Monopoly Screening of Environmentally Conscious Consumers with Voluntary Carbon Offsets

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Abstract

I characterize market equilibria in which the seller has access to an offsetting technology to mitigate the pollution generated by the consumption and production of the core product it sells. In contrast to an intrinsic environmental quality, offsets allow consumers to pay to reduce the pollution emitted by the core product sold to *other* consumers, independently of their own consumption. How a monopolistic seller employs these offsets in equilibrium depends on the nature of the environmental preferences of conscious consumers. Under responsibility-based preferences – where consumers care exclusively about the net pollution of their own consumption good – the seller maintains high demand and profits by offering no offsets to selfish consumers and full offsets for the pollution generated by the core product sold to environmentally conscious consumers. Because pollution from selfish consumers' consumption remains unmitigated, this market outcome is inefficient. A benevolent social planner corrects this inefficiency by setting a carbon tax, which works as a mandatory offset of emissions for all core products. In contrast, under outcome-based preferences – where consumers care about the total pollution emitted in the market – a seller benefits by adding cross-offsets to the bundle of the most environmentally concerned consumers which reduce the pollution emitted by the core products sold to selfish consumers. Only under outcome-based preferences can the market achieve net-zero pollution. Moreover, only under outcome-based preferences does an equilibrium exist in which the seller runs a dual business: selling the dirty core product to selfish consumers and only cross-offsets to the most environmentally concerned consumers.

1 Introduction

How can private firms and consumers contribute to the fight against global warming? Although economic theory has long advocated market-based policies to mitigate carbon emissions from the production and consumption of products, the implementation of carbon taxes (Pigou, 1920) or cap-and-trade mechanisms (Dales, 2002) remains slow (Bénabou and Tirole, 2010; Aghion et al., 2023).[1] Willing to incur private costs to reduce environmental harm, environmentally conscious consumers have the potential to fill the action gap left by lagging governance. On the supply side, sellers can exploit consumers' intrinsic motivation and benefit from vertically differentiating their products along the dimension of environmental quality (Mussa and Rosen, 1978). However, less attention has been given to how the integration of voluntary carbon offsets shapes product design and equilibria in consumer markets. The voluntary carbon market is projected to

[1] As of 2021, explicit carbon taxes exist in only 30 jurisdictions worldwide (Metcalf, 2021)

reach $100 billion by 2030 (Morgan Stanley, 2023), with firms increasingly offering bundles of products with offsets – such as in aviation (Berger et al., 2022) and online retail (Rodemeier, 2023).

There are reasons that speak in favour of firms purchasing carbon credits in Voluntary Carbon Markets (VCMs) on behalf of consumers. First, consumers have a preference for donations that mitigate negative externalities and hence contribute to the fight against global warming, and firms could act as an intermediary on behalf of consumers (Bénabou and Tirole, 2010). Second, firms have lower transaction costs. Firms are better informed than consumers the pollution of its business activities which they have to report regularly.[2] Moreover, consumers have inaccurate beliefs regarding the carbon footprint of their consumption and in general an inaccurate understanding how the VCM works (Imai et al., 2026; Rodemeier, 2023). In addition, some emissions are hard to abate, in which case it is best to compensate for them by purchasing carbon credits in the Voluntary Carbon Market (Calel et al., 2025; Panizza et al., 2026). Finally, it has been shown that moral values erode in markets, especially if consumers believe they can be easily replaced by others. By purchasing carbon offsets consumers can have an influence on the negative externality generated in consumer markets (Kaufmann et al., 2024; Abellán et al., 2026).

In this paper, I study the optimal product design of sellers who want to sell a core product and have access to the Voluntary Carbon Market. The difference to an intrinsic environmental quality is that voluntary carbon offsets can be sold to a consumer, but the retired carbon credits reduce the pollution emitted by core products sold to other consumers. How the availability of voluntary carbon offsets affects market outcomes depends crucially on how consumers perceive their responsibility for pollution. Consumers may care strictly about the emissions tied directly to their own consumption in which case they have an incentive to minimize the pollution associated to their consumption (Guias, 2026). Alternatively, they may be concerned with the total externality generated in the consumption market, regardless of who causes it.[3] Therefore, I study how optimal product-offset design is shaped by environmentally conscious consumers who have responsibility-based preferences as opposed to outcome-based preferences.

I study a monopolistic seller who wants to sell a core product and faces consumers who value the intrinsic quality of the core product and are heterogeneous in their distaste for the pollution emitted by the production of the consumption good. If the source of the distaste stems from responsibility-based preferences, I find that the seller maintains high demand by offering full carbon offsets to *all* environmentally concerned consumers but not to purely selfish consumers. Offering offsets is costly for the seller and selfish consumers are not willing to pay for them. This decision does not affect the demand of environmentally conscious consumers. Furthermore, offering carbon offsets is incentive-compatible only if they offset at least the pollution caused by the production of the product because an environmentally conscious consumer's willingness to pay for a core product with partial offsets is strictly below that of a selfish consumer. If a seller offered a menu option with partial offsets, purely selfish consumers would select into that option.

The optimal product design changes if the source of intrinsic motivation to reduce pollution is outcome-based. Then in the equilibrium with full market coverage the seller segments the market into three groups:

[2] In the European Union, firms are mandated to report the emissions caused by their business activity under the Corporate Sustainability Reporting Directive (CSRD — Directive (EU) 2022/2464). Moreover, many firms report their Scope 1, Scope 2, and Scope 3 emissions to the *Carbon Disclosure Project*, a not-for-profit organization. Investors, consumers and regulators use this data to verify the climate performance as well as public environmental claims made by firms (Panizza et al., 2026).

[3] The most important types of preferences that are concerned with final outcomes of others are altruism (Charness and Rabin, 2002) and inequity-aversion (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000).

purely selfish consumers again do not receive any carbon offsets. Consumers with low-to-moderate environmental concerns receive offsets that fully compensate for the pollution generated by their consumption. For consumers with the highest concerns the seller bundles the core product with offsets for the pollution of their own product *and* cross-offsets for the pollution generated by the core products of selfish consumers. To make this incentive-compatible, the seller needs to grant information rents to the most environmentally concerned consumers. Nevertheless, by offering an offset schedule that is strictly increasing in the environmental type, I show that the seller makes additional profits compared to segmenting the market into two groups. Crucially, however, the seller cannot extract this surplus if the highest environmental types care only about the pollution generated by their own consumption. Their willingness to pay for additional offsets beyond the carbon footprint is exactly 0. Moreover, I show that there exists an equilibrium in which the seller cannot profitably bundle the core product with offsets. However, she can profitably run a dual business model by offering the core product to the selfish fringe of consumers and pure offsets to the most concerned consumers about the environment. Under responsibility-based preferences, this type of corporate philanthropy does not exist because environmentally conscious consumers do not care about the emissions generated by the core products sold to selfish consumers.

Turning to the policy side, I show that a benevolent social planner who cares about consumer surplus, profits, and total pollution emitted in the market wants to offset aggregate pollution emitted in the market. Hence, the market outcome is inefficient when consumers exclusively care about the pollution emitted by their own product. When allowed to set a carbon tax, the social planner corrects for this inefficiency by setting it equal to the marginal social cost of pollution. In further research, I plan to extend the analysis to a duopolistic setting, studying how competition affects market outcomes when sellers compete with product lines consisting of a core product and carbon offsets.

By studying the market for voluntary carbon offsets, I abstract away from several issues that have affected the market for voluntary carbon offsets in recent years. On the one hand, it has been shown that many offset credits are of low quality (Panizza et al., 2026; Kim et al., 2025). Moreover, many of those carbon credits lack additionality because the financial investment is allocated to projects in which it is not pivotal for removing or reducing carbon emissions (Calel et al., 2025). On the other hand, there could be a potential moral hazard problem, if the carbon credits claimed by the seller are not verifiable. I abstract away from supply-side problems of the market for voluntary carbon offsets and focus on the demand side in consumer markets. For this purpose, I hold the quality of voluntary carbon offsets fixed and assume that the carbon credits retired by the seller are verifiable.[4] I then look how different types of consumer preferences regarding the negative externality shape the employment of voluntary carbon offsets in equilibrium.

