$. Again, it is optimal for the regulator to implement the environmental contest if and only if the marginal investment costs are sufficiently low compared to the strength of the environmental externality. However, now the threshold is lower than for the welfare maximizing contest. Comparative statics results are analogous to the case of a welfare maximizing regulator. Proposition 3 summarizes the results.

Proposition 3. *On a covered market, a regulator who maximizes net consumer surplus implements an environmental all-pay auction contest if and only if the marginal* *investment costs are sufficiently low compared to the strength of the environmental externality:* $0 < c/\delta < 2/3$. *In this case, the optimal environmental award equals* $\mu_w^{CS} = \mu_\ell + (27c(2\delta - 3c))/(10\delta)$, *with* $d\mu_w^{CS}/d\delta > 0$, *and* $d\mu_w^{CS}/dc > 0$ *if and only if* $0 < c/\delta < 1/3$.

Based on the results of Lemmata 1 and 2 and Proposition 3, the third column of Table 1 summarizes the equilibrium values of the respective variables if $0 < c/\delta < 2/3$; otherwise, the regulator does not implement the contest ($\mu_w^{CS} = \mu_\ell$) and the first column applies.

4.4.3 Comparison

We now compare the APA-contests that maximize total welfare and net consumer surplus, respectively. By definition, the consumer surplus maximizing contest generates the highest level of consumer surplus, while the welfare maximizing contest generates the highest level of total surplus. Remember that the contest gives rise to product differentiation and, thereby, shifts rents from consumers to producers – all the more the larger the award. In the range where both contests are implemented, i.e., for $0 < c/\delta < 2/3$, we thus observe that the consumer surplus maximizing regulator chooses a lower environmental award ($\mu_w^{CS} < \mu_w^*$): Products are less differentiated, and firms have less market power, set lower market prices ($p_i^{CS} < p_i^*$), and make fewer profits ($PS^{CS} < PS^*$). On the other hand, this implies also weaker incentives for green investments ($\sum_{i=1}^2 E[x_i]^{CS} < \sum_{i=1}^2 E[x_i]^*$) and, thus, stronger environmental externalities ($\epsilon^{CS} > \epsilon^*$). Proposition 4 summarizes the results.

Proposition 4. *Compared to a welfare maximizing regulator, a regulator who maximizes net consumer surplus chooses a (weakly) lower environmental award,* $\mu_w^{CS} \leq \mu_w^*$, *thereby accepting a (weakly) higher environmental damage. The inequality is strict whenever the welfare maximizing regulator implements the contest, i.e., for* $0 < c/\delta < 10/9$.

5 Discussion

In this section, we discuss the robustness of our findings considering several variations of our model. In particular, we formally prove below that the main results will qualitatively hold if the market is not fully covered or if the regulator uses a different design for the environmental contest. Aside from that, we would like to mention that the same is true for different forms of competition. If firms compete in quantities (à la Cournot or Stackelberg) instead of prices (à la Bertrand), however, the effects will be less pronounced: As firms already have some market power in the laissez-faire equilibrium without the environmental contest, i.e., with homogeneous products, they have weaker incentives to gain additional market power by differentiating their products via green investments in the presence of the contest.

5.1 Uncovered market

In the laissez-faire economy, the market is covered for all non-negative reservation prices, $r \geq p = 0$. By contrast, in presence of the environmental contest, the market will only be covered if even the consumer with the lowest valuation for environmental quality ($\theta = 0$) buys the product at the loser's equilibrium price $p_\ell > 0$, i.e., if the reservation price is sufficiently large. We now consider the case in which this condition is violated and the regulated market is not fully covered. For the sake of concreteness, we restrict the following analysis to a welfare maximizing regulator. An uncovered market thus arises if $r < p_\ell^* = (9c(10\delta - 9c))/(50\delta)$.

5.1.1 *Stage 3: Price game*

In the third stage of the game, the awarded firm, w, and the non-awarded firm, ℓ, simultaneously choose their prices p_w and p_ℓ. Now, under the assumption of an uncovered market, we have two margins: Consumers decide whether to buy the good produced by the firm having won the contest with perceived environmental quality μ_w or to buy the good produced by the firm having lost the contest with perceived environmental quality μ_ℓ or not to buy the good at all. As before, the marginal consumer being indifferent between the two quality levels is thus defined by $\overline{\theta} \equiv (p_w - p_\ell)/(\mu_w - \mu_\ell)$. Similarly, the marginal consumer being indifferent between not buying and buying the good of perceived environmental quality μ_ℓ is described by $\underline{\theta} \equiv (p_\ell - r)/\mu_\ell$.

