Going Net Zero? Carbon Footprinting and Pricing Under Climate Concerns*

Marco Bertini, Stefan Buehler, Daniel Halbheer, and Donald R. Lehmann†

January 24, 2020

Abstract

This paper studies how marketers should design a product by choosing the carbon footprint and price when consumers have climate concerns. The authors first show how the cost and demand effects of reducing the carbon footprint determine the profit-maximizing carbon footprint and price, and examine how marketers should adjust the product design in the face of stronger climate concerns. Paradoxically, they find that stronger climate concerns may increase the firm's overall climate impact. Next, the authors establish that offsetting the carbon emissions to reach a net zero carbon footprint may create an economically efficient win-win outcome for the firm and the climate, even if the product's carbon footprint is higher than without offsetting. The authors also show how government regulation in the form of a cap-and-trade scheme or a carbon tax affects product design, firm profitability, and the adoption of green technologies. Finally, the authors study optimal product design and carbon offsetting under competition.

Keywords: Green marketing, product design, organizational carbon footprint, carbon regulation.

---

*We thank Samuel Haefner, Vasiliki Kostami, Armin Schmutzler, and participants at the EMAC 2019 (Hamburg) for helpful comments and suggestions. Daniel Halbheer gratefully acknowledges the financial support of the HEC Foundation and Labex Ecodec (ANR-11-LABEX-0047).

†Marco Bertini (corresponding author): ESADE—Ramon Llull University, Avinguda de la Torre Blanca, 59, 08172 Sant Cugat del Vallès, Spain (marco.bertini@esade.edu). Stefan Buehler: University of St. Gallen, Institute of Economics (FGN), Varnbüelstrasse 19, 9000 St. Gallen, Switzerland (stefan.buehler@unisg.ch); CESifo, Munich. Daniel Halbheer: HEC Paris, Marketing Department, 1 rue de la Libération, 78351 Jouy-en-Josas Cedex, France (halbheer@hec.fr); member of the CNRS unit GREGHEC, UMR CNRS 2959. Donald R. Lehmann: Columbia Business School, Uris Hall, 3022 Broadway, New York, NY 10027, United States (drl2@columbia.edu).

1 Introduction

The consequences of climate change have become apparent and touch everything (IPCC 2018). Although most nations have committed themselves to reducing greenhouse gas emissions at the Rio Summit in 1992, 50 percent of the carbon dioxide humankind has released into the atmosphere since the industrial revolution was added after 1990 (*The Economist* 2019). As the planet warms up, the debate about climate change gets increasingly heated. Greta Thunberg, a teenage climate activist, condemned world leaders gathered at the 2019 U.N. Climate Action Summit held in New York: “How dare you continue to look away!”[1]

Business is also under attack. In December 2019, the *The Guardian* (2019) accused fossil fuel companies of “dither and denial.” Airlines also face strong headwinds: “Flight-shaming” (*Forbes* 2019) and the European Commission’s Green Deal, which challenges tax exemptions on kerosene and free carbon allowances under Europe’s emissions trading system, pose a threat to their business model (*Bloomberg* 2019). Amid much fanfare, several airlines have responded by adopting approaches that are broadly in line with the three-step process “Measure, Reduce, Offset” outlined in the U.N. Climate Neutral Now initiative.[2] *EasyJet* announced its decision to go net zero and claims to be “the first major airline to offset the carbon emissions from the fuel used for every single flight.” *British Airways* made a similar move and communicated that “from January 2020, we’ll become the first UK airline to offset carbon emissions on domestic flights.” *JetBlue* goes net zero as of July 2020, making it the first major US airline to do so. Other airlines, however, do not offset their carbon emissions. This raises the natural question of how marketers should adjust the design of their products in response to climate concerns of consumers and regulators.

This paper develops a model of profit-maximizing carbon footprinting and pricing under climate concerns and studies when marketers should go net zero by offsetting

[1] The video of the Special Address is available at `http://bit.ly/Thunberg2019`.

[2] See `https://offset.climateneutralnow.org/`.

their carbon emissions. The emergence of climate concerns across the world is well documented (Whitmarsh and Capstick 2018; Wicker and Becken 2013), and the media coverage of climate change, especially the need to reduce the carbon footprint, drives consumers to make more sustainable consumption decisions (Chen et al. 2019; Holt and Barkemeyer 2102). Calculating *carbon footprints*—the climate impact measured in carbon dioxide equivalent (CO_2eq) emissions—has become standard (Meinrenken et al. 2012; Vandenbergh, Dietz, and Stern 2011) in life-cycle analysis. In many markets, these footprints are certified by consulting firms based on international accounting standards (GHG Protocol 2011; ISO 2006) and communicated to consumers.[3] Knowing the carbon footprint is also key to assess the profitability of going net zero by offsetting carbon emissions. In principle, any company can go net zero by buying offset services (investing in projects that provide for the planting of trees, renewable energy, etc.) from providers such as *Carbon Footprint Ltd*, *Gold Standard*, or *myclimate*.

The starting point of our analysis is a monopoly setting in which a marketer designs a product (or service) by choosing the carbon footprint and price.[4] Importantly, changes in the carbon footprint not only have a cost effect but also a demand effect. The key difference from a standard model where the firm chooses price and (inverse) "quality" is that the total number of purchases made by consumers not only determines the firm's profit but also its climate impact, which may cause a market externality (depending on the strength of the consumers' climate concerns). In addition, a regulator may want to curb the firm's climate impact. Product design is therefore endogenously determined by the interplay of the choices made by the firm, consumers, and the regulator. Figure 1 summarizes the main components of the analytical framework.

[3]Carbon footprinting plays not only a role in firm-to-consumer markets but also in business-to-business markets to understand the climate impact of the supply chain (Diabat and Simchi-Levi 2010).

[4]Using terminology from the Greenhouse Gas Protocol (2011), we define the carbon footprint as "cradle-to-gate emissions," which include production emissions (Scope 1) and emissions from purchased energy (Scope 2). The model abstracts from consumption emissions (Scope 3) because they are hard to measure in practice (Meinrenken et al. 2012).

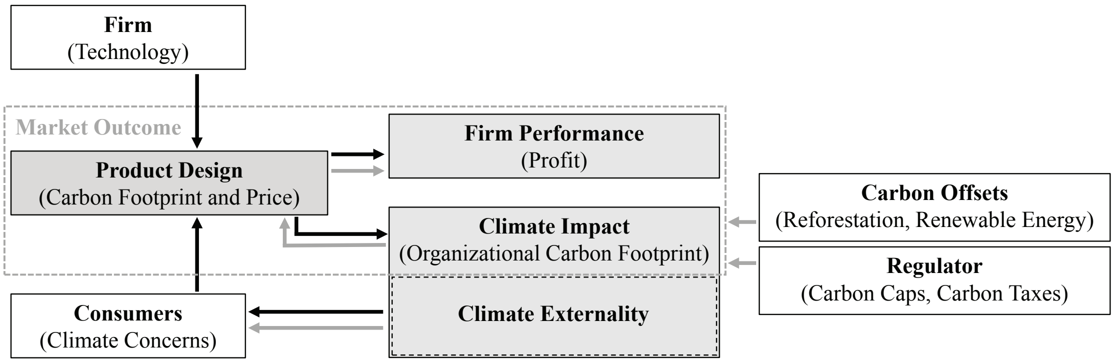

Figure 1: Components of the analytical framework.

We derive three key results for this basic analytical framework. *First*, we show that the optimal carbon footprint depends on the size of the cost effect relative to the demand effect of reducing the carbon footprint.[5] This result reflects the familiar "return on quality" logic (Rust, Moorman, and Dickson 2002; Rust and Zahorik 1993; Rust, Zahorik, and Keiningham 1995). *Second*, we analyze how marketers should respond to stronger climate concerns. If reducing the carbon footprint lowers cost, stronger climate concerns do not affect product design and profit. Otherwise, the impact on profit-maximizing product design is ambiguous. We identify the conditions under which it is optimal for marketers to decrease the carbon footprint and increase the price. In addition, we note that, depending on the shape of the demand curve, stronger climate concerns may motivate the firm to increase (rather than decrease) its carbon footprint. *Third*, we show that the firm's climate impact may increase with stronger climate concerns even when it reduces the product's carbon footprint. This result is reminiscent of the rebound effect from technological progress (Alcott 2005) and occurs if the demand-enhancing effect of lowering the carbon footprint outweighs the reduction in the carbon footprint (i.e., the firm falls victim to its success in reducing the carbon footprint at the individual product level).