This paper makes two key contributions: first, it shows that the nature of environmental preferences determines whether markets achieve social efficiency when using voluntary carbon offsets. Second, it provides a novel mechanism showing how voluntary carbon offsets can be leveraged by firms to internalize third-party externalities when consumers hold outcome-based environmental preferences. This paper proceeds as follows: section 2 presents the model set-up. Section 3 discusses the resulting market equilibria if environmentally conscious consumers have responsibility-based and outcome-based preferences. Section 4, which is work in progress, discusses welfare implications of the two resulting market equilibria. Section 5 concludes. Work in

[4]Panizza et al. (2026) discuss institutions such as the Carbon Disclosure Project (CDP) that promote transparency in the retired carbon credits by the firm, and can be leveraged by various stakeholders such as consumers or shareholders.

progress extends the setting to a duopoly by studying how competitive forces shape the use of carbon offsets in consumer markets.

Related Literature: A large literature studies green consumerism in markets focusing mostly on how firms want to differentiate their products in respond to environmental preferences. Green consumerism has been studied in horizontal models of differentiation (Eriksson, 2004; Conrad, 2005) as well as in vertical models of differentiation. The first group of models of vertical differentiation study uni-dimensional differentiation along the environmental quality (Moraga-González and Padrón-Fumero, 2002; Lombardini-Riipinen, 2005; Deltas et al., 2013). A second group studies a bi-dimensional vertical differentiation based on hedonic and environmental quality by assuming perfect correlation between the two (Mantovani et al., 2016). Burani and Mantovani (2020) study a duopoly between sellers of a brown and a green product, who differentiate their product along the dimension of hedonic quality or environmental quality when firms account for consumer selection into the rival's product. Instead, I study a vertical differentiation model on the carbon offset dimension which can be sold to one consumer but mitigate the pollution emitted by the goods sold to other consumers.

Theoretically, it has been studied how carbon offsets affect donations in public good games (Vicary, 2000; Kotchen, 2009). However, they have not been studied as a screening tool by sellers in consumer markets.

2 Model Setup

I study a market served by a monopolistic firm offering a core product of normalized hedonic quality $q = 1$ to a continuum of consumers. Moreover, I normalize the marginal cost of the core product to 0. Each consumer has unit demand for the core product. The production of one unit of the core product generates a deterministic amount of carbon emissions $e > 0$, and the constant marginal cost of production is normalized to 0. The seller has access to reparation technology that allows bundling each unit of the core product with a quantity $o \geq 0$ of carbon offsets at a convex quadratic offsetting cost $C(o) = \frac{1}{2}\kappa o^2$, with $\kappa > 0$. I assume the seller takes κ as given and that the offsets reduce the aggregate externality generated by the production of the consumption goods.

I define a product-offset bundle as (q, o, p), where $q \in \{0, 1\}$ specifies whether the core product is included, $o \geq 0$ indicates the quantity of emissions offset, and $p \geq 0$ denotes the bundle price.[5] Consumers derive a gross valuation $v > 0$ from consuming the core product, but differ in their intrinsic motivation to reduce environmental pollution. A consumer's environmental type is indexed by a parameter $\theta \geq 0$. I assume that a fraction $\lambda \in (0, 1)$ of consumers are purely selfish ($\theta = 0$) and derive no disutility from environmental pollution. The remaining fraction $1-\lambda$ have environmental concerns and experience disutility from pollution. I assume that environmental types are distributed uniformly on $(0, \bar{\theta}]$. The seller cannot observe a consumer's environmental type θ, but knows the cumulative distribution function $F(\theta)$ and whether consumers care exclusively about the pollution of their own product or about total environmental pollution.

If consumers derive disutility exclusively from their own product's net pollution, the utility of type θ from purchasing bundle (q, o, p) is:

[5] In principle, the seller is allowed to offer offsets to consumers without the core product ($q = 0, o > 0$).

$$u(q, o, p; \theta) = qv - \theta \max\{qe - o, 0\} - p, \tag{1}$$

and the outside option utility from not purchasing any consumption-offset-bundle ($q = 0, o = 0, p = 0$) is $u_0(\theta) = 0$ for all θ. Thus, consumers care about the carbon emissions associated with their consumption. Crucially, they do not experience any disutility from the negative externality generated by the products sold to other consumers.

In contrast, under outcome-based preferences consumers care about aggregate pollution in the market. Define $(q_\theta, o_\theta, p_\theta)$ as the product-offset-bundle the seller offers to consumer type θ. Then, $E = e \cdot \int_0^{\bar{\theta}} q_\theta \, dF(\theta)$ denotes aggregate emissions and $O = \int_0^{\bar{\theta}} o_\theta \, dF(\theta)$ aggregate offsets, so that $E_{\text{net}} = E - O$ represents aggregate net pollution generated in the market. Conditional on type θ purchasing bundle $c = (q, o, p)$, her beliefs regarding aggregate net emissions are given by the following:

$$\mathbb{E}\left[E_{\text{net}} \mid c = (q, o, p)\right] = qe - o + \mathbb{E}\left[E_{\text{net}} \mid c = (0, 0, 0)\right], \tag{2}$$

where $\mathbb{E}\left[E_{\text{net}} | c = (0, 0, 0)\right]$ are her beliefs conditional on not purchasing the good. Her expected utility from purchasing bundle (q, o, p) is:

$$\mathbb{E}[u(q, o, p; \theta)] = qv - \theta \left(qe - o + \mathbb{E}\left[E_{\text{net}} \mid c = (0, 0, 0)\right]\right) - p. \tag{3}$$

If a consumer chooses not to purchase ($q = 0, o = 0, p = 0$), they do not derive consumption utility but suffer a disutility from baseline aggregate net market pollution: $u_0(\theta) = -\theta \mathbb{E}\left[E_{\text{net}} \mid c = (0, 0, 0)\right]$. Thus, the net payoff from purchasing bundle (q, o, p) relative to the outside option is:

$$\mathbb{E}[u(q, o, p; \theta)] - u_0(\theta) = qv - p - \theta(qe - o). \tag{4}$$

When choosing to consume, the consumer does not evaluate the pollution generated by her consumption but internalizes the net pollution impact of their choice relative to non-purchase, $\theta(qe - o)$.

The seller offers $(q_\theta, o_\theta, p_\theta)$ to each consumer type θ. She chooses the optimal menu by maximizing expected profits subject to participation and incentive constraints. Moreover, I assume that the seller cannot offer more offsets than generated in the market. Thus, he solves the following maximization problem:

$$\max_{\{(q_\theta, o_\theta, p_\theta)\}_{\theta \in [0, \bar{\theta}]}} \int_0^{\bar{\theta}} \left[p_\theta - \frac{1}{2} \kappa o_\theta^2\right] dF(\theta) \tag{5}$$

subject to:

$$\text{(IC)} \quad u(q_\theta, o_\theta, p_\theta; \theta) \geq u(q_{\theta'}, o_{\theta'}, p_{\theta'}; \theta) \quad \forall \theta, \theta' \in [0, \bar{\theta}], \tag{IC}$$

$$\text{(IR)} \quad u(q_\theta, o_\theta, p_\theta; \theta) \geq u_0(\theta) \quad \forall \theta \in [0, \bar{\theta}], \tag{IR}$$

$$\text{(FEAS)} \quad \int_0^{\bar{\theta}} o_\theta \, dF(\theta) \leq \int_0^{\bar{\theta}} q_\theta e \, dF(\theta). \tag{FEAS}$$

The timing of the game is the following:

1. The seller posts a menu of product-offset options $\{(q_\theta, o_\theta, p_\theta)\}_{\theta \in [0, \bar{\theta}]}$.
2. Each consumer type θ privately select a product-offset bundle from the menu or choose their outside option.