Accordingly, firms' demand functions are $D_w = 1 - \overline{\theta}$ and $D_\ell = \overline{\theta} - \underline{\theta}$, where $\underline{\theta}$ is the share of consumers not buying. Firm $i \in \{\ell, w\}$ thus chooses the price p_i in order to maximize its profit $\pi_i = p_i \cdot D_i$. We derive the firms' best response functions from the first-order conditions for solutions of these maximization problems and use them to compute the equilibrium. Lemma 3 summarizes the results.

Lemma 3. *Assume that the market is uncovered. Denote by w (ℓ) the firm that wins (loses) the contest and offers the perceived environmental quality μ_w (μ_ℓ). Then, third-stage equilibrium prices, market shares, and profits are* $p_w^* = ((\mu_w - \mu_\ell)(r + 2\mu_w))/(4\mu_w - \mu_\ell)$, $p_\ell^* = ((\mu_w - \mu_\ell)(2r + \mu_\ell))/(4\mu_w - \mu_\ell))$, $D_w^* = (r + 2\mu_w)/(4\mu_w - \mu_\ell)$, $D_\ell^* = (\mu_w(2r + \mu_\ell))/(4\mu_w - \mu_\ell)$, $\pi_w^* = ((\mu_w - \mu_\ell)(r + 2\mu_w)^2)/(4\mu_w - \mu_\ell)^2$, *and* $\pi_\ell^* = (\mu_w(\mu_w - \mu_\ell)(2r + \mu_\ell)^2)/(\mu_\ell(4\mu_w - \mu_\ell)^2)$.

Lemma 3 shows that the difference in prices and profits is even higher in the uncovered market than in the covered market.

5.1.2 *Stage 2: Investment game*

In the second stage, the firms anticipate these profits and decide simultaneously on their green investments x_i, $i \in \{1, 2\}$, which determine their success in the environmental contest. As above, the unique Nash-equilibrium is in mixed strategies and can be derived form the property that the mixed strategy of Firm j must leave Firm i indifferent between all its pure strategies (played with positive density), where $i, j \in \{1, 2\}$ and $i \neq j$. This implies, again, that Firm i's expected profit from choosing any investment level $x_i > 0$ (with positive density) equals the expected profit from choosing an investment level of $x_i = 0$ and losing the contest almost surely:

$$E[\pi_i] = \pi_w \cdot F_j(x_i) + \pi_\ell \cdot (1 - F_j(x_i)) - cx_i = \pi_\ell$$

for $i, j \in \{1, 2\}$ and $i \neq j$. In combination with Lemma 3, this yields

$$F_i^*(x_i) = \frac{cx_i}{\pi_w - \pi_\ell} = cx_i \frac{\mu_\ell(4\mu_w - \mu_\ell)}{(\mu_w - \mu_\ell)(\mu_\ell\mu_w - r^2)}$$

as the mixed equilibrium strategy of Firm $i \in \{1, 2\}$. Lemma 4 summarizes the results.

Lemma 4. *Assume that the market is uncovered and the environmental contest is organized as an all-pay auction with award $\mu_w > \mu_\ell$. In the second-stage equilibrium, firm $i \in \{1, 2\}$ makes an expected green investment of*

$$E[x_i] = (\pi_w - \pi_\ell)/(2c) = \frac{1}{2c}\frac{(\mu_w - \mu_\ell)(\mu_\ell\mu_w - r^2)}{\mu_\ell(4\mu_w - \mu_\ell)}$$

and has a winning probability of $\alpha_i = 1/2$. Moreover, conditional on the outcome of the contest, the expected green investment of the winner and loser, respectively, are

$$E[x_w|x_w > x_\ell] = 2 \cdot \frac{(\mu_w - \mu_\ell)(\mu_\ell\mu_w - r^2)}{3c\mu_\ell(4\mu_w - \mu_\ell)}, \tag{6}$$

$$E[x_\ell|x_\ell < x_w] = \frac{(\mu_w - \mu_\ell)(\mu_\ell\mu_w - r^2)}{3c\mu_\ell(4\mu_w - \mu_\ell)}. \tag{7}$$