[5]In particular, it is optimal to offer the product with the lowest cost and highest carbon footprint if the demand effect is zero (i.e., in the standard setting where consumers have no climate concerns).

We then extend the analysis in several directions. First, we introduce the ability of the firm to purchase carbon offsets to attain a net zero climate impact ("go net zero"). As a result, a firm may be able to offer a climate-neutral product (after offsetting) even if its carbon footprint (before offsetting) is large. We show that it is optimal for marketers to go net zero if the compensation cost is sufficiently low relative to the demand-enhancing effect of reducing the carbon footprint to net zero. In this case, going net zero is a "win-win" strategy in the sense that the climate impact decreases while the firm's profit increases relative to the case without offsetting. We show that going net zero is more attractive for marketers when climate concerns are stronger.

Second, we examine the profit-maximizing product design from a welfare perspective. Specifically, we explore how the marketer's decisions reflect on corporate social responsibility (CSR), assuming that the firm is sensitive to the triple bottom line of profit, planet and people. We show that the profit-maximizing carbon footprint generally deviates from the socially optimal level in the absence of offsetting. A net-zero carbon footprint, in turn, is economically efficient if the cost of offsetting is sufficiently low compared to the social cost of the climate impact. These results support the view that a focus on the profit bottom line may be inconsistent with corporate social responsibility.

Third, we analyze how carbon regulation affects a firm's product design and climate impact. We study three popular instruments (The World Bank 2015): carbon caps, cap-and-trade systems, and carbon taxes. We find that these instruments typically reduce firm profit. In addition, we show that while a carbon cap is well-suited to curbing the firm's overall climate impact, it may increase (rather than decrease) the product carbon footprint, whereas a carbon tax may reduce the carbon footprint but has an ambiguous impact on the climate impact. We also consider the impact of carbon regulation on the adoption of a green technology.

Finally, we show that our results on the profit-maximizing product design and carbon offsetting generalize to settings with competition. Considering a setting with two firms and both horizontal and vertical product differentiation, we show that going net zero is a "win-win" strategy for both firms under reasonable assumptions: Specifically, while the decision of the competitor to go net zero reduces the competitive advantage of adopting an offset strategy, it remains the strictly dominant strategy for both firms if the offset technology is sufficiently cost effective. This suggest that providing efficient carbon removal technologies can accelerate the transition to a low-carbon economy.

Our results contribute to the marketing literature along several dimensions. First, we add to the research on green product development (Chen 2001) by showing how carbon footprinting and pricing are determined by the interplay of climate concerns of consumers (Kotler 2011), firm technology, and market regulation (Porter and van der Linde 1995). By endogenizing product design, this paper also adds to the "return on quality" literature (Rust, Moorman, and Dickson 2002; Rust and Zahorik 1993; Rust, Zahorik, and Keiningham 1995). Importantly, we provide a welfare analysis to help managers understand the climate impact of product design decisions, and thereby add to the sustainability literature in marketing (Cronin et al. 2011; Huang and Rust 2011; Luo and Bhattacharya 2006; Papadas, Avlonitis, and Carrigan 2017) by providing a formal analysis of the triple bottom line approach. We extend Chen (2001) and related literature in supply chain management and engineering (Cheng and Zhang 2017; Diabat and Simchi-Levi 2010; He et al. 2019; Yalabik and Fairchild 2011) by showing that the carbon footprint creates a climate externality and determines the organization's climate impact. The key difference is that we derive demand from primitives and account for the climate externality, which allows us to provide the first analysis of carbon offsetting.

Our results also contribute to the economics literature on regulation (Armstrong and Sappington 2007) by showing how carbon caps and carbon taxes (Cremer and Thisse 1999) affect profit-maximizing product design. We extend classic work by (Spence 1975) by showing how climate externalities affect optimal price and quality decisions. In addition, we show that climate regulation can trigger investments in green technologies, thereby adding to the insights of Porter and van der Linde (1995) on the dynamic impact of regulation and the economics of climate science more broadly (Hsiang and Kopp 2018; Nordhaus 2019; Stern 2008).

The remainder of the paper is organized as follows. Section 2 introduces the model. Section 3 focuses on the profit-maximizing product design, studies the impact of stronger climate concerns of consumers on the optimal carbon footprint and price, and examines the firm's overall climate impact. Section 4 examines the conditions under which it is profitable for the firm to offset its climate impact. Section 5 studies the extent to which profit-maximizing product design is consistent with corporate social responsibility. Section 6 investigates the impact of carbon regulation. Section 7 generalizes the analysis to a setting with competition. Section 8 concludes by highlighting limitations and offering directions for future work. To facilitate exposition, all proofs are relegated to the Appendix.

2 The Model

Consider a marketer that designs a product (or service) by choosing the price $p \geq 0$ and carbon footprint $\kappa \in [0, \overline{\kappa}]$, the emissions generated by producing a single unit of the product measured in carbon dioxide equivalents (CO_2eq). The set $[0, \overline{\kappa}]$ indicates the technologically feasible carbon footprints, where the marketer offers a *carbon neutral product* with zero emissions if $\kappa = 0$ and a maximally polluting *brown product* if $\kappa = \overline{\kappa}$. The technology of the firm gives rise to the unit cost function $c(\kappa)$ over the interval $[0, \overline{\kappa}]$.

There is a unit measure of consumers who have climate concerns and evaluate the product based not only on intrinsic features and price p, but also on the carbon footprint κ. Specifically, a buyer derives utility

$$u(\kappa, p; \lambda) = v - p - z(\kappa; \lambda) - E, \tag{1}$$

where v is the valuation of the intrinsic product features, $z(\kappa; \lambda)$ measures the disutility from purchasing a product with carbon footprint κ, with $\lambda \geq 0$ capturing the strength of climate concerns, and where $E \geq 0$ is the disutility from the climate externality caused by other buyers. Because a single buyer has no impact on the climate externality, E is the same irrespective of whether or not the consumer purchases the product. Normalizing the intrinsic utility of the outside option to zero, a consumer therefore purchases the product if the valuation of the intrinsic product features v exceeds the perceived price $p+z(\kappa;\lambda)$.

The unobserved valuation of the intrinsic features v is distributed independently across consumers according to the cumulative distribution function $F(v)$. The disutility $z(\kappa;\lambda)$ is increasing and convex in κ, that is, $z_{\kappa}(\kappa;\lambda)>0$ and $z_{\kappa\kappa}(\kappa;\lambda)\geq 0$, and can be interpreted as the guilt or "cold prickle" (Andreoni 1995) of causing a climate impact. We set the disutility to zero if consumers do not have climate concerns or if the product is carbon neutral, that is, $z(\kappa;0)=z(0;\lambda)=0$.[6] The other boundary case occurs if consumers have strong climate concerns, in which case we assume that $\lim_{\lambda\to\infty} z(\kappa;\lambda)=\kappa$. We further assume that stronger climate concerns increase the disutility from a given carbon footprint, that is, $z_{\lambda}(\kappa;\lambda)>0$.

Consumers purchase if the utility from the product exceeds their utility from the outside option. Therefore, the demand for the product is derived as

$$D(\kappa,p;\lambda)=1-F(p+z(\kappa;\lambda)). \tag{2}$$

Demand is decreasing in the carbon footprint and price. Interpreting the carbon footprint as an inverse measure for product quality, a lower κ means higher quality and therefore higher demand. Lowering the carbon footprint implies *demand neutrality* when consumers do not care about the climate impact ($D_{\kappa}=0$) and *demand expansion* when consumers have climate concerns ($D_{\kappa}<0$). The novel aspect here is that "product quality" not only affects demand but also has a climate impact.

The climate impact of the firm is calculated by multiplying the product carbon footprint by demand and therefore given by $\kappa D(\kappa,p;\lambda)$. If buyers do not fully account for their carbon emissions, they create a climate externality (see Figure 1), "the biggest market failure the world has seen" (Stern 2008, 1). The climate externality results from adding up the non-internalized carbon emissions across buyers:

[6] Alternatively, one can interpret the disutility $z(\kappa;\lambda)$ as the extent to which the product deviates from the "should expectation" (Boulding, Staelin, Kalra and Zeithaml 1994; Tse and Wilton 1988) of a carbon neutral product, an assumption that can be relaxed to include an arbitrary reference point.

$$E(\kappa, p; \lambda) = [\kappa - z(\kappa; \lambda)]D(\kappa, p; \lambda). \tag{3}$$

This externality is reduced to zero when consumers have strong climate concerns ($z(\kappa;\lambda) = \kappa$) and equals the overall climate impact if consumers do not care about creating a carbon footprint ($z(\kappa; 0) = 0$). Note that the externality therefore has distributional consequences but does not affect the overall climate impact.