3 Equilibrium Analysis

This section characterizes the resulting market equilibria under responsibility-based preferences in Section 3.1 and under outcome-based preferences in Section 3.2. All proofs are relegated to Appendix B.

3.1 Market Equilibrium under Responsibility-Based Preferences

To analyze the seller's optimal product design, I first examine consumer choice across available product-offset bundles. Selfish consumers ($\theta = 0$) do not value environmental quality and select the product bundle with the lowest posted price, purchasing if and only if $p \leq v$. Conversely, environmentally conscious types $\theta > 0$ evaluate the utility of purchasing a bundle (q, o, p) relative to their outside option of non-consumption. Under responsibility-based preferences, an environmentally conscious type purchases bundle $(1, o, p)$ if and only if:

$$v - \theta \max\{e - o, 0\} - p \geq 0. \tag{6}$$

I begin the equilibrium analysis by characterizing the optimal bundle offered to purely selfish consumers. Because selfish types derive no utility from voluntary carbon offsets, offering offsets to this segment increases the seller's production costs without extracting any additional surplus from selfish consumers.

Lemma 1 (Dirty Bundle for Selfish Consumers)**.** *Assume $\kappa > 0$ and $\lambda \in (0, 1)$. In any equilibrium, the seller offers the bundle $b_0^* = (q_0^* = 1, o_0^* = 0, p_0^* = v)$ to purely selfish consumers ($\theta = 0$).*

Lemma 1 establishes that the seller extracts the full surplus v from selfish consumers by selling the core product without carbon offsets. Crucially, offering a brown bundle $b_0 = (q_0, 0, v)$ to selfish consumers does not affect the pollution generated by the consumption of conscious types $\theta > 0$, and thus does not affect their demand. Any conscious type evaluating b_0^* obtains net utility $v - \theta e - v = -\theta e < 0$, and strictly prefers the outside option yielding zero utility.

Next, I characterize the optimal menu of product-offset-bundles offered in equilibrium.

Proposition 1 (Equilibrium under Responsibility-Based Preferences)**.** *Assume $\kappa > 0$ and $\lambda \in (0,1)$. Under responsibility-based preferences, the equilibrium market outcome is characterized as follows:*

1. ***Coexistence of Clean and Dirty Products*** *($v > \frac{1}{2}\kappa e^2$)**:** The seller offers a menu consisting of a brown and a fully pollution-free product-offset-bundle:*

$$b^*_{brown} = (1, 0, v) \quad \textit{and} \quad b^*_{clean} = (1, e, v). \tag{7}$$

Selfish consumers ($\theta = 0$) purchase b^*_0, while all environmentally conscious consumers ($\theta \in (0, \bar{\theta}]$) purchase b^*_{clean}. Total seller profit is:

$$\Pi^*_{resp} = v - (1-\lambda)\frac{1}{2}\kappa e^2. \tag{8}$$

2. ***Exclusion of Conscious Consumers*** *($v \leq \frac{1}{2}\kappa e^2$)**:** The seller offers only the brown product-offset-bundle $b^*_{brown} = (1, 0, v)$. Selfish consumers purchase b^*_{brown}, whereas conscious consumers choose to not consume. Total seller profit is $\Pi^* = \lambda v$.*

The economic intuition behind Proposition 1 rests on incentive compatibility. To prevent selfish consumers from selecting the bundle intended for conscious types $\theta > 0$, the price of the conscious bundle must satisfy $p_\theta \geq v$ for all $\theta > 0$. However, θ's willingness to pay for a product with partial offsets ($e - o > 0$) is $v - \theta(e-o) < v$. Consequently, even if the seller extracts type θ's full willingness to pay for a partially offset product, the seller cannot prevent selfish consumers from purchasing that product-offset-bundle with partial offsets. Together, the incentive compatibility constraint for selfish types and the participation constraints for conscious types force $o_\theta = e$ and $p_\theta = v$. Thus, partial offsets are incentive-incompatible, while overcompensation ($o > e$) is unprofitable because the seller does not extract additional surplus from environmentally conscious consumers by offsetting more than the product's pollution. If offering full offsets is profitable, the seller serves conscious types and otherwise he excludes them from the market.

3.2 Market Equilibrium under Outcome-Based Preferences

I now characterize the market equilibrium when environmentally conscious consumers care about total pollution caused in the market. Recall from Section 2 that the net payoff of a type-θ consumer purchasing bundle $(1, o, p)$ relative to non-consumption $(q = 0, o = 0, p = 0)$ is:

$$\mathbb{E}[u(1, o, p; \theta)] - u_0(\theta) = v - p - \theta(e - o) = v - p + \theta(o - e). \tag{9}$$

In contrast to responsibility-based preferences, when the seller offers overcompensation ($o > e$), the term $\theta(o - e) > 0$ strictly increases θ's willingness to pay above their hedonic product valuation v. Because the environmental types care about total pollution emitted, they are willing to pay to offset emissions generated by other market participants. Lemma 2 shows that the seller can extract this additional surplus from high environmental types.

Lemma 2. *Assume $\kappa e < \bar{\theta}$, $\lambda \in (0,1)$, and $v > \frac{1}{2}\kappa e^2$. Under outcome-based preferences, the brown and fully clean product-offset-bundle $\{b^*_{brown} = (1,0,v), b^*_{clean} = (1,e,v)\}$ cannot be sustained as a market equilibrium.*

Lemma 2 demonstrates that by offering only a brown and a clean product-offset-bundle the seller leaves surplus on the table. High environmental types are willing to pay to minimize the total externality generated in the market, and thus the seller has a profitable incentive to expand its product line by introducing a bundle that includes overcompensating offsets ($o > e$). The condition $\bar{\theta} > \kappa e$ ensures that the seller derives profits from selling the additional product-offset-bundle at least to the highest environmental type $\bar{\theta}$. The following proposition characterizes the full profit-maximizing menu schedule.

Proposition 2 (Equilibrium under Outcome-Based Preferences)**.** *Suppose that $\bar{\theta} \in (\kappa e, \chi(\lambda)\kappa e]$, where $\chi(\lambda) = \frac{1+\sqrt{\lambda}}{1-\sqrt{\lambda}}$. Then, the seller offers the following menu in equilibrium:*

1. ***Case 1:*** $v > \frac{1}{2}\kappa e^2$

   The optimal menu segments the market into three subgroups.

   - ***Selfish consumers****: if $\theta = 0$, then the seller offers a dirty core-product at a price $p(0) = v$. $b^*_{brown} = (1,0,v)$.*
   - ***Low environmental types****: If $\theta \in (0, \theta_c]$, the seller offers a clean product-offset-bundle with full offsets for the core product's emission $o(\theta) = e$ at price $p(\theta) = v$. $b^*_{clean} = (1,e,v)$.*
   - ***High environmental types****: if $\theta \in (\theta_c, \bar{\theta}]$, then the seller offers the core product with an offset schedule that is strictly increasing in θ and offsets more than the core product's emissions $o^*(\theta) = \frac{2\theta - \bar{\theta}}{\kappa}$. The optimal price schedule is $p^*(\theta) = v + \frac{\theta^2}{\kappa} - \frac{(\bar{\theta}+\kappa e)^2}{4\kappa} > v$.*

   Total seller profit is:

   $$\Pi^*_{outcome} = v - (1-\lambda)\frac{1}{2}\kappa e^2 + (1-\lambda)\frac{(\bar{\theta} - \kappa e)^3}{12\kappa\bar{\theta}}.$$

   Aggregate net emissions are:

   $$E_{net} = \lambda e - \frac{1-\lambda}{4\kappa}\bar{\theta}$$

2. ***Case 2:*** $v \leq \frac{1}{2}\kappa e^2$

   The seller runs a dual-business model and sells the core product to selfish consumer types and offsets to high environmentally conscious consumer types. Let $\theta_c = \frac{\bar{\theta}}{2}$.