5.1.3 Stage 1: Setting the environmental award

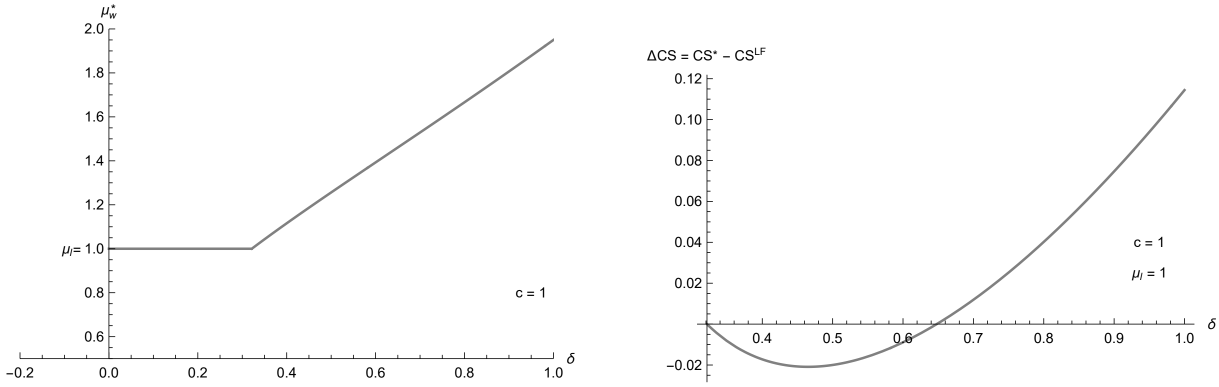
In the first stage, the regulator sets the level of the environmental award μ_w in order to maximize total welfare, which we compute based on Lemmata 3 and 4:

$$\begin{aligned} W &= p_\ell \cdot D_\ell + p_w \cdot D_w - c \cdot (E[x_\ell|x_\ell < x_w] + E[x_w|x_w > x_\ell]) \\ &\quad + \int_{\underline{\theta}}^{\overline{\theta}} (r - p_\ell)\, d\theta + \int_{\overline{\theta}}^{1} (r - p_w)\, d\theta \\ &\quad - \delta \cdot (D_\ell \cdot (1 - E[x_\ell|x_\ell < x_w]) + D_w \cdot (1 - E[x_w|x_w > x_\ell]))^2 \\ &= \frac{\mu_w(\mu_\ell^2 - \mu_w\mu_\ell + 3r\mu_\ell + 3r^2)}{\mu_\ell(4\mu_w - \mu_\ell)} \\ &\quad - \delta\big\{(\mu_\ell - \mu_w)[5\mu_\ell\mu_w + 2r(\mu_\ell + \mu_w)](\mu_\ell\mu_w - r^2) \\ &\quad + 3c\mu_\ell(4\mu_w - \mu_\ell)[2r\mu_w + \mu_\ell(3\mu_w + r)]\big\}^2 \cdot \frac{1}{9c^2\mu_\ell^4(4\mu_w - \mu_\ell)^4}. \end{aligned} \tag{8}$$

If the market is not covered, increasing prices will not only shift surplus from consumers to producers, but also reduce aggregate demand. Thus, when choosing the award μ_w to promote environmental investments, the welfare maximizing regulator not only faces a trade-off between investment costs on the one hand and greener production on the other. The regulator also accounts for two opposing effects that stem from the reduced market volume: While a lower production level leads to a lower aggregate level of the environmental externality, lower market coverage reduces the aggregate utility of consumers.

Based on the first-order condition $dW/d\mu_w = 0$, we use numerical methods of the software *Mathematica* to exemplarily compute the equilibrium value μ_w^* for the (corner) case of $r = 0$,[12] fixed investment costs $c = 1$, fixed standard quality $\mu_\ell = 1$, and different values of the strength of the externality δ. As Figure 2 illustrates, the main results of the covered market model also hold for the uncovered market: If the ratio c/δ is less

[12]Notice that for $r = 0$ the lower market coverage does not reduce the aggregate utility of consumers because, then, consumer surplus net of environmental concerns is zero even in the laissez-faire benchmark. Here, we show that even in this case where the environmental contest does not cause additional harm to consumers due to lower consumption, a welfare maximizing environmental contest may still reduce consumer surplus.