3 Baseline Case

This section first derives the profit-maximizing carbon footprint and price, and studies how the climate concerns of consumers affect the optimal product design. Next, we consider the impact of product-level decisions on the firm's overall carbon emissions. We assume throughout that the profit function is strictly concave and thus has unique constrained global maximizer.

3.1 Profit-Maximizing Carbon Footprint and Price

The marketer chooses the carbon footprint κ and the price p of the product to maximize profit. More formally, the marketer solves

$$\begin{aligned} \max_{\kappa, p} \quad & \pi(\kappa, p; \lambda) = [p - c(\kappa)]D(\kappa, p; \lambda) \\ \text{s.t.} \quad & 0 \leq \kappa \leq \overline{\kappa}. \end{aligned} \tag{4}$$

The profit function shows that both the carbon footprint and price have a dual impact on markup and demand. Our first result characterizes the optimal product design denoted by $(\kappa^*, p^*(\kappa^*))$.

Proposition 1. *If reducing the carbon footprint lowers unit cost, marketers should offer a carbon neutral product with* $\kappa^* = 0$ *at price* $p^*(0)$*. Instead, if reducing the carbon footprint increases unit cost but not demand, then it is optimal to offer a brown product* *with* $\kappa^* = \overline{\kappa}$ *at price* $p^*(\overline{\kappa})$. *Offering a green product with* $\kappa^* \in (0, \overline{\kappa})$ *at price* $p^*(\kappa^*)$ *is optimal if the demand effect outweighs the cost effect.*

Proposition 1 mirrors the familiar "return on quality" logic (Rust, Moorman, and Dickson 2002; Rust and Zahorik 1993; Rust, Zahorik, and Keiningham 1995) and has two important implications for marketers. First, if lowering the carbon footprint reduces unit cost, then it is optimal to increase efficiency (e.g., by eliminating waste) and thereby increase "process quality" (Deming 1986; Crosby 1979). Such green cost cutting is more attractive to the marketer when lowering the carbon footprint not only reduces cost but also increases demand because of higher perceived "product quality" (Parasuraman, Zeithaml, and Berry 1985). This result helps to explain why many sustainability efforts increase firm profit (Winston, Favaloro, and Healy 2017).

Second, if lowering the carbon footprint increases unit cost, there may be a tradeoff between the cost effect and the demand effect. Absent a demand effect, lowering the carbon footprint only results in higher unit cost and is therefore suboptimal under profit maximization. However, when the increase in demand outweighs the profit impact of higher unit cost, marketers should offer a *green product* that has a smaller carbon footprint than the maximally polluting product. In contrast to cost-cutting sustainability, cost-increasing sustainability reflects the idea that "major pressure for changing marketing practices may come from consumers themselves" (Kotler 2011) and can be viewed as one of the "sustainability programs worthy of the name" (*The Economist* 2014). Figure 2 summarizes the optimal product design strategies derived in Proposition 1 as a function of the cost and demand effects.

3.2 The Impact of Stronger Climate Concerns

Stronger climate concerns strengthen the negative demand effect and affect the optimal product design and firm profitability. The next result summarizes the implications for marketers.

<table>
<tr><th></th><th>Demand Neutrality
($D_\kappa = 0$)</th><th>Demand Expansion
($D_\kappa < 0$)</th></tr>
<tr><td>Cost Reduction
($c' > 0$)</td><td colspan="2">$\kappa^* = 0$ and $p^*(0)$
Carbon Neutral Product</td></tr>
<tr><td>Cost Increase
($c' < 0$)</td><td>$\kappa^* = \overline{\kappa}$ and $p^*(\overline{\kappa})$
Brown Product</td><td>$\kappa^* \in (0, \overline{\kappa})$ and $p^*(\kappa^*)$
Green Product</td></tr>
</table>

Figure 2: Cost and demand effects of lowering the carbon footprint, and optimal product design.

Proposition 2. *If reducing the carbon footprint lowers unit cost, stronger climate concerns affect neiter the optimal product design nor profit. However, if reducing the carbon footprint increases unit cost, stronger climate concerns reduce profit and have an ambiguous effect on the optimal product design. Lowering the carbon footprint and increasing price is optimal if the demand effect is sufficiently strong compared to the cost effect.*

Proposition 2 has two implications for marketers. First, it shows that stronger climate concerns may increase (rather than decrease) the profit-maximizing carbon footprint. Intuitively, a lower carbon footprint may lead to a large cost effect and thereby create upward pressure on the price that outweighs the demand effect of the lower carbon footprint. Interpreting the carbon footprint as an inverse measure for product quality, Proposition 2 implies an ambiguous relationship between product quality and price and thereby adds to the literature on price-quality relationships (Gerstner 1985; Parasuraman, Zeithaml and Berry 1985).

Second, Proposition 2 implies that marketers have a motive to downplay climate concerns due to their negative impact on profit. It suggests an intuitive explanation for climate change denial by polluting firms (Krugman 2018; Mann and Toles 2016). This result also points to a potential tension between marketers and managers who are in charge of corporate social responsibility (CSR). As we will show in Section 5, one way organizations can resolve this tension is by adopting a triple bottom line.

3.3 Climate Impact

The first two propositions are intuitive and essentially extend the logic of profit-maximizing product design to a setting where consumers have climate concerns and may suffer from a climate externality. This section provides new insights on how product design affects the overall climate impact of the firm (also referred to as organizational carbon footprint).

Proposition 3. *The climate impact of the firm is* $\Phi^* = \kappa^* D(\kappa^*, p^*; \lambda)$. *Stronger climate concerns may increase the climate impact* Φ^* *even when it is optimal for marketers to reduce the product carbon footprint* κ^*.

Proposition 3 shows that reducing the product carbon footprint in response to stronger climate concerns does not necessarily reduce a firm's overall level of carbon emissions. This occurs because the demand effect may result in higher sales and thus a greater climate impact—a situation where marketers who offer a product with a lower carbon footprint fall victim to their own success. This is reminiscent of the rebound effect from technological progress (Alcott 2005): higher efficiency leads to an initial reduction in demand that is outweighed by an increase in demand due to relatively lower resource cost ("Jevons paradox"). Proposition 3 thus suggests that, surprisingly, designing greener products may be in conflict with the objective of meeting climate targets mandated by law.

4 Carbon Offsetting

Since climate change is a global environmental phenomenon, marketers can achieve climate neutrality either by offering a product with a zero carbon footprint ($\Phi^* = 0$), or by adopting an offset strategy where the firm's climate impact ($\Phi^* > 0$) is fully compensated for elsewhere (by funding projects that achieve an equivalent level of carbon dioxide saving), thereby creating a net zero carbon footprint.[7] While carbon offsetting is arguably

[7] In contrast, there is no offset strategy for a local environmental problem such as water pollution where the damage cannot be eliminated by reducing the pollution elsewhere.

not the solution to climate change, it may allow marketers to achieve climate neutrality even if the available production technology does not (yet) allow for a zero carbon footprint.

The purpose of this section is to study under what conditions marketers can benefit from adopting an offset strategy. To this end, suppose that an offset provider charges a fixed price $\omega \geq 0$ per unit of carbon offset. The marketer then chooses the carbon footprint κ and the price p to

$$\begin{aligned} \max_{\kappa,p} \quad & \pi(\kappa,p;\omega) = [p - c(\kappa) - \omega\kappa]\, D(0,p) \\ \text{s.t.} \quad & 0 \leq \kappa \leq \overline{\kappa}, \end{aligned} \tag{5}$$

where $\omega\kappa D(0,p)$ is total cost of compensating for the emissions to the firm to achieve a net zero carbon footprint. Importantly, with carbon offsets, demand depends on the net zero carbon footprint rather than the product carbon footprint κ. The next result points to the possibility of a win-win outcome for the marketer and the climate, where the benchmark is provided by the no-offset strategy where marketers do not compensate for the emissions.