   - ***Selfish consumers****: if $\theta = 0$, then the seller offers a dirty core-product at a price $p(0) = v$. $b^*_{brown} = (1,0,v)$*
   - ***Low environmental types****: if $\theta \in (0, \theta_0]$, then the seller offers no consumption product: $b^*(\theta) = (0,0,0)$*
   - ***High environmental types****: if $\theta \in (\theta_0, \bar{\theta}]$, the seller offers pure offsets. The optimal offset schedule is strictly increasing in θ and given by $o^*(\theta) = \frac{2\theta - \bar{\theta}}{\kappa}$. The optimal price schedule is given by $p^*(\theta) = \frac{\theta^2}{\kappa} - \frac{(\bar{\theta}+\kappa e)^2}{4\kappa}$.*

Equilibrium profits are given by:

$$\pi^*_{outcome} = \lambda \upsilon + \frac{1-\lambda}{12\kappa}\bar{\theta}^2$$

Aggregate net emissions are given by:

$$E_{net} = \lambda e - \frac{1-\lambda}{4\kappa}\bar{\theta}$$

Proposition 2 shows how the seller can exploit the willingness to pay of the highest environmental types to reduce aggregate pollution in the market. For this purpose, he offers them carbon offsets that do not only neutralize the emissions polluted by the product sold to these types but also offset the pollution generated by the core products sold to selfish consumers. To extract surplus, the seller must concede information rent to each environmental type θ. Therefore, the seller offers an offset and price schedule which are strictly increasing in the environmental type θ.

For low environmentally conscious types, the seller would like to offer partial offsets. However, in order to not violate the incentive compatibility constraint of selfish consumer types who choose the cheapest product-offset bundle, the seller must price the product-offset bundle offered to low environmentally conscious types above υ. Using partial offsets violates their participation constraint. For a similar reason, the seller cannot offer the core product at a price of υ to low environmentally conscious types. In turn, because $\upsilon > \frac{\kappa}{2}e^2$, it is strictly beneficial to include the core product with full offsets. Therefore, the cheapest product-offset bundle that satisfies all constraints is one that contains full offsets for the pollution emitted by the core product.

If including the core product with full offsets for the emissions it generates is no longer profitable, the seller sets up a dual-business model. He separates the bundle and offers the core product to the selfish consumers and the carbon offsets for the pollution that the production of the core product generates to the highest environmental types. Crucially, the latter do not receive the core product because compensating the emissions generated by the product is no longer profitable. Under responsibility-based preferences, this dual-business model is not feasible because environmental types only care about the pollution that is associated to their consumption. But if they do not purchase any consumption good, then the pollution associated to their consumption choice is exactly 0. Conditional on non-consumption, their marginal willingness to pay for carbon offsets of the products sold to selfish consumers is 0 and the seller cannot extract any surplus.

Finally, if the marginal willingness of the highest environmental type $\bar{\theta}$ is below a mark-up on marginal costs $\chi(\lambda)$, then the feasibility constraint is not binding. Hence, the net emissions in the market are positive. In contrast, if $\bar{\theta} > \chi(\lambda)\kappa e$, then the seller would like to offset more than the total pollution in the market e and the feasibility constraint is binding. Proposition 5 in Appendix A states the optimal menu in this case. Figure 1 graphically illustrates the optimal offset schedule in the equilibrium where environmentally conscious consumers have purely outcome-based preferences regarding the pollution under the case in which they receive the core product and when they do not receive the core product.

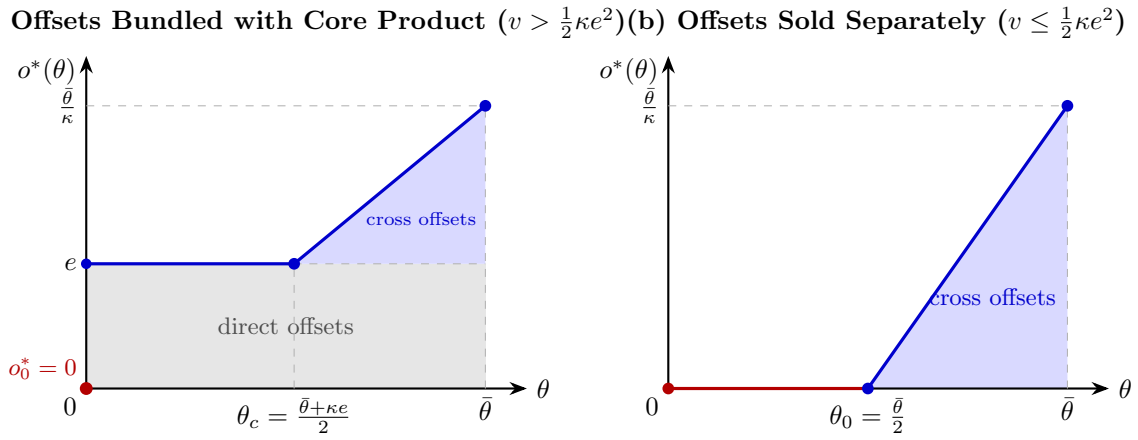


Figure 1: Optimal Carbon Offset Schedule $o^*(\theta)$ under Outcome-Based Preferences (Proposition 2). Panel (a) shows the equilibrium offset-schedule when the seller bundles offsets with the core product. Panel (b) shows the equilibrium offset-schedule when the seller sells them separately from the core product. The gray-shaded area denotes the offsets for the pollution generated by the core product included in the bundle. The blue-shaded area denotes the cross offsets that compensate for the pollution generated by the product sold to selfish consumers.

4 Welfare Implications and Policy Analysis

The previous section has shown that the nature of consumers' environmental preferences, in particular whether they are outcome-based or responsibility-based, matters for the menu offered in equilibrium. The key difference is that under responsibility-based preferences the pollution generated by the core product sold to selfish consumers are not compensated. Under outcome-based preferences, if the highest type's marginal willingness to pay for the eth unit of pollution exceeds the marginal cost, the seller wants to include cross-offsets for the pollution emitted by core product sold to the selfish fringe. He maximizes profits by selling these cross-offsets to the highest environmental types.

These two equilibria can be ranked in terms of welfare. It is easy to see that the seller makes higher profits in the equilibrium under outcome-based preferences than the equilibrium that corresponds to responsibility-based preferences.[6] Also, high environmentally conscious types are better off under the equilibrium under outcome-based preferences. Let $U(\theta)$ denote the equilibrium utility of consumer type θ. Then the consumer surplus is defined by $\text{CS}_{\text{outcome}} = \int_0^{\bar{\theta}} U(\theta)d\theta = \int_{\theta_c}^{\bar{\theta}} U(\theta)d\theta > 0 = \text{CS}_{\text{resp}}$. Furthermore, aggregate net emissions are lower in the equilibrium based on outcome-based preferences. Therefore, it is easy to see that the equilibrium under outcome-based preferences is superior to the equilibrium under responsibility-based preferences. Proposition 3 formalizes the intuition. The proof is relegated to Appendix B.

Proposition 3. *Suppose $\bar{\theta} > \kappa e$ and $v > \frac{\kappa}{2}e^2$. Let $W_j = \int_0^{\bar{\theta}} U_j(\theta)d\theta + \pi_j - \gamma E_{net,j}$ be aggregate welfare in the equilibrium under outcome-based preferences or responsibility-based preferences, where $j \in \{outcome, resp\}$. γ is the marginal social cost of pollution. Then $W_{outcome} > W_{resp}$.*

While the equilibrium under outcome-based preferences is welfare superior to the equilibrium under responsibility-

[6] He has the possibility to offer clean offsets to all environmentally conscious consumers and a core product to selfish consumers but strictly prefers to add cross-offsets to some product-offset-bundles.

based preferences when assuming a utilitarian welfare criterion, it is not clear what allocation would be chosen by a social planner who also incorporates the aggregate pollution that is generated in the market. I assume that the social planner can directly observe the choices of the consumers who have responsibility-based preferences. The social planner chooses the optimal menu of product-offset bundles that maximizes social welfare which is given by the sum of consumer surplus, the seller's profit and the disutility from the aggregate net pollution. Formally,

$$W = \lambda(\upsilon - \frac{\kappa}{2}o(0)^2 + \gamma o(0)) + \frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}}(\upsilon - \theta\max\{e - o(\theta), 0\} - \frac{\kappa}{2}o(\theta)^2 + \gamma o(\theta))d\theta - \gamma e \tag{10}$$

where the price schedule cancels out. Moreover, because consumers and sellers benefit from trading the core product, $q(\theta) = 1$ for all θ. Therefore, the social planner maximizes social welfare that is given by equation (10) by choosing the optimal offset schedule when choices are observable. Proposition 4 summarizes the optimal choice of the social planner if $\gamma > \kappa e$, i.e. if the marginal social benefit of offsetting the eth unit of pollution is higher than the marginal social cost.