(a) (b)

Figure 2: Uncovered market: *(a)* The optimal level of the environmental award as a function of marginal environmental damage δ. *(b)* Difference in consumer surplus between a contest-designed (all-pay auction) equilibrium and a laissez-faire equilibrium.

than a first threshold (that is, here, $\delta > 9/28$), the regulator implements the contest, cf. Proposition 1 and Figure 2(a); but as long as that ratio is not less than a second threshold (that is, here, δ is not greater than about 0.648), the implementation of the contest is detrimental to consumers, cf. Proposition 2 and Figure 2(b).

5.2 A welfare maximizing lottery contest

In the baseline model of Section 4, the environmental contest is organized as an all-pay auction. The deterministic all-pay auction is fully discriminatory in the sense that the contestant with the highest investment wins for sure. It is well known that, in symmetric settings like ours, the all-pay auction is the contest success function that provokes the highest possible investments, which is desirable in our context for an effective reduction of the environmental externality. The assumption that the regulator can perfectly observe firms' investments and fully discriminate when assigning the environmental award may, however, not always be fulfilled in practice.

In this section, we consider an environmental contest organized as a lottery contest. Being based on a random success function, the lottery contest incorporates some noise: A contestant's winning probability is given by the ratio between her own investment and the aggregate investments of all contestants. Thus, the player with the higher investment is more likely to succeed but does not win for sure. Assuming a covered market and a welfare maximizing regulator, we replicate the analysis of Section 4 for this alternative contest success function and compare the results.

5.2.1 Stage 3: Price game

In the third stage, firms face the same pricing game as described in section 4.2. Lemma 1 describes market prices, profits, and the respective demand levels.

5.2.2 Stage 2: Investment game

In the second stage, firms choose the amount of green investments x_i. For $i, j \in \{1, 2\}$, $i \neq j$, firm i's probability of winning the environmental award is given by the lottery contest success function[13]

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

Hence, firm $i \in \{1, 2\}$, $i \neq j$, chooses x_i in order to maximize the expected profit

$$E[\pi_i] = p_w \cdot D_w \cdot \frac{x_i}{x_i + x_j} + p_\ell \cdot D_\ell \cdot \left(1 - \frac{x_i}{x_i + x_j}\right) - cx_i.$$

We use the first order conditions $dE[\pi_i]/dx_i$ to compute the equilibrium investment levels, when applying a lottery contest, indexed L:

$$x_1^L = x_2^L = \frac{\mu_w - \mu_\ell}{12c}. \tag{9}$$

5.2.3 Stage 1: Setting the environmental award

In the first stage, the regulator sets the award μ_w in order to maximize total welfare

$$\begin{aligned} W^L &= p_\ell \cdot D_\ell + p_w \cdot D_w - c \cdot \left(x_\ell^L + x_w^L\right) \\ &\quad + \int_0^{\tilde{\theta}} (r - p_\ell)\, d\theta + \int_{\tilde{\theta}}^1 (r - p_w)\, d\theta - \delta \cdot \left(D_\ell(1 - x_\ell^L) + D_w(1 - x_w^L)\right)^2 \\ &= r - \frac{1}{6}(\mu_w - \mu_\ell) - \delta \left(\frac{12c + \mu_\ell - \mu_w}{12c}\right)^2. \end{aligned} \tag{10}$$

We use the first order condition $dW^L/d\mu_w$ to compute the optimal level of the environmental award

$$\mu_w^L = \mu_\ell + \frac{12c(\delta - c)}{\delta}. \tag{11}$$

It satisfies the constraint $\mu_w^L > \mu_\ell$ if and only if $0 < c/\delta < 1$. As for the all-pay auction, it is optimal for the regulator to implement the lottery contest if and only if the marginal investment costs are sufficiently low compared to the strength of the environmental externality. The condition is, however, somewhat stricter. Comparative statics results are analog to the case of the all-pay auction as well. Therefore, qualitatively, the results of Proposition 1 apply. Based on Lemma 1 and Equations (9) and (11), Table 2 summarizes the equilibrium values of the respective variables if $0 < c/\delta < 1$; otherwise, the regulator does not implement the lottery contest ($\mu_w^L = \mu_\ell$) and the laissez-faire results apply (see first column of Table 1).

5.2.4 Lottery contest vs. all-pay auction

As a reference for comparison we use the equilibrium outcomes of the welfare maximizing all-pay auction design (see second column of Table 2). We find that, throughout, the all-pay auction is a more effective instrument than the lottery contest in the sense that it

[13] Skaperdas (1996) provides an axiomatic foundation.

Table 2: Equilibrium outcomes of a welfare maximizing lottery contest (L) for $0 < c/\delta < 1$ and a welfare maximizing all-pay auction contest (*) for $0 < c/\delta < 10/9$.