Proposition 4. *Adopting an offset strategy is optimal for marketers if the compensation costs are sufficiently low compared to the demand-enhancing effect of reducing the climate impact to net zero. Surprisingly, using an offset strategy motivates marketers to increase the carbon footprint before offsetting the emissions. Stronger climate concerns make the adoption of an offset strategy more attractive to marketers.*

Proposition 4 shows that offsetting carbon emissions can boost profit *and* do good for the climate. The key driver for this result is that relieving consumers from guilt by offering a product with a net zero carbon footprint has a demand-enhancing effect that directly translates into higher profit. Intuitively, the increase in demand comes from the ability of the marketer to monetize guilt by bundling the product with carbon removal in a cost-efficient way to achieve a net zero carbon footprint. This profit effect may be reinforced by the lower unit cost that result from a higher carbon footprint (before compensation). In exchange, marketers must cover offsetting costs that are otherwise absent.

Our analysis shows that marketers are more prone to adopting an offset strategy when the price per unit of carbon offset is low. This suggests that providing low-cost carbon offset options to firms might curb their climate impact even when the standard tools of carbon regulation (see Section 6 below) are not effective.

5 Corporate Social Responsibility

Sustainability is generally viewed as the triple bottom line of economic profitability, respect for the environment, and social justice (Boyd 2001; Huang and Rust 2011; Johnson 2009). To integrate these pillars of sustainability into the analysis, we define corporate social responsibility as the total welfare: the firm and the offset provider (profit), the climate impact (planet), and consumer surplus (people). That is, marketers behave in a manner that is consistent with corporate social responsibility if they go beyond the profit bottom line and effectively consider welfare. The issue of social justice is captured by the climate externality contained in consumer surplus. Our next result shows that the adoption of an offset strategy can create a triple-win outcome for firms.

Proposition 5. *The carbon footprint under a no-offset strategy is positive and generally different from the socially optimal level. Adopting an offset strategy that results in net zero emissions is economically efficient if the cost of carbon removal is sufficiently low compared to the social cost of the climate impact.*

Proposition 5 confirms the notion that an exclusive focus on a profit bottom line leads marketers to make decisions that are generally inconsistent with corporate social responsibility. Intuitively, marketers have an incentive to strategically distort the carbon footprint to exploit pricing power, which leads to an economically inefficient carbon footprint (Spence 1975). Interestingly, under an offset strategy, profit-maximization may result in a net zero carbon footprint even if it is socially undesirable to fully compensate for the emissions. However, if the carbon removal technology is sufficiently cost effective, the win-win outcome for the marketer and the climate under an offset strategy translates into a triple-win outcome and therefore produces benefits for society at large. This suggests that subsidizing carbon removal technology rather than carbon removal itself may be a more attractive government strategy.

In addition, Proposition 5 sheds light on the controversial debate about carbon offsets that "have been used by polluters as a free pass for inaction" (*United Nations Environment Programme* 2019). The cost efficiency of carbon compensation arguably stems from the fact that emissions are mostly offset in developing countries. Even though these offsets may be economically efficient, marketers have to bear in mind "whose mess this is" and that "some of these places would welcome investment in reforestation and afforestation, but they would also need to be able to integrate such endeavours into development plans which reflect their people's needs" (*The Economist* 2019).

6 Carbon Regulation

Regulators increasingly try to limit carbon emissions of firms to meet climate targets and address climate change. The most recent examples include the Green New Deal in the United States and the European Green Deal that aim to address climate change by introducing various regulatory interventions. We next show how marketers should respond to carbon caps, cap-and-trade systems, and carbon taxes, and study their impact on expected firm profitability. While the institutional details of these interventions vary across industries and legislations, we focus on their key characteristics and show that the risk of regulation accelerates investments in green technology.

6.1 Carbon Caps

The most direct approach to limit a firm's climate impact $\Phi(\kappa, p; \lambda)$ is to impose a binding carbon cap $R \geq 0$. In such a business environment, the marketer solves the following problem:

$$\max_{\kappa,p} \quad \pi(\kappa,p;\lambda) = [p-c(\kappa)]D(\kappa,p;\lambda) \tag{6}$$
$$\text{s.t.} \quad 0 \leq \kappa \leq \overline{\kappa} \quad \text{and} \quad \Phi(\kappa,p;\lambda) \leq R.$$

The next result summarizes the impact of a strict limit on overall emissions.

Proposition 6. *A binding carbon cap reduces the firm's climate impact and profit, but may induce the marketer to increase the product carbon footprint to reduce sales and thereby comply with the regulation.*

A binding carbon cap has the obvious effect of reducing the firm's climate impact and profit. More interestingly, a binding carbon cap may have the unintended consequence of increasing the carbon footprint. The intuition for this result is driven by the demand effect of lowering κ: If $\Phi_\kappa(\kappa, p; \lambda) < 0$, then lowering the carbon footprint leads to higher overall emissions even though κ is smaller. Consequently, the marketer has an incentive to increase κ and thereby purposely reduce sales to meet the carbon target (demarketing). Instead, if $\Phi_\kappa(\kappa, p) > 0$, lowering κ relaxes the carbon constraint, this provides an incentive for the marketer to lower the carbon footprint. The impact on price is ambiguous because of the simultaneous cost and demand effects of a change in κ. In reality, carbon caps are often coupled with a carbon market, where firms can sell or purchase carbon allowances, which gives rise to emissions trading systems.

6.2 Cap-and-Trade Systems

The leading examples of cap-and-trade systems are California's Cap-and-Trade Program, the Chinese National Carbon Trading Scheme, and the European Union Emissions Trading System. Cap-and-trade systems have an advantage over carbon caps: Marketers of firms with low compliance costs can sell carbon allowances in the emissions market and turn them into a source of revenue. For example, *Tesla* generates significant revenues by selling zero emission vehicle credits in the United States (*Financial Times* 2019).

The uncertain introduction of carbon regulation leads to regulatory uncertainty for marketers. To capture this uncertainty, suppose that a regulator is expected to introduce a cap-and-trade system with probability $\rho \in [0,1]$, with carbon cap $R \geq 0$. In this case, marketers can choose among two options: adjust the product design to meet the regulatory constraint at the organizational level, or stick to the current product design and purchase carbon allowances at a market price $\varpi \geq 0$ in an emissions market. Suppressing the arguments of the functions to simplify exposition, the respective profits are denoted by π^r and $\pi^* - \varpi(\Phi^* - R)$, where $\varpi(\Phi^* - R)$ is the cost to the firm of purchasing carbon allowances if the marketer decides to not meet the carbon cap. The following result summarizes the expected cost of regulation (CR).

Proposition 7. *The expected cost of a carbon cap to the firm is given by* $CR = \rho \min\{\pi^* - \pi^r, \varpi(\Phi^* - R)\}$*, where* $\rho(\pi^* - \pi^r)$ *is the expected reduction in profit if the firm complies with the carbon cap and* $\rho\varpi(\Phi^* - R)$ *is the expected reduction in profit if the firm purchases carbon allowances to offset the emissions. The cost of regulation increases when the implementation probability* ρ *is higher, when the carbon cap* R *is more severe, and when the carbon price* ϖ *is higher.*

Proposition 7 confirms the intuition that cap-and-trade regulation with a binding carbon cap reduces the expected profit of the firm. Further, the cost of regulation to the firm is increasing in the probability of regulation and the market price for emissions. This is important because companies should anticipate changes in the regulatory environment and thus want to invest in the adoption of a greener technology to comply with expected regulation. Similar to a binding carbon cap, the impact of the regulation on the product design is generally ambiguous.

6.3 Carbon Taxation

In December 2019, the International Monetary Fund issued a report suggesting that a global average carbon price of 75$ a ton could hit the Paris accord (IMF 2019). While a carbon cap directly limits the climate impact, a Pigouvian-style carbon tax alters the cost structure of the firm with the goal of achieving a more socially optimal level of emissions. To reflect this, assume that $t \geq 0$ is the fixed tax rate on carbon emissions. Under this proportional carbon tax, the marketer solves

$$\begin{aligned} \max_{\kappa,p} \quad & \pi(\kappa,p;\lambda,t) = [p - c(\kappa) - t\kappa]D(\kappa,p;\lambda) \\ \text{s.t.} \quad & 0 \leq \kappa \leq \overline{\kappa}. \end{aligned} \tag{7}$$

The next result summarizes the impact on the marketing activities and firm profit, where the optimized product profit under a carbon tax is denoted by $\pi^*(t)$.