Proposition 4. *Suppose social welfare is given by equation (10). Moreover, suppose $\gamma > \kappa e$. Then the optimal offset schedule is a constant function and given by $o^*(\theta) = e$ for all θ.*

The main insight of proposition (4) is that if it is socially beneficial to offset the entire emissions that are generated in the market, the social planner would mandate full offsets for all consumers. Hence, the market equilibrium under responsibility-based preferences is clearly inefficient. Moreover, if the feasibility constraint is not binding, the equilibrium under outcome-based preferences is also inefficient. However, if the marginal willingness to pay to reduce negative externalities of the highest environmental consumer type is sufficiently high, the feasibility constraint binds and the market is efficient. Yet, under responsibility-based preferences, this can never happen because neither the consumers nor the seller are willing to pay to offset the pollution generated by the core products sold to selfish consumers.

The remainder of this section is work in progress. I plan to formulate a more general proposition for the social planner's problem. After that, I show how the social planner can achieve the first-best outcome by setting a unit tax equal to γ on each unit of net pollution. Because he effectively makes the seller internalizing the aggregate net pollution, the seller optimally chooses to sell full offsets to all consumers to avoid paying the unit tax. Finally, I want to extend the framework to a duopoly and study the resulting equilibria under outcome-based and responsibility-based preferences.

5 Conclusion

In this paper, I show that voluntary carbon offsets do help in mitigating pollution, however whether they are efficient depends on the nature of consumers' environmental preferences. If consumers care exclusively about their own carbon footprint and ignore the pollution caused by others, then market outcomes are inherently inefficient. The pollution that is emitted by products sold to selfish consumers remains unaddressed because nobody feels responsible for them. A benevolent social planner who acknowledges that these emissions need to be avoided and corrects the inefficiency with a carbon tax that is equal to the marginal social cost of pollution and thus forces the seller to internalize the aggregate pollution generated in the market. Moreover,

this paper proposes theoretically a novel mechanism through which carbon offsets can operate in markets: a seller can offer them to consumers that are highly concerned about the environmental consequences of economic activity as a means to compensate for pollution generated by consumers that are not concerned about the environment.

In showing this mechanism, I made some simplifying assumptions. For example, I assumed that it can be fully verified whether the seller indeed carries out the offsets on behalf of consumers. It remains an open question under which conditions on consumer preferences and sophistication this mechanism survives when the assumption of full verifiability is relaxed. Another assumption that I have made is that consumers are fully aware and fully informed about the pollution that is generated by their purchased product. However, it has been shown that there consumers systematically misperceive the carbon footprint of their purchased products (Imai et al., 2026). How the employment of voluntary carbon offsets interacts with the seller's commitment to an information structure that informs consumers about the pollution their product emits is a further interesting research avenue.

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A Additional Propositions

Proposition 5 (Equilibrium under Binding Feasibility Constraint)**.** *Assume outcome-based preferences, $\kappa > 0$, and $\lambda \in (0,1)$. When the aggregate feasibility constraint (FEAS) binds, the seller faces a positive shadow price $\mu^* > 0$ on market emissions capacity, and the equilibrium market outcome is characterized as follows:*

1. ***Case 1: High Product Valuation** ($v > \frac{1}{2}\kappa e^2$)*
   Feasibility binds when $(1-\lambda)\frac{(\bar{\theta}-\kappa e)^2}{4\kappa\bar{\theta}} > \lambda e$. The shadow price is $\mu^* = \bar{\theta} - \kappa e - 2\sqrt{\frac{\lambda}{1-\lambda}\kappa e\bar{\theta}} > 0$, and the overcompensation cutoff shifts upward to:

$$\theta_c^* = \bar{\theta} - \sqrt{\frac{\lambda}{1-\lambda}\kappa e\bar{\theta}} > \theta_c. \tag{11}$$

   The profit-maximizing product-offset menu $\{(q^*(\theta), o^*(\theta), p^*(\theta))\}_{\theta\in[0,\bar{\theta}]}$ is:

   - *Selfish consumers ($\theta = 0$): $b^*_{brown} = (q_0^* = 1,\, o_0^* = 0,\, p_0^* = v)$.*
   - *Clean core product ($\theta \in (0, \theta_c^*]$): $b^*_{clean} = (q^*(\theta) = 1,\, o^*(\theta) = e,\, p^*(\theta) = v)$.*
   - *Constrained super-clean core products ($\theta \in (\theta_c^*, \bar{\theta}]$):*

$$q^*(\theta) = 1, \quad o^*(\theta) = e + \frac{2(\theta - \theta_c^*)}{\kappa}, \quad p^*(\theta) = v + \frac{\theta^2 - (\theta_c^*)^2}{\kappa}. \tag{12}$$

   Aggregate market offsets equal total emissions ($O_{total} = e$), and total seller profit is:

$$\Pi^*_{constrained} = v - (1-\lambda)\frac{1}{2}\kappa e^2 + \mu^*\lambda e + \frac{2\lambda e}{3}\sqrt{\frac{\lambda}{1-\lambda}\kappa e\bar{\theta}}. \tag{13}$$

2. ***Case 2: Low Product Valuation** ($v \le \frac{1}{2}\kappa e^2$) **with Standalone Offsets Permitted***
   Feasibility binds when $(1-\lambda)\frac{\bar{\theta}}{4\kappa} > \lambda e$. The shadow price is $\mu^* = \bar{\theta} - 2\sqrt{\frac{\lambda}{1-\lambda}\kappa e\bar{\theta}} > 0$, and the standalone offset cutoff shifts upward to:

$$\theta_0^* = \bar{\theta} - \sqrt{\frac{\lambda}{1-\lambda}\kappa e\bar{\theta}} > \theta_0. \tag{14}$$

   The profit-maximizing product-offset menu $\{(q^*(\theta), o^*(\theta), p^*(\theta))\}_{\theta\in[0,\bar{\theta}]}$ is:

   - *Selfish consumers ($\theta = 0$): $b^*_{brown} = (q_0^* = 1,\, o_0^* = 0,\, p_0^* = v)$.*
   - *Excluded conscious consumers ($\theta \in (0, \theta_0^*]$): $q^*(\theta) = 0$, $o^*(\theta) = 0$, $p^*(\theta) = 0$.*
   - *Constrained standalone offset contracts ($\theta \in (\theta_0^*, \bar{\theta}]$):*

$$q^*(\theta) = 0, \quad o^*(\theta) = \frac{2(\theta - \theta_0^*)}{\kappa}, \quad p^*(\theta) = \frac{\theta^2 - (\theta_0^*)^2}{\kappa}. \tag{15}$$

   Aggregate standalone offsets equal brown consumer emissions ($O_{total} = \lambda e$), and total seller profit is:

$$\Pi^*_{constrained} = \lambda v + \mu^*\lambda e + \frac{2\lambda e}{3}\sqrt{\frac{\lambda}{1-\lambda}\kappa e\bar{\theta}}. \tag{16}$$

B Omitted Proofs

B.1 Proof of Lemma 1

Let $b_0 = (q_0, o_0, p_0)$ denote the equilibrium bundle selected by selfish types ($\theta = 0$). Individual rationality (IR) for $\theta = 0$ requires $q_0 v - p_0 \geq 0$. Since production cost is normalized to zero, unit profit from selfish consumers is $\pi_0 = p_0 - \frac{1}{2}\kappa o_0^2 \leq v - \frac{1}{2}\kappa o_0^2$.