Welfare maximizing lottery contest	Welfare maximizing APA
$\mu_w^L = \mu_\ell + \frac{12c(\delta-c)}{\delta}$	$\mu_w^* = \mu_\ell + \frac{27c(10\delta-9c)}{50\delta}$
$p_w^L = \frac{8c(\delta-c)}{\delta}$ $p_\ell^L = \frac{4c(\delta-c)}{\delta}$	$p_w^* = \frac{9c(10\delta-9c)}{25\delta}$ $p_\ell^* = \frac{9c(10\delta-9c)}{50\delta}$
$x_1^L = x_2^L = 1 - \frac{c}{\delta}$ $\epsilon^L = \left(\frac{c}{\delta}\right)^2$	$E[x_1]^* = E[x_2]^* = \frac{9}{100}(10 - \frac{9c}{\delta})$ $E[x_w \mid x_w > x_\ell]^* = \frac{6}{5} - \frac{27c}{25\delta}$ $E[x_\ell \mid x_\ell < x_w]^* = \frac{3}{5} - \frac{27c}{50\delta}$ $\epsilon^* = \left(\frac{9c}{10\delta}\right)^2$
$CS^L = r - \frac{20c}{3} + \frac{17c^2}{3\delta}$ $PS^L = \frac{14c(\delta-c)}{3\delta}$ $W^L = r - 2c + \frac{c^2}{\delta}$	$CS^* = r - 3c + \frac{189c^2}{100\delta}$ $PS^* = \frac{3c(10\delta-9c)}{25\delta}$ $W^* = r - \frac{9c}{5} + \frac{81c^2}{100\delta}$

leads to both, higher welfare and lower environmental damage. Proposition 5 summarizes the results.

Proposition 5. *Comparing the welfare maximizing all-pay auction and the welfare maximizing lottery contest for $0 < c/\delta < 1$ in a covered market, the all-pay auction induces*

(i) higher social welfare ($W^* > W^L$),

(ii) lower environmental damage ($\epsilon^* < \epsilon^L$).

Moreover, if the marginal investment costs are sufficiently low compared to the strength of the environmental externality, i.e., if $0 < c/\delta < \frac{110}{119}$, the all-pay auction involves

(iii) a lower environmental award ($\mu_w^* < \mu_w^L$),

(iv) lower prices ($p_i^* < p_i^L$),

(v) higher consumer surplus ($CS^* > CS^L$), but lower producer surplus ($PS^* < PS^L$).

Intuitively, as the all-pay auction is more competitive than the lottery contest, the regulator can induce the same level of aggregate green investments as in the optimal lottery contest using a lower award. This, in turn, results in a lower degree of vertical product differentiation and, hence, in lower market prices, in higher consumer surplus, but lower producer surplus when applying the all-pay auction design. While both firms choose the same (pure strategy) level of green investments in the lottery contest, the expected (mixed strategy) investment of the winning firm is larger than the expected (mixed strategy) investment of the losing firm in the all-pay auction. Since the winner of the contest has a higher market share, the same aggregate green investments reduce the expected environmental damage more effectively and, thus, increase the expected welfare more effectively if the regulator uses an all-pay auction instead of a lottery contest. A fortiori, the superiority of the all-pay auction will hold if the respective award is chosen optimally rather than for inducing the same level of aggregate green investments as in the optimal lottery contest.[14] Figure 3 illustrates the results regarding consumer surplus.

[14]More generally, in the class of Tullock contests (Tullock, 1980), the all-pay auction constitutes an upper bound for environmental effectiveness. Notice that the standard Tullock contest with the contest success function $\alpha_i(x_1, ..., x_n) = \frac{x_i^r}{\sum_{j=1}^n x_j^r}$ converges to an all-pay auction as $r \to \infty$ (Ewerhart, 2017).