Proposition 8. *A carbon tax reduces the optimal carbon footprint if the demand effect is sufficiently strong compared to the cost effect but has an ambiguous effect on the climate impact. The expected cost of taxation is given by* $CR = \rho\{\pi^*(0) - \pi^*(t)\} > 0$*, which increases in the probability* ρ *that a tax will be implemented and the tax rate* t*.*

Proposition 8 mirrors stronger climate concerns of the regulator. While a higher tax rate may reduce the profit-maximizing carbon footprint, the effect on climate impact is ambiguous because the product's lower carbon footprint may increase sales and therefore the overall emissions (a rebound effect). The result also shows that the uncertain introduction of a carbon tax reduces expected profit for the firm: The carbon tax increases unit cost and thereby reduces firm profitability, as the increase in cost can only be partially passed on to consumers in the form of higher prices, similar to the imperfect pass-through of trade deals in the channel literature (Nijs, Misra, Anderson and Hansen 2010; Ailawadi and Harlam 2009; Kumar, Rajiv and Jeuland 2001; Moorthy 2005; Tyagi 1999).

The results show, similar to the climate concerns of consumers, that regulatory constraints reduce profit but have an ambiguous impact for marketers: the incentives to adjust the carbon footprint and price depend on the relative size of the cost and demand effects. The profit impact may explain why marketers lobby against regulation (Viscusi, Vernon and Harrington 2005). On the other hand, the results show why an offsetting strategy is an interesting option: a net zero carbon footprint makes regulation obsolete and has an immediate positive impact on the climate. In contrast, a carbon tax affects the carbon footprint and raises revenue for the government without offsetting the emissions. However, carbon offsets do not provide an incentive for firms to invest in green technologies and are therefore often considered an interim measure while new technologies are developed.

6.4 Green Technology Adoption

The need to comply with carbon regulation may trigger investments in green technologies. To demonstrate this, we consider the case of a carbon cap and assume that an existing *brown technology* $c_0(\kappa)$ can be replaced with a new *green technology* $c_1(\kappa)$ at a fixed cost $f > 0$, where $c_0(\kappa) \geq c_1(\kappa)$ for all κ and $\overline{\kappa}_0 \geq \overline{\kappa}_1$. Letting π_0^* and π_1^* denote the profits in the absence of carbon regulation with the brown and the green technology, respectively, and letting CR_0^* and CR_1^* denote the corresponding costs of complying with regulation, the following result holds.

Proposition 9. *A firm facing the risk of regulation adopts the green technology if* $\pi_1^* - f \geq \pi_0^* - (CR_0^* - CR_1^*)$.

Proposition 9 shows that regulatory risk may provide an incentive for the firm to adopt the green technology. In particular, the uncertainty about the likelihood of carbon regulation relaxes the standard adoption condition $\pi_1^* - f \geq \pi_0^*$ if the green technology reduces the cost of regulation ($CR_1^* < CR_0^*$). Thus, the mere threat of carbon regulation may lead to the adoption of a green technology, greener product design, and a lower climate impact. Regulatory pressure can thus provide incentives for marketing managers and firms to do good for the climate by offering greener products, the standard link from regulation to promoting innovation (Porter and can der Linde 1995).

7 Competition

To this point we have explored a monopoly setting. In this section, we extend the setting to include competition. We first describe the interaction between the firms and the consumers, and then study conditions under which adopting an offset strategy is consistent with pursuing a triple bottom line.

7.1 Model

We now consider a market with two single-product firms $i = 1,2$ that compete on the carbon footprint κ_i and price p_i. The technology of the firm is represented by the unit cost function $c_i(\kappa_i) = c_i^0(1-\kappa_i)^2$, where $c_i^0 > 0$ is a firm-specific cost parameter. Carbon offsetting to achieve a net zero carbon footprint is provided by an independent provider at cost $\omega \geq 0$ per unit of carbon emissions. The carbon removal technology of the provider is represented by the unit cost $\phi \geq 0$ and fixed cost $F > 0$. Each firm can choose among two strategies: a no-offset strategy where the product is marketed with carbon footprint κ_i or an offset strategy where the product is marketed with a net zero carbon footprint.

The products are differentiated horizontally and vertically. Horizontal differentiation is à la Hotelling, with the firms located at the extremes of the characteristics space $[0,1]$, that is, $x_1 = 0$ and $x_2 = 1$. Vertical differentiation on the carbon footprint reflects the notion that a lower carbon footprint enhances the worth of the product in the minds of climate concerned consumers. The market consists of a unit mass of consumers. Individual preferences are described by a conditional indirect utility function

$$u_i(\kappa_i, p_i; \lambda) = v - p_i - z_i(\kappa_i; \lambda) - \frac{1}{2}|x - x_i| - E, \tag{8}$$

where v is the valuation of the intrinsic product features, $z_i(\kappa_i; \lambda) = \lambda \kappa_i$ is the disutility from purchasing a product with carbon footprint κ_i, and where $E \geq 0$ indicates the disutility from the climate externality caused by other buyers in the market. Following convention, we let $x \in [0,1]$ denote the consumer's preferred product characteristic and $|x - x_i|$ denote the horizontal distance to the product of firm i (Anderson, de Palma, and Thisse 1992).

		Firm 2	
		No Offset	*Offset*
Firm 1	*No Offset*	$\frac{1}{4}$, $\frac{1}{4}$	B, A
	Offset	A, B	$\frac{1}{4}$, $\frac{1}{4}$

Figure 3: Possible combinations of competitive interactions and corresponding profits for $c_1^0 = c_2^0 = 1$ and $\lambda = 1$, where $A > \frac{1}{4}$ and $B < \frac{1}{4}$.

The preferred product characteristics are drawn independently across consumers from a uniform distribution over the interval $[0,1]$. Demand of firm i as a function of the carbon footprints $\boldsymbol{\kappa} = (\kappa_1, \kappa_2)$ and prices $\mathbf{p} = (p_1, p_2)$ can be derived as

$$D_i(\boldsymbol{\kappa}, \mathbf{p}; \lambda) = \frac{1}{2} - \lambda(\kappa_i - \kappa_j) - (p_i - p_j). \tag{9}$$

Each firm can therefore obtain a competitive advantage over its rival by offering a product with a lower carbon footprint, by charging a lower price, or both.

7.2 Competitive Strategy

In a setting with two firms where each firm can either choose a no-offset strategy or an offset strategy, there are four possible competitive interactions: both firms adopt a no-offset strategy, both firms adopt an offset strategy, or one firm adopts an offset strategy while the other firm adopts a no-offset strategy. Figure 3 summarizes these competitive interactions. The following result holds.

Proposition 10. *When consumers have strong climate concerns and the offset technology is sufficiently effective, each firm can unilaterally increase its profit by adopting an offset strategy. Whereas the initial competitive advantage of an offset strategy is eroded by the reaction of the rival, each firm's choice of strategy is consistent with corporate social responsibility.*

To see what governs the optimal choice of strategy, consider a situation where both firms choose to not offset their carbon emissions initially (see the top-left cell in Figure 3). Once offsetting carbon emissions becomes sufficiently cheap, each firm can improve its profit due to the demand-enhancing effect of offering a product with a net zero carbon footprint. More specifically, under some conditions, each firm can create a win by adopting the offset strategy—irrespective of the rival's choice of strategy. In the symmetric equilibrium, each firm chooses an offset strategy and ends up earning the same profit as in the initial situation. However, had the firm not exploited the profit opportunity, its profit would have been lower because the rival would have attained a competitive advantage.

Interestingly, Proposition 10 shows that if the offset technology is sufficiently cost effective, competitive forces can indeed create a triple-win outcome for the industry. This has an important implication for policy makers: Providing efficient carbon removal technologies can accelerate the transition to a zero carbon economy by providing incentives for marketers to offer climate neutral products and services.

8 General Discussion

This paper has explored the impact of climate concerns on product design and the overall level of carbon emissions. Our analysis showed that reducing the carbon footprint of a product is always optimal if it increases efficiency by eliminating waste. If reducing carbon emissions increases cost, the optimal carbon footprint and price are not only driven by the cost effect, but also by the demand effect, which results from reducing the climate impact of the product. Furthermore, we showed that greener product design may actually increase the climate impact, where a firm that offers a green product falls victim to its own success due to higher sales. Finally, we showed how marketing activities, firm profitability, and green technology adoption are affected by carbon regulation in the form of cap-and-trade systems and carbon taxes.