Suppose $o_0 > 0$, or $p_0 < v$. Consider a deviation where the seller replaces b_0 with $b_0^* = (1, 0, v)$. Type $\theta = 0$ obtains utility $v - v = 0$, satisfying IR. Any conscious type $\theta > 0$ evaluating b_0^* obtains net utility:

$$u(1, 0, v; \theta) = v - \theta e - v = -\theta e < 0, \tag{17}$$

which is strictly below their utility of not purchasing, $u_0(\theta) = 0$. Thus, no conscious type $\theta > 0$ selects b_0^*.

Per-capita profit on the mass λ of selfish consumers strictly increases to $v > p_0 - \frac{1}{2}\kappa o_0^2$, while the incentive constraints and choices of conscious consumers remain entirely unaffected. Hence, in any equilibrium, $q_0^* = 1$, $o_0^* = 0$, and $p_0^* = v$. ■

B.2 Proof of Proposition 1

By Lemma 1, the equilibrium bundle for selfish consumers is $b^*_{\text{brown}} = (1, 0, v)$, yielding utility $u(1, 0, v; 0) = 0$ to selfish types.

To serve any conscious type $\theta > 0$ with a bundle $b_\theta = (q_\theta, o_\theta, p_\theta)$, two conditions must hold simultaneously:

1. **Incentive Compatibility for Selfish Types ($\text{IC}_{0,\theta}$):** Selfish consumers must not prefer b_θ over b^*_{brown}:
$$\underbrace{v - p_\theta}_{\text{Utility of } (1, o_\theta, p_\theta)} \leq \underbrace{0}_{\text{Utility of } b^*_{\text{brown}}} \implies p_\theta \geq v. \tag{18}$$
2. **Individual Rationality for Type θ (IR_θ):** Conscious type θ needs to obtain utility of at least 0:
$$v - \theta \max\{e - o_\theta, 0\} - p_\theta \geq 0 \implies p_\theta \leq v - \theta \max\{e - o_\theta, 0\}. \tag{19}$$

Combining (18) and (19) yields:

$$v \leq p_\theta \leq v - \theta \max\{e - o_\theta, 0\}. \tag{20}$$

For any $\theta > 0$, inequality (20) holds if and only if $\max\{e - o_\theta, 0\} = 0$, which implies $o_\theta \geq e$ and $p_\theta = v$. Thus, offering partial offsets ($o_\theta < e$) is impossible in equilibrium because setting $p_\theta < v$ causes selfish types to select $(1, o_\theta, p_\theta)$, whereas setting $p_\theta \geq v$ violates IR for conscious types.

Because responsibility-based preferences imply zero marginal willingness to pay for offsets beyond consumption-generated emissions ($o_\theta > e$), setting $o_\theta > e$ strictly increases offset cost $\frac{1}{2}\kappa o_\theta^2$ without allowing a price premium above $p_\theta = v$. Thus, the profit-maximizing offset level for conscious types is $o_\theta^* = e$.

Offering $b^*_{\text{clean}} = (1, e, v)$ yields unit profit $v - \frac{1}{2}\kappa e^2$ on the mass $1 - \lambda$ of conscious consumers. The seller includes b^*_{clean} in the menu if and only if $v - \frac{1}{2}\kappa e^2 > 0$.

If $v > \frac{1}{2}\kappa e^2$, total seller profit when serving all consumers is:

$$\Pi^*_{\text{resp}} = \lambda v + (1 - \lambda)\left(v - \frac{1}{2}\kappa e^2\right) = v - (1 - \lambda)\frac{1}{2}\kappa e^2. \tag{21}$$

If $v \leq \frac{1}{2}\kappa e^2$, offering b^*_{clean} is unprofitable, and the seller offers only $b^*_0 = (1, 0, v)$, yielding profit $\Pi^* = \lambda v$. ■

B.3 Proof of Lemma 2

Suppose $b^*_{\text{brown}} = (1, 0, v)$ and $b^*_{\text{clean}} = (1, e, v)$ constitute an equilibrium, yielding profit $\Pi_{\text{cand}} = v - (1 - \lambda)\frac{1}{2}\kappa e^2$.

Consider a deviation where the seller retains b^*_{brown} and b^*_{clean}, but introduces an additional super-clean option $b_{\text{super}} = (1, o_{\text{super}}, p_{\text{super}})$ sold to types $\theta' \in (\kappa e, \bar{\theta}]$, where $o_{\text{super}} = e + \zeta$ and $p_{\text{super}} = v + \theta'\zeta$ for an arbitrarily small $\zeta > 0$.

Any type $0 < \theta < \theta'$ does not purchase b^*_{super} because their utility decreases by $\zeta(\theta - \theta')$ compared to purchasing b^*_{clean}. By construction, type θ' obtains utility $v - p_{\text{super}} + \theta'(o_{\text{super}} - e) = 0$, satisfying participation. The net change in unit profit from type θ relative to b^*_{clean} is:

$$\Delta\pi(\theta) = \left[v + \theta\zeta - \frac{1}{2}\kappa(e + \zeta)^2\right] - \left[v - \frac{1}{2}\kappa e^2\right] = \zeta\left(\theta - \kappa e\right) - \frac{1}{2}\kappa\zeta^2. \tag{22}$$

Taking the marginal profit derivative with respect to ζ at $\zeta = 0$ yields:

$$\left.\frac{\partial\Delta\pi(\theta)}{\partial\zeta}\right|_{\zeta=0} = \theta - \kappa e. \tag{23}$$

For all $\theta > \kappa e$, this marginal profit is strictly positive. If $\bar{\theta} > \kappa e$, then the seller wants to offer b^*_{super} at least to $\bar{\theta}$. ■

B.4 Proof of Proposition 2

B.4.1 Feasibility Constraint not Binding

I apply the relevation principle and solve for the truth-telling equilibrium of a direct mechanism in which consumers report a type $\hat{\theta}$ to the seller and the seller offers a menu of product-offset-bundles $\{q(\hat{\theta}), o(\hat{\theta}), p(\hat{\theta})\}$ in for each reported type $\hat{\theta}$. The timing is that the seller first posts the menu of product-offset-bundles after which consumers report a type $\hat{\theta} \in [0, \bar{\theta}]$.

Define $\Delta U(\hat{\theta}; \theta) = q(\hat{\theta})v + \theta \cdot (o(\hat{\theta}) - q(\hat{\theta})e) - p(\hat{\theta})$ as the consumer type $\theta's$ utility of reporting $\hat{\theta}$. In any truth-telling equilibrium it must be the case that

$$\frac{\partial \Delta U(\hat{\theta};\theta)}{\partial \hat{\theta}} = \theta o'(\hat{\theta}) - p'(\hat{\theta}) = |_{\hat{\theta}=\theta} 0$$

Case 1: $v > \frac{\kappa}{2}e^2$: If $v - \frac{\kappa}{2}e^2 > 0$, the seller wants to include the core product to the bundle of every consumer. There exists a profitable deviation from not offering the core product to some $\theta \in [0, \hat{\theta}]$ with full offsets. All other consumers either receive the same utility of 0 in equilibrium or higher. Therefore, the market will be fully covered.