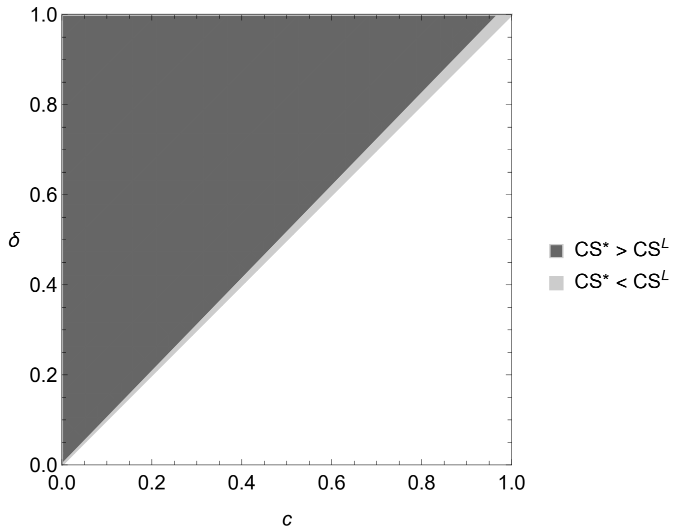


Figure 3: Consumer surplus dependent on marginal green investment cost c and marginal damages δ in a covered market. In the dark gray area, implementing the welfare maximizing all-pay auction contest yields higher consumer surplus, compared to the lottery contest. In the light gray area, implementing the welfare maximizing lottery contest yields higher consumer surplus, compared to the all-pay auction. The white area represents the constraint $0 < c/\delta < 1$.

6 Conclusion

Beyond well-known policy instruments such as green subsidies, emission trading, or taxation, this paper has studied an environmental contest, issuing an environmental award, as an alternative measure to control greenhouse gas emissions. An advantage of an environmental contest is that firms have an incentive to participate voluntarily. The presence of an award allows firms to differentiate their products and increase their profits. This holds irrespective of whether or not a firm ends up winning the environmental award. Furthermore, firms do not have to disclose confidential data to implement the mechanism. Only the documentation of firms' green investments is required.

In particular, we have investigated the impact of an environmental award in a Bertrand duopoly with green consumers considering a three-stage game. First, the regulator designs the environmental contest. Second, firms choose their green investments, and the winner of the contest is awarded. Third, firms compete in prices, and consumption takes place. We have illustrated that the award not only incentivizes green investments and thus reduces environmental externalities. As consumers perceive the product of the awarded firm to be of superior quality, it also gives rise to vertical product differentiation. This induces market power, and thus anti-competitive effects: Rents shift from consumers to producers, and consumer surplus may decrease, particularly if marginal investment costs in green technologies are high. In search of a suitable instrument, a policy maker has to confront these potential drawbacks of an environmental contest with its aforementioned advantages.

Our paper provides first insights into the mechanics of an environmental contest. We have shown that our main results are robust to variations of market demand (covered vs. uncovered market) and contest technologies (all-pay auction vs. lottery contest). To generalize the results even further, it may be worthwhile to extend the model to more than two firms and possibly several awards.[15] Further possible extensions include dynamic structures such as sequential decisions or additional periods. In a related working paper, Heidelmeier and Schmitt (2025) compare green investment incentives and welfare effects of an environmental contest with those of eco-labeling.

References

Amacher, G. S., Koskela, E., and Ollikainen, M. (2004). Environmental quality competition and eco-labeling. *Journal of Environmental Economics and Management*, 47(2):284–306.

Ansink, E. and Weikard, H.-P. (2025). Agreeing on public goods or bads. *Journal of Environmental Economics and Management*, page 103123.

Baye, M. R., Kovenock, D., and De Vries, C. G. (1996). The all-pay auction with complete information. *Economic Theory*, 8:291–305.

Ben Youssef, A. and Lahmandi-Ayed, R. (2008). Eco-labelling, Competition and Environment: Endogenization of Labelling Criteria. *Environmental and Resource Economics*, 41:133–154.

Berger, J. (2019). Signaling can increase consumers' willingness to pay for green products. Theoretical model and experimental evidence. *Journal of Consumer Behaviour*, 18(3):233–246.

Bordalo, P., Gennaioli, N., and Shleifer, A. (2016). Competition for Attention. *The Review of Economic Studies*, 83(2):481–513.

Bos, O., Roussillon, B., and Schweinzer, P. (2016). Agreeing on Efficient Emissions Reduction. *The Scandinavian Journal of Economics*, 118(4):785–815.

Brécard, D. (2017). Consumer misperception of eco-labels, green market structure and welfare. *Journal of Regulatory Economics*, 51(3):340–364.

Carroni, E., Mantovani, A., and Minniti, A. (2023). Price signaling with salient-thinking consumers. *Games and Economic Behavior*, 138:238–253.

Dijkstra, B. R. (2007). An investment contest to influence environmental policy. *Resource and Energy Economics*, 29(4):300–324.