The results confirm the intuition that climate concerns of consumers and regulators tend to reduce the carbon footprint of products and organizations. However, in many plausible cases, overall carbon emissions can increase due to the increase in demand for products with a lower carbon footprint. Importantly, the logic here applies beyond carbon emissions, e.g. to other pollutants and water or plastic footprints, and ecological footprints more broadly, which all play a key role in managing corporate social responsibility.

8.1 Managerial Implications

The analysis provides new insights into how marketers should respond to climate concerns by adjusting product design and pricing. Consumers with climate concerns have a lower willingness to pay for the product for a given carbon footprint and price, which provides an incentive for the firm to adjust product design and pricing. In some cases, this can lead to a firm offering two products: A non (or less) polluting one to appeal to consumers who are concerned with the environment and another targeted to consumers who are not. In contrast, climate concerns of the government that lead to carbon regulation force the firm to adjust its marketing activities to account for the specific type of regulation. These insights inform marketers under what conditions their activities contribute to a better world by reducing the climate impact of the organization. Designing greener products is not sufficient to reduce the firm's climate impact. More broadly, our results can also be used to help understand how firms can contribute to reduce anthropogenic greenhouse gas emissions.

Based on our analysis, climate concerns reduce firm profitability. The best a firm can do with a given technology is to adjust the product design. However, climate concerns may provide an opportunity to invest in green technologies, which allow the firm to reduce the cost of compliance with regulation. Interestingly, climate regulation can motivate marketers to push for a greener technology that reduces the carbon footprint of the product. Hence, taking a proactive approach to deal with climate concerns can mitigate the impact of more stringent regulation on firm profitability.

Our analysis can help marketers to set an internal carbon price—a shadow price used within an organization to reflect the external cost of carbon emissions. An internal carbon price impacts the marketing activities and the overall carbon footprint in the same way as a carbon tax set by a regulator. The *United Nations Global Compact* calls for companies to set an internal price at a minimum of $100 per metric ton by 2020 to put climate change at the heart of strategy and decision-making.[8] *Microsoft* took a leadership role in this by introducing an internal carbon fee in 2012 to achieve carbon neutrality and "maximizing the impact for our company on the three Ps (people, planet, and profit)" (*Microsoft* 2015).

Furthermore, our analysis highlights that marketing greener products may be in conflict with the goal of reducing the overall climate impact of the organization. This points to a possible tension between internal stakeholders, such as product managers and managers who are responsible for carbon management at the organizational level. Resolving the tension between "green products" and "green organizations" is important for positioning products and brands.

8.2 Limitations and Future Research Directions

Our analysis leads to several directions for future research. First, future research could examine how climate concerns are being shaped and are evolving over time. One approach is to assume that climate concerns are influenced by the firm's climate impact. Another approach is to assume that the firm or regulators can influence climate concerns via persuasive advertising. We predict that regulators will become more concerned over time and hence implement either stricter regulations or provide stronger incentives to reduce carbon emissions. These could either occur gradually or be influenced by a major event (e.g., Three-Mile Island, Chernobyl, and Exxon-Valdez incidents), i.e., have a discontinuity. However, because dealing with climate concerns typically increases cost, the incentives for a firm to produce and advertise less polluting products must come from the demand-enhancing effect of having a greener brand image. In that regard, one could explore the relative impact of different appeals (e.g., fear, currently used extensively, vs. social). Interestingly, the health communication literature suggests fear appeals are

[8] See `https://www.unglobalcompact.org/take-action/action/carbon` for details.

not very effective as are general appeals to society while implications for individuals or in-group members have more impact (Keller and Lehmann 2008).

Second, while our model provides a basis for thinking about the interplay between firm behavior and carbon emissions, the "real world" is more nuanced. Individuals differ in both their price sensitivity and the weight they put on carbon emissions (and these may not be independent of each other). One can extend the model to the case of a bimodal distribution of preferences (or the special case of a single mode plus a spike at zero for those who do not pay attention to the carbon footprint in their purchase decisions). Another interesting extension is to assume firms care intrinsically about carbon *per se*, in addition to profits. This would imply expanding the firms' objective function, as advocated by the triple bottom line approach (Cronin et al. 2011, Huang and Rust 2011). One could also assume the weight customers place on carbon footprints will increase the more customers "adopt" products with lower carbon emissions in a diffusion/contagion process.

In our model, we assume the firm is focused on a single product. To the extent reducing carbon output of one product causes the sales mix to change, the firm's total carbon output may change (go up if it switches customers from less-polluting options in its product line, down if they switch from more-polluting options). Similarly if the product draws customers from products outside the industry, their relative carbon output levels determine the impact on total carbon output. Another extension of the model is to consider not only production emissions, but also emissions that occur in the consumption stage. This would allow marketers to understand what drives the life-cycle carbon footprint of a product (a cradle-to-grave approach). The interesting aspect of such an extension is that the emissions in the consumption are driven by consumer behavior that cannot be easily influenced by the firm.

Third, one could study the role of competition in a more nuanced way. For example, competition is often asymmetric in terms of brand equity, resources, technical capabilities, and even objective functions (e.g., across countries). The behavior of current competitors can affect both demand and the likelihood and severity of governmental regulations

(Moorman, Du, and Mela 2005). In addition, new competitors may enter the market, including some with innovative ways to reduce carbon emissions.

Technological breakthroughs that improve the ability to produce products with lower carbon footprints and lead to higher demand (e.g., by adding new features) will also affect markets. Similarly, government regulations are likely to depend both on total industry pollution/carbon emissions and country level emissions, and may include both caps and taxes.

Another extension would be to explore in more depth the impact of climate concerns on the overall level of (industry or economy-wide) carbon emissions. For example, if one company decided to focus on those customers who care about carbon and lower their carbon footprint, another might choose to focus on consumers who do not care about the carbon footprint. If the second gained sales volume, industry carbon emissions could increase. Similarly, if regulators impose a specific target or limit, consumers might interpret that level as "good enough" and not reward companies that produced even lower levels. Relatedly, if regulators (e.g., the FTC) punished carbon reduction overstatement, this could lead companies to produce a higher level carbon product, similar to the result regarding regulating advertised quality in Kopalle and Lehmann (2015).

A significant limitation is that we do not have data on what managers or consumers would (as opposed to should) do. Empirical analysis of actual behavior would definitely be helpful in this regard. Alternatively, survey data (e.g., using conjoint analysis) on how managers would respond (or have responded) to increased climate concerns could provide important insights, although their accuracy is suspect.

Attempts to derive insights from actual data are hampered by the non-orthogonal design of the natural experiments in the world. For example, one could compare the carbon-sensitivity at the country level based on the average energy efficiency of appliances purchased, per capita electricity, gasoline consumption, or reliance on fossil fuels, with where the distribution of purchases falls on a price-carbon consequences line. Unfortunately the standard econometric issues of selection, omitted variable bias, and endogeneity make such analysis difficult.

Prescriptive research and suggestions is another potentially important focus. For example, one way for marketers to the reduce carbon footprint is to convert interactions with the customer to being more digital, for example purchasing (if transportation costs in fact are reduced) and service (e.g., by making self-service easier). Given the importance of the topic, further empirical, analytical, and simulation work is definitely called for. Agent-based simulation in particular can be useful for incorporating many of the extensions mentioned here.

References

Ailawadi, K.L., & Harlam, B.A. (2009). Retailer promotion pass-through: A measure, its magnitude, and its determinants. *Marketing Science*, 28(4), 782–791.

Alcott, B. (2005). Jevons' paradox. *Ecological Economics*, 54(1), 9–21.

Anderson, S.P., A. de Palma, & Thisse, J.-F. (1992), *Discrete Choice Theory of Product Differentiation*, MIT Press.

Andreoni, J. (1995). Warm-glow versus cold-prickle: the effects of positive and negative framing on cooperation in experiments. *Quarterly Journal of Economics*, 110(1), 1–21.

Armstrong, M., & Sappington, D.E.M. (2007). Recent developments in the theory of regulation. In M. Armstrong and R. Porter (eds.), *Handbook of Industrial Organization, Volume 3* (pp. 1557–1700). Amsterdam, North-Holland.