The seller then chooses the optimal price and offset schedule that maximize his expected profits subject to the incentive compatibility and participation constraints for each $\theta \in [0, \bar{\theta}]$. Formally:

$$\begin{aligned} \max_{\{o(\theta),p(\theta)\}} \quad & \lambda\left(p(0) - \frac{\kappa}{2}o(0)^2\right) + \frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}}\left(p(\theta) - \frac{\kappa}{2}o(\theta)^2\right)d\theta \\ \text{s.t.} \quad & \Delta U(\theta;\theta) \geq 0 \quad \forall\theta & \text{[IR]} \\ & \Delta U(\theta;\theta) \geq \Delta U(\hat{\theta};\theta) \quad \forall\theta,\hat{\theta} & \text{[IC]} \end{aligned} \tag{24}$$

The optimal offset schedule in a truth-telling equilibrium must be non-decreasing in θ. To see this, fix two consumer types θ_1 and θ_2 such that $\theta_2 > \theta_1$. From the incentive-compatibility constraint that θ_1 must prefer the product-offset-bundle designed for herself to the product-offset-bundle designed for θ_2, and thus $p(\theta_2) - p(\theta_1) \geq \theta_1(o(\theta_2 - \theta_2)$. From an analagous incentive-compatibility constraint for θ_2 it follows that $\theta_2(o(\theta_2) - o(\theta_1)) \geq p(\theta_2) - p(\theta_1)$. Thus, it follows that $\theta_2(o(\theta_2) - o(\theta_1)) \geq \theta_1(o(\theta_2) - o(\theta_1))$ which only holds if $\theta_2 \geq \theta_1$.

Let $U(\theta) \equiv \Delta U(\theta;\theta)$ be the utility that consumer type θ receives in equilibrium relative to non-consumption. From the first-order condition of truth-telling it follows that:

$$U'(\theta) = o(\theta) - e + \underbrace{\theta o'(\theta) - p'(\theta)}_{=0} = o(\theta) - e$$

Therefore, we can write $U(\theta) = U(0) + \int_0^\theta (o(s) - e)ds$, and pin down the price schedule $p(\theta) = v + \theta(o(\theta) - e) - U(\theta)$. Plugging $p(\theta)$ into the seller's expected profits, we can restate the seller's optimization problem:

$$\begin{aligned} \max_{U(0),\{o(\theta)\}} \quad & \lambda(v - \frac{\kappa}{2}o(0)^2) + \frac{(1-\lambda)}{\bar{\theta}}\int_0^{\bar{\theta}}(v + \theta(o(\theta) - e) - U(\theta) - \frac{\kappa}{2}o(\theta)^2)d\theta \\ & \text{s.t. } o(\theta) \text{ non-decreasing} \\ & \text{s.t. } \Delta U(\theta;\theta) \geq 0 \,\forall\theta & \text{[IR]} \end{aligned} \tag{25}$$

In the truth-telling equilibrium, the seller has to set $U(0) = 0$. If $U(0) > 0$ he could profitably deviate to

setting $U(0) = 0$ without violating any incentive-compatibility constraint or participation constraint of type 0. Aggregate information rents $\int_0^{\bar{\theta}} U(\theta)\frac{(1-\lambda)}{\bar{\theta}}d\theta$ are computed using integration by parts by setting $u = U(\theta)$ and $v' = \frac{1-\lambda}{\bar{\theta}} = f(\theta)$. By setting $v = -(1 - F(\theta)) = -\frac{1-\lambda}{\bar{\theta}}(\bar{\theta} - \theta)$. Applying integration by parts gives:

$$\int_0^{\bar{\theta}} U(\theta)\frac{1-\lambda}{\bar{\theta}}d\theta = |U(\theta)(-\frac{1-\lambda}{\bar{\theta}}(\bar{\theta}-\theta))|_0^{\bar{\theta}} + \int_0^{\bar{\theta}} (o(\theta)-e)(\lambda + (1-\lambda)\frac{\theta}{\bar{\theta}}d\theta$$
$$= \frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}} (o(\theta)-e)(\bar{\theta}-\theta)d\theta$$

Plugging aggregate information rents into the seller's expected profits yields:

$$\lambda(\upsilon - \frac{\kappa}{2}o(0)^2) + \frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}} (\upsilon + (2\theta - \bar{\theta})(o(\theta)-e) - \frac{\kappa}{2}o(\theta)^2)d\theta$$

For selfish consumer types, the seller optimally sets offsets to 0 to minimize offsetting costs. From the price schedule, it follows that $p^*(0) = \upsilon$. For any environmentally conscious consumer type define the virtual surplus $\mathcal{J}(\theta, o(\theta)) = \upsilon + (2\theta - \bar{\theta})(o(\theta) - e) - \frac{\kappa}{2}o(\theta)^2$. For each environmentally conscious type θ the interior solution for the offset that maximizes $\mathcal{J}(\theta, o(\theta))$ is given by $o^*_{\text{unc}} = \frac{2\theta-\bar{\theta}}{\kappa}$.

There exists a threshold type $\theta_c = \frac{\bar{\theta}+\kappa e}{2}$ for which $o^*_{\text{unc}} = e$, and this type is formally defined by

$$\frac{2\theta_c - \bar{\theta}}{\kappa} = e$$

Thus, for all $\theta \leq \theta_c$ $o^*_{\text{unc}} \leq e$. In order to satisfy incentive-compatibility for the selfish consumer type, it must be the case that $p(\theta) \geq p(0) = \upsilon$. If $o^*_{\text{unc}} < e$, this violates the participation constraint of environmentally conscious type θ. Therefore, if $o^*_{\text{unc}} < e$, the seller sets the lowest offset level that satisfies all incentive-compatibility and participation constraints which is e. Hence, the optimal offset schedule can be defined as follows:

$$o^*(\theta) = \begin{cases} 0, & \text{if} \quad \theta = 0 \\ e, & \text{if} \quad \theta \in (0, \theta_c] \\ \frac{2\theta-\bar{\theta}}{\kappa} & \text{otherwise} \end{cases}$$

Case 2: $\upsilon \leq \frac{\kappa}{2}e^2$ If $\upsilon \leq \frac{\kappa}{2}e^2$, the seller no longer wants to bundle the core product with offsets that compensate for full emissions. First, consider an equilibrium where $q(\theta) = 0$ for all environmentally conscious types $\theta > 0$. According to Lemma 1, the seller offers the core product without offsets to the selfish fringe and sets $p(0) = \upsilon$.

For all environmentally conscious consumers, indirect utility relative to non-consumption becomes

$$U(\theta) = \theta o(\theta) - p(\theta)$$

In a truth-telling equilibrium, therefore $U(\theta) = \int_0^\theta U'(s)ds = \int_0^\theta o(s)ds$. The price schedule for environmentally conscious types is pinned down by $p(\theta) = \theta o(\theta)$. For a similar logic as in the case of $\upsilon > \frac{\kappa}{2}e^2$, in equilibrium $o(\theta)$ must be non-decreasing in θ. The seller's maximization problem becomes:

$$\begin{aligned} \max_{o(\theta)} \quad & \lambda(\upsilon - \frac{\kappa}{2}o(0)^2) + \frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}}(\theta o(\theta) - \frac{\kappa}{2}o(\theta)^2 - U(\theta))d\theta \\ & \text{s.t.} \quad o(\theta) \text{ non-decreasing} \\ & \text{s.t.} \quad U(\theta) \geq 0 \, \forall \theta \qquad [IR] \end{aligned}$$

Computing aggregate information rents using integration by parts yields

$$\int_0^{\bar{\theta}} U(\theta)\frac{1-\lambda}{\bar{\theta}}d\theta = \frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}} o(\theta)(\bar{\theta} - \theta)d\theta$$

Thus, the seller's expected profits can be rewritten as

$$\lambda(\upsilon - \frac{\kappa}{2}o(0)^2) + \frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}}((2\theta - \bar{\theta})o(\theta) - \frac{\kappa}{2}o(\theta)^2)d\theta$$

For the selfish consumer types, offsets are again only costly for the seller, and therefore $o^*(0) = 0$. Let $\mathcal{J}(\theta, o(\theta)) = (2\theta - \bar{\theta})o(\theta) - \frac{\kappa}{2}o(\theta)^2$ denote the virtual surplus the seller makes with consumer type θ. For each $\theta > 0$ the first-order condition yields the unconstrained offset schedule $o^*(\theta) = \frac{2\theta - \bar{\theta}}{\kappa}$. The offsets offered by the seller have to be non-negative. Therefore, the optimal offset schedule is given by $o^*(\theta) = \max\{0, \frac{2\theta-\bar{\theta}}{2}\}$ which pins down a threshold type $\theta_c = \frac{\bar{\theta}}{2}$ such that

$$o^*(\theta) = \begin{cases} 0 & \text{if} \quad \theta <= \frac{\bar{\theta}}{2} \\ \frac{2\theta-\bar{\theta}}{2} & \text{otherwise} \end{cases}$$