Eliaz, K. and Spiegler, R. (2011). On the strategic use of attention grabbers. *Theoretical Economics*, 6(1):127–155.

European Commission—Directorate-General for Communication. (2024). Attitudes of Europeans towards the environment. *Eurobarometer Report*. `https://europa.eu/eurobarometer/surveys/detail/3173`. Accessed: 2024-10-10.

Ewerhart, C. (2017). Revenue ranking of optimally biased contests: The case of two players. *Economics Letters*, 157:167–170.

[15]Notice, however, that only a limited number of firms can be active in a vertically differentiated quality model (Gabszewicz and Thisse, 1980).

Fischer, C. and Lyon, T. P. (2019). A Theory of Multitier Ecolabel Competition. *Journal of the Association of Environmental and Resource Economists*, 6(3):461–501.

Gabszewicz, J. J. and Thisse, J.-F. (1980). Entry (and exit) in a differentiated industry. *Journal of Economic Theory*, 22(2):327–338.

Ghazzai, H. and Lahmandi-Ayed, R. (2021). Ecolabel: Is More Information Better? *Environmental Modeling & Assessment*, 27:505–524.

Giebe, T. and Schweinzer, P. (2014). Consuming your way to efficiency: Public goods provision through non-distortionary tax lotteries. *European Journal of Political Economy*, 36:1–12.

Gomes, S., Lopes, J. M., and Nogueira, S. (2023). Willingness to pay more for green products: A critical challenge for Gen Z. *Journal of Cleaner Production*, 390:136092.

Hefti, A. and Liu, S. (2020). Targeted information and limited attention. *The RAND Journal of Economics*, 51(2):402–420.

Heidelmeier, L. and Schmitt, S. Y. (2025). Awards vs. Labels: Incentivizing Investments in Environmental Quality. *BERG Working Paper*, no. 206.

Heyes, A., Kapur, S., Kennedy, P. W., Martin, S., and Maxwell, J. W. (2020). But What Does It Mean? Competition between Products Carrying Alternative Green Labels When Consumers Are Active Acquirers of Information. *Journal of the Association of Environmental and Resource Economists*, 7(2):243–277.

Heyes, A. G. (1997). Environmental Regulation by Private Contest. *Journal of Public Economics*, 63(3):407–428.

Hulshof, D. and Mulder, M. (2020). Willingness to Pay for CO 2 Emission Reductions in Passenger Car Transport. *Environmental and Resource Economics*, 75(4):899–929.

Ibanez, L. and Grolleau, G. (2008). Can Ecolabeling Schemes Preserve the Environment? *Environmental and Resource Economics*, 40(2):233–249.

IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegria, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., `https://doi.org/10.1017/9781009325844`.

Kolmar, M. and Sisak, D. (2014). (In) efficient public-goods provision through contests. *Social Choice and Welfare*, 43:239–259.

Konrad, K. A. (2009). *Strategy and Dynamics in Contests*. Oxford University Press.

Kuhn, K.-U. and Uler, N. (2019). Behavioral sources of the demand for carbon offsets: An experimental study. *Experimental Economics*, 22:676–704.

Lai, H., Wang, F., and Guo, C. (2022). Can environmental awards stimulate corporate green technology innovation? Evidence from Chinese listed companies. *Environmental Science and Pollution Research*, 29(10):14856–14870.

Li, Y., Chen, J., Li, L., and Huang, X. (2024). Government innovation awards, innovation funds acquisition and enterprise innovation. *Economic Analysis and Policy*, 82:846–864.

Li, Y. and van't Veld, K. (2015). Green, greener, greenest: Eco-label gradation and competition. *Journal of Environmental Economics and Management*, 72:164–176.

Liston-Heyes, C. (2001). Setting the Stakes in Environmental Contests. *Journal of Environmental Economics and Management*, 41(1):1–12.

MacKenzie, I. A., Hanley, N., and Kornienko, T. (2009). Using contests to allocate pollution rights. *Energy Policy*, 37(7):2798–2806.

Morgan, J. (2000). Financing Public Goods by Means of Lotteries. *The Review of Economic Studies*, 67(4):761–784.

Motta, M. (1993). Endogenous Quality Choice: Price vs. Quantity Competition. *The Journal of Industrial Economics*, pages 113–131.

Mussa, M. and Rosen, S. (1978). Monopoly and Product Quality. *Journal of Economic Theory*, 18(2):301–317.

OECD (2017). Investing in Climate, Investing in Growth. A synthesis. *OECD Publishing, Paris.*
`https://doi.org/10.1787/9789264273528-en`. Accessed: 2025-04-03.

Osorio, A. and Zhang, M. (2022a). Incentivizing environmental investments: The contest-based subsidy allocation mechanism. *Journal of Cleaner Production*, 380:135132.

Osorio, A. and Zhang, M. (2022b). Using contests to design emission tax mechanisms. *Sustainable Production and Consumption*, 31:762–776.

Peitz, M. (1995). Utility maximization in models of discrete choice. *Economics Letters*, 49(1):91–94.

Ruggeri, G., Mazzocchi, C., Bergamelli, C., and Tosca, A. (2024). Plant the pot! Understanding consumer willingness to pay for sustainability in garden shop products. *Journal of Cleaner Production*, 477:143855.

Shaked, A. and Sutton, J. (1982). Relaxing Price Competition Through Product Differentiation. *The Review of Economic Studies*, pages 3–13.

Skaperdas, S. (1996). Contest success functions. *Economic Theory*, 7(2):283–290.

Tullock, G. (1980). Efficient rent-seeking. In Buchanan, J. M., Tollison, R. D., and Tullock, G., editors, *Toward a Theory of the Rent-Seeking Society*, pages 97–112. Texas A & M University, College Station.

van't Veld, K. (2020). Eco-Labels: Modeling the Consumer Side. *Annual Review of Resource Economics*, 12(1):187–207.

Ward, D. O., Clark, C. D., Jensen, K. L., and Yen, S. T. (2011). Consumer willingness to pay for appliances produced by Green Power Partners. *Energy Economics*, 33(6):1095–1102.

Yokessa, M. and Marette, S. (2019). A Review of Eco-labels and their Economic Impact. *International Review of Environmental and Resource Economics*, 13(1-2):119–163.

BERG Working Paper Series (most recent publications)

190 Roberto **Rozzi** and Stefanie Y. **Schmitt**, *Vertical product differentiation, prominence, and costly search*

191 Florian **Herold** and Christoph **Kuzmics**, *Farkas' Lemma and Complete Indifference*

192 Sarah **Mignot**, Paolo **Pellizzari**, and Frank **Westerhoff**, *Fake News and Asset Price Dynamics*

193 Fabian **Dietz** and Marco **Sahm**, *Fairness in Round-Robin Tournaments with Four Players and Endogenous Sequences*

194 Jan **Schulz**, Caleb **Agoha**, Anna **Gebhard**, Bettina **Gregg** and Daniel M. **Mayerhoffer**, *Excessive White Male Privilege Biases the Measurement of Intersectional Wage Discrimination*

195 Leonhard **Ipsen** and Jan **Schulz**, *The (Dis-)Equalizing Effects of Production Networks*

196 Ivan **Savin**, Philipp **Mundt** and Margherita **Bellanca**, *The paradox of climate policy diffusion*

197 Dominik **Bruckner** and Marco **Sahm**, *Party Politics: A Contest Perspective*

198 Lasare **Samartzidis**, Philipp **Mundt** and Jan **Schulz**, *Input specificity and labor's bargaining power: A production tree approach to functional income distribution*

199 Maybrit **Wächter**, Christian R. **Proaño**, and Juan Carlos **Peña**, *How Fitting is "one-size-fits-all"? Revisiting the Dynamic Effects of ECB's Interest Policy on Euro Area Countries*

200 Sarah **Mignot**, *Coevolution of stock prices and their perceived fundamental value*

201 Arne **Lauber**, Christoph **March** and Marco **Sahm**, *Round-Robin Tournaments in the Lab: Lottery Contests vs. All-Pay Auctions*

202 Stefanie Y. **Schmitt**, *Investments in environmental quality under limited attention*

203 Jan **Schulz** and Jan David **Weber**, *Power Laws in Socio-Economics*

204 Rafael **Kothe**, *Connecting the Dots: How Social Networks Shape Expectations Through Economic Narratives*

205 Jan **Schulz** and Leonhard **Ipsen**, *Poor Households and the Weight of Inflation*

206 Lisa **Heidelmeier** and Stefanie Y. **Schmitt**, *Awards vs. Labels: Incentivizing Investments in Environmental Quality*

207 Lisa **Heidelmeier** and Marco **Sahm**, *Environmental Awards in a Duopoly with Green Consumers*

Free access to all publications at: www.uni-bamberg.de/en/economics/research/wp/