Bloomberg (2019). Business Class Flying Is Under Attack. Retrieved from `https://bloom.bg/2TOP9cff` (Last accessed: January 6, 2020).

Boulding W., Kalra A., Staelin, R. & Zeithaml V.A. (1993). Dynamic process model of service quality: From expectations to behavioral intentions. *Journal of Marketing Research*, 30(1), 7–27.

Boyd, C. (2001). Sustainability is good business. OECD Observer, 228 (September), bit.ly/2RDf6hu (Last accessed: December 12, 2019).

Chen, C. (2001). Design for the environment: A quality-based model for green product development. *Management Science*, 47(2), 250–263.

Chen, Y., Ghosh, M., Liu, Y. & Zhao, L. (2019). Media coverage of climate change and sustainable product consumption: Evidence from the hybrid vehicle market. *Journal of Marketing Research*, 56(6), 995–1011.

Cheng, Y. & Zhang, P. (2017). Optimal pricing and product carbon footprint strategies with different carbon policies and its implications. IEE, *International Conference on Service Systems and Service Management*, 1–6.

Cremer, H. & Thisse, J.J. (1999). On the taxation of polluting products in a differentiated industry. *European Economic Review*, 43(3), 575–594.

Cronin, J.J., Smith, J.S., Gleim, M.R., Ramirez, E., & Martinez, J.D. (2011). Green marketing strategies: An examination of stakeholders and the opportunities they present. *Journal of the Academy of Marketing Science*, 39(1), 158–174.

Crosby, P.B. (1979). *Quality is free: The art of making quality certain*. McGraw-Hill.

Deming, W.E. (1986). *Out of the crisis*. Boston: MIT Center for Advanced Engineering Study.

Diabat, A. & Simchi-Levi, D. (2010). A carbon-capped supply chain network problem. IEEE International Conference on Industrial Engineering and Engineering Management, 2009 (Piscataway, N.J.: IEEE): 523–527.

Financial Times (2019). *Fiat Chrysler pools fleet with Tesla to avoid EU emissions fines.* Retrieved from on.ft.com/2G4Lp2r (Last accessed: June 12, 2019).

Forbes (2019). Does Flight-Shaming Over Climate Change Pose An Existential Threat To Airlines? Retrieved from bit.ly/2WOx8wf (Last accessed: June 18, 2019).

Gerstner, E. (1985). Do higher prices signal higher quality? *Journal of Marketing Research*, 22(2), 209–215.

GHG Protocol (2011). *Corporate value chain (scope 3) accounting and reporting standard.* Retrieved from bit.ly/2SeYVDY (Last accessed: November 29, 2018).

He, B., Liu, Y., Zeng, L., Wang, S., Zhang, D., & Yu, Q. (2019). Product carbon footprint across sustainable supply chain. *Journal of Cleaner Production*, 241:118320.

Holt, D., & Barkemeyer, R. (2012). Media coverage of sustainable development issues–attention cycles or punctuated equilibrium? *Sustainable Development*, 20(1), 1–17.

Hsiang, S. & Kopp, R.E. (2018). An economist's guide to climate change science. *Journal of Economic Perspectives*, 32(4), 3–32.

Huang, M.H. & Rust, R.T. (2011). Sustainability and consumption. *Journal of the Academy of Marketing Science*, 39(1),

40–54.

IMF—International Monetary Fund (2019). *Putting a price on pollution*. *Finance & Development*, 56(4), Retrieved from bit.ly/2uw6Vd5 (Last accessed: January 23, 2020).

IPCC—Intergovernmental Panel on Climate Change (2018). *Global warming of 1.5°C: Summary for policymakers*. Retrieved from bit.ly/2znPTxn (Last accessed: December 7, 2019).

ISO—International Organization for Standardization (2006). *ISO 14064-1:2006 Greenhouse gases – Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.* Geneva, Switzerland. Retrieved from bit.ly/2DSR9fh (Last accessed: November 29, 2018).

Johnson, R.L. (2009). Organizational motivations for going green or profitability versus sustainability. *The Business Review*, 13(1), 22-–28.

Keller, P.A., & Lehmann, D.R. (2008). Designing effective health communications: A meta-analysis. *Journal of Public Policy & Marketing*, 27(2), 117–130.

Kopalle, P.K., & Lehmann, D.R. (2015). The truth hurts: How customers may lose from honest advertising. *International Journal of Research in Marketing*, 32(3), 251–262.

Kotler, P. (2011). Reinventing marketing to manage the environmental imperative. *Journal of Marketing*, 75(4), 132–135.

Krugman, P. (2018, November 26). The depravity of climate-change denial: Risking civilization for profit, ideology and ego. *The New York Times*. Retrieved from nyti.ms/2P2OdBX (Last accessed: November 29, 2018).

Kumar, N., Rajiv, S., & Jeuland, A. (2001). Effectiveness of trade promotions: Analyzing the determinants of retail pass through. *Marketing Science*, 20(4), 382–404.

Luo, X. & Bhattacharya, C.B. (2006). Corporate social responsibility, customer satisfaction, and market value. *Journal of Marketing*, 70(4), 1–18.

Mann, M.E. & Toles, M. (2016). *The madhouse effect: How climate change denial is threatening our planet, destroying our politics, and driving us crazy.* Columbia University Press.

Meinrenken, C.J., Kaufman, S.M., Ramesh, S., & Lackner, K.S. (2012). Fast carbon footprinting for large product portfolios. *Journal of Industrial Ecology*, 16(5), 669–679.

Microsoft (2015). Making an impact with Microsoft's carbon fee: Inspiring a virtuous cycle of environmental investment and action. Retrieved from bit.ly/2REjdYJ (Last accessed: June 23, 2019).

Moorman, C., Du, R. and Mela, C.F. (2005). The effect of standardized information on firm survival and marketing strategies. *Marketing Science*, 24(2), 263–274.

Moorthy, S. (2005). A general theory of pass-through in channels with category management and retail competition. *Marketing Science*, 24(1), 110–122.

Nijs, V., Misra, K., Anderson, E.T., Hansen, K., & Krishnamurthi, L. (2010). Channel pass-through of trade promotions. *Marketing Science*, 29(2), 250–267.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review*, 109(6), 1991—2014.

Papadas, K.K., Avlonitis, G.J. & Carrigan, M. (2017). Green marketing orientation: Conceptualization, scale development and validation. *Journal of Business Research*, 80, 236–246.

Parasuraman, A., Zeithaml, V.A., & Berry, L.L. (1985). A conceptual model of service quality and its implications for future research. *Journal of Marketing*, 49(4), pp. 41–50.

Porter, M.E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, 9(4), 97–118.

Rust, R.T., Moorman, C., & Dickson, P.R. (2002). Getting return on quality: Revenue expansion, cost reduction, or both? *Journal of Marketing*, 66(4), 7–24.

Rust, R.T. and Zahorik, A.J. (1993). Customer satisfaction, customer retention, and market share. *Journal of Retailing*, 69(2), 193–215.

Rust, R.T., Zahorik, A.J., & Keiningham, T.L. (1995). Return on quality (ROQ): Making service quality financially accountable. *Journal of Marketing*, 59(2), 58–70.

Spence, A.M. (1975). Monopoly, quality, and regulation. *The Bell Journal of Economics*, 6(2), 417–429.

Stern, N. (2008), The economics of climate change. *American Economic Review: Papers and Proceddings*, 98(2), 1–37.

The Guardian (2019, October 9). *Half a century of dither and denial – a climate crisis timeline.* Retrieved from http://bit.ly/2EVPVim (Last accessed: December 27, 2019).

The Economist (2019, December 7). *Climate change – The necessity of pulling carbon dioxide out of the air.* Retrieved from econ.st/36nQopi (Last accessed: December 10, 2019).

The Economist (2014, August 30). *Schumpeter – The new green wave.* Retrieved from econ.st/2vqKeEM (Last accessed: June 12, 2019).

The New York Times (2019, March 14). *Students across the world are protesting on Friday. Why?* Retrieved from nyti.ms/2O7oCFT (Last accessed: June 18, 2019).

The World Bank (2015). State and Trends of Carbon Pricing 2015 (Washington, DC). Retrieved from bit.ly/2VyBdVL (Last accessed: January 7, 2019).

Tse, D.K., & Wilton, P.C. (1988). Models of consumer satisfaction formation: An extension. *Journal of Marketing Research*, 25(2), 204–212.

Tyagi, R.K. (1999). A characterization of retailer response to manufacturer trade deals. *Journal of Marketing Research*, 36(4), 510–516.

United Nations Environment Programme (2019, June 10th). Carbon offsets are not our get-out-of-jail free card. Retrieved from bit.ly/349DZ6M (Last accessed: December 10, 2019).

Vandenbergh, M.P., Dietz, T., & Stern, P.C. (2011). Time to try carbon labelling. *Nature Climate Change*, 1(1), p. 4.

Viscusi, W.K., Vernon, J.M., & J.E. Harrington Jr. (2005). *Economic of Regulation and Antitrust* (4th ed.). MIT Press.

Whitmarsh, L. & Capstick, S. (2018). Perceptions of climate change. In S. Clayton and C. Manning (eds.), *Psychology and Climate Change* (pp. 13–33). Academic Press.

Wicker, P., & Becken, S. (2013). Conscientious vs. ambivalent consumers: Do concerns about energy availability and climate change influence consumer behaviour? *Ecological Economics*, 88, 41–48.

Winston, A., Favaloro, G., & Healy, T. (2017). Energy strategy for the C-suite. *Harvard Business Review*, 95(1), 139–146.

Yalabik, B., & Fairchild, R.J. (2011). Customer, regulatory, and competitive pressure as drivers of environmental innovation. *International Journal of Production Economics*, 131(2), 519–527.

Appendix

Proof of Proposition 1. Assuming that the profit function $\pi(\kappa, p; \lambda)$ is strictly concave, the profit-maximizing product carbon footprint κ^* and price p^* must satisfy the following necessary and sufficient Kuhn-Tucker conditions (the multipliers $\mu_i \geq 0$ are associated with the inequality constraints):

$$-c'(\kappa^*)D(\kappa^*, p^*; \lambda) + [p^* - c(\kappa^*)]D_\kappa(\kappa^*, p^*; \lambda) + \mu_1 - \mu_2 = 0 \tag{A.1}$$

$$D(\kappa^*, p^*; \lambda) + [p^* - c(\kappa^*)]D_p(\kappa^*, p^*; \lambda) = 0 \tag{A.2}$$

$$\mu_1 \kappa^* = 0 \text{ and } \mu_2(\kappa^* - \overline{\kappa}) = 0.$$

Depending on the slope of the cost function, there are two cases. First consider the case where $c'(\kappa) > 0$. Suppose that $D_\kappa = 0$ and that $\kappa^* > 0$. Then, (A.1) leads to a contradiction as $\mu_1 = 0$, so that $\kappa^* = 0$. This result holds a fortiori if $D_\kappa < 0$. Second, assume that $c'(\kappa) < 0$. If $D_\kappa = 0$, then a solution that involves $\kappa^* < \overline{\kappa}$ leads to a contradiction in (A.1), so that $\kappa^* = \overline{\kappa}$. Next, if $D_\kappa < 0$, then the optimal choice of the carbon footprint is governed by the relative strength of the cost effect and the demand effect: If $-c'(0)D + [p^* - c(0)]D_\kappa \leq 0$, then $\kappa^* = 0$, whereas if $-c'(\overline{\kappa})D + [p^* - c(\overline{\kappa})]D_\kappa \geq 0$, then $\kappa^* = \overline{\kappa}$; otherwise there is an interior solution with $\kappa^* \in (0, \overline{\kappa})$. □

Proof of Proposition 2. First, from Proposition 1, the firm sets $\kappa^* = 0$ and $p^*(0)$ under cost-decreasing sustainability. Since $D(0, p^*(0); 0) = D(0, p^*(0); \lambda)$ for $\lambda > 0$, stronger climate concerns leave profit unchanged.

Second, under cost-increasing sustainability, there are two subcases: the emergence and the reinforcement of climate concerns. In the absence of climate concerns ($\lambda = 0$), the profit at the optimal κ is given by $\pi(\overline{\kappa}, p; 0) = [p - c(\overline{\kappa})]D(\overline{\kappa}, p; 0)$. Instead, when consumers have climate concerns, ($\lambda > 0$), the profit at the optimal $\kappa^* \leq \overline{\kappa}$ is given by $\pi(\kappa^*, p; \lambda) = [p - c(\kappa^*)]D(\kappa^*, p; \lambda)$. Since the emergence of climate concerns reduces demand and (weakly) increases unit cost, this implies that

$$\pi(\kappa^*, p^*; \lambda) < \pi(\overline{\kappa}, p^0; 0), \tag{A.3}$$

where $p^* = \arg\max_p \pi(\kappa^*, p; \lambda)$ and $p^0 = \arg\max_p \pi(\overline{\kappa}, p; 0)$, which means that the emergence of climate concerns reduces profit. Note that while $\kappa^* \leq \overline{\kappa}$, the impact on pricing is ambiguous due to the countervailing cost and demand effects.

Instead, when climate concerns are reinforced, applying the envelope theorem yields

$$\frac{\pi(\kappa^*, p^*; \lambda)}{d\lambda} = [p^* - c(\kappa^*)]D_\lambda(\kappa^*, p^*; \lambda) < 0, \tag{A.4}$$

where $D_\lambda = -f(p + z(\kappa; \lambda))z_\lambda(\kappa; \lambda)$ from (2) and $z_\lambda(\kappa; \lambda) > 0$ by assumption, which means that the reinforcement of climate concerns reduces profit. To understand the impact of reinforced climate concerns on product design and pricing, consider a green product strategy where $\kappa^* \in (0, \overline{\kappa})$ and where the first-order conditions (A.1) and (A.2) hold with equality. Applying Cramer's rule yields

$$\frac{d\kappa^*(\lambda)}{d\lambda} = -\frac{\pi_{pp}\pi_{\kappa\lambda} - \pi_{\kappa p}\pi_{p\lambda}}{\pi_{pp}\pi_{\kappa\kappa} - \pi_{\kappa p}\pi_{p\kappa}} \tag{A.5}$$

and

$$\frac{dp^*(\lambda)}{d\lambda} = -\frac{\pi_{\kappa\kappa}\pi_{p\lambda} - \pi_{p\kappa}\pi_{\kappa\lambda}}{\pi_{pp}\pi_{\kappa\kappa} - \pi_{\kappa p}\pi_{p\kappa}}. \tag{A.6}$$

The expression in the denominators of (A.5) and (A.6) is the determinant of the Hessian matrix of $\pi(\kappa, p; \lambda)$, which is positive under the concavity assumption. Without additional restrictions on the profit function (and thus the demand function), the impact of stronger climate concerns on the optimal carbon footprint and price is ambiguous. Clearly, the carbon footprint is decreasing in λ if $\pi_{\kappa\lambda} > \frac{\pi_{\kappa p}\pi_{p\lambda}}{\pi_{pp}}$ and the price is increasing in λ if $\pi_{p\lambda} < \frac{\pi_{p\kappa}\pi_{\kappa\lambda}}{\pi_{\kappa\kappa}}$. □

Proof of Proposition 3. The organizational carbon footprint is obtained by multiplying the carbon footprint per unit of product by the corresponding demand:

$$\Phi^*(\lambda) = \kappa^*(\lambda) D(\kappa^*(\lambda), p^*(\lambda); \lambda). \tag{A.7}$$

Differentiating (A.7) with respect to λ yields

$$\frac{d\Phi^*(\lambda)}{d\lambda} = \frac{d\kappa^*(\lambda)}{d\lambda} D + \kappa^*(\lambda) \left(D_\kappa \frac{d\kappa^*(\lambda)}{d\lambda} + D_p \frac{dp^*(\lambda)}{d\lambda} + D_\lambda \right), \tag{A.8}$$

where the arguments of the demand function are suppressed for convenience. Proposition 2 implies that the terms on the right-hand side cannot be signed unambiguously. Therefore, under some conditions, stronger climate concerns may increase the organizational footprint even if it is optimal for the firm to lower the carbon footprint of the product. □

Proof of Proposition 4. Consider the case of cost-increasing sustainability. Adopting an offset strategy yields the optimal profit

$$\pi(\kappa^o, p^o; \omega) = [p^o - c(\kappa^o) - \omega\kappa^o] D(0, p^o).$$

Applying the envelope theorem