Computing aggregate offsets:

To compute aggregate offsets for the case notice that $o^*(\theta) = e + \frac{2(\theta-\theta_c)}{\kappa}$ if $\theta \geq \theta_c$. Hence,

$$\frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}} o^*(\theta)d\theta = (1-\lambda)\cdot e + \frac{1-\lambda}{\kappa\bar{\theta}}\int_{\theta_c}^{\bar{\theta}}(\theta - \theta_c)d\theta$$

The integral can be computed using the substitution method by defining $x = \theta - \theta_c$. Moreover, letting $L = \theta - \theta_c = \frac{\bar{\theta} - \kappa e}{2}$ this gives

$$\frac{2(1-\lambda)}{\kappa\bar{\theta}} \int_0^L x dx = (1-\lambda)\frac{(\bar{\theta} - \kappa e)^2}{4\kappa\bar{\theta}}$$

In the case of $\upsilon \leq \frac{\kappa}{2}e^2$, aggregate offsets are given by

$$\frac{1-\lambda}{\kappa\bar{\theta}} \int_{\frac{\bar{\theta}}{2}}^{\bar{\theta}} (2\theta - \bar{\theta}) d\theta = \frac{1-\lambda}{4\kappa}\bar{\theta}$$

Computing Equilibrium profits:
For the case $\upsilon > \frac{\kappa}{2}e^2$, notice that the virtual surplus for the selfish consumer is given by $\mathcal{J}(0,0) = \upsilon$. Noticing that $2\theta_c = \bar{\theta} + \kappa e$ and $2\theta - \bar{\theta} = 2(\theta - \theta_c) + \kappa e$, the virtual surplus for consumer type $\theta \in (0, \bar{\theta}]$ becomes:

$$\mathcal{J}(\theta, o(\theta)) = \upsilon + \frac{(2(\theta - \theta_c) + \kappa e)^2}{2\kappa} - \frac{2\kappa e(2(\theta - \theta - c) + \kappa e)}{2\kappa}$$

After expanding the second and third term, the virtual surplus can be rewritten as $\mathcal{J}(\theta, o(\theta)) = \upsilon - \frac{\kappa}{2}e^2 + \frac{2}{\kappa}(\theta - \theta_c)^2$. Using this expression, aggregate virtual surplus can be rewritten as

$\upsilon - (1-\lambda)\frac{\kappa}{2}e^2 + \frac{2(1-\lambda)}{\kappa\bar{\theta}} \int_{\theta_c}^{\bar{\theta}} (\theta - \theta_c)^2 d\theta = \upsilon - (1-\lambda)\frac{\kappa}{2}e^2 + \frac{(1-\lambda)(\bar{\theta} - \kappa e)^3}{12\kappa\bar{\theta}}$

For the case $\upsilon \leq \frac{\kappa}{2}e^2$ notice that aggregate virtual surplus is given by

$$\lambda\upsilon + \frac{1-\lambda}{\bar{\theta}} \int_{\frac{\bar{\theta}}{2}}^{\bar{\theta}} \mathcal{J}(\theta, o(\theta)) d\theta,$$

where $\mathcal{J}(\theta, o(\theta)) = (2\theta - \bar{\theta})o(\theta) - \frac{\kappa}{2}o(\theta)^2 = \frac{(2\theta - \bar{\theta})^2}{2\kappa}$. Plugging into the expression for expected profits:

$$\pi^* = \lambda\upsilon + \frac{1-\lambda}{2\kappa\bar{\theta}} \int_{\frac{\bar{\theta}}{2}}^{\bar{\theta}} (2\theta - \bar{\theta})^2 d\theta = \lambda\upsilon + \frac{1-\lambda}{12\kappa\bar{\theta}}\bar{\theta}^3$$

This concludes the proof.■

B.5 Proof of Proposition 3

It is easy to see that in the equilibrium under responsibility-based preferences, consumer surplus is 0 and equilibrium profits are given by $\pi^*_{\text{resp}} = \upsilon - (1-\lambda)\frac{\kappa}{2}e^2$. Moreover, aggregate net emissions are given by $E_{\text{net,resp}} = \lambda e$. Hence, welfare is equal to

$$W_{\text{resp}} = \upsilon - (1-\lambda)\frac{\kappa}{2}e^2 - \gamma\lambda e$$

In the equilibrium under outcome-based preferences, we know from Proposition 2 that equilibrium profits are given by $\pi^*_{\text{outcome}} = \upsilon - (1-\lambda)\frac{\kappa}{2}e^2 + \frac{\bar{\theta}-\kappa e)^3}{12\kappa\bar{\theta}}$. Moreover, aggregate net emissions are given by $E_{\text{net,outcome}} = \lambda e - \frac{1-\lambda}{4\kappa\bar{\theta}}$. To calculate total welfare, compute the consumer surplus in the resulting outcome-based equilibrium. Notice that $\text{CS}_{\text{outcome}} = \int_{\theta_c}^{\bar{\theta}} U(\theta)\frac{1-\lambda}{\bar{\theta}}d\theta = \frac{1-\lambda}{\bar{\theta}}\int_{\theta_c}^{\bar{\theta}}(\bar{\theta}-\theta)(o^*(\theta)-e)d\theta$. Moreover, using the fact that $o^*(\theta) - e = 2(\theta - \theta_c)$ for all $\theta > \theta_c$, we can rewrite the integral as follows:

$$\frac{2(1-\lambda)}{\bar{\theta}\kappa}\int_0^L (\bar{\theta}-\theta)xdx,$$

where $x = \theta - \theta_c$ and $L = \frac{\bar{\theta}-\kappa e}{2}$. Moreover, $\theta = x + \theta_c$, and hence, we can rewrite the integral as

$$\frac{2(1-\lambda)}{\bar{\theta}\kappa}\int_0^L (\bar{\theta}-\theta_c-x)xdx$$

Computing this integral gives the solution $\text{CS}_{\text{outcome}} = (1-\lambda)\frac{(\bar{\theta}-\kappa e)^3}{24\bar{\theta}\kappa}$.

Thus, it is easy to see that

$$\Delta W = W_{\text{outcome}} - W_{\text{resp}} = (1-\lambda)\frac{(\bar{\theta}-\kappa e)^3}{24\bar{\theta}\kappa} + \frac{1-\lambda}{4\kappa}\bar{\theta} > 0$$

which concludes the proof.■

B.6 Proof of Proposition 4

Suppose $\gamma > \kappa e$. The seller solves the following problem:

$$\max_{\{o(\theta)\}} \quad \lambda(\upsilon - \frac{\kappa}{2}o(0)^2 + \gamma o(0)) + \frac{1-\lambda}{\bar{\theta}}\int_0^{\bar{\theta}}(\upsilon - \theta\max\{e-o(\theta),0\} - \frac{\kappa}{2}o(\theta)^2 + \gamma o(\theta))d\theta - \gamma e$$

$$\text{s.t.} \quad \int_0^{\theta} o(\theta)dF(\theta) \leq e \quad \text{[Feasibility]}$$

From the first-order condition of the selfish consumer it follows that $o^*(0) = \frac{\gamma}{\kappa}$. For environmentally conscious consumers, if $\gamma > \kappa e$ it also follows that the interior solution is given by $o^*(\theta) = \frac{\gamma}{\kappa}$.

Because $\frac{\gamma}{\kappa} > e$, this solution violates the feasibility constraint. Moreover, the objective function is strictly concave in o. Therefore, the social planner optimally sets $o^*(\theta) = e$ for all θ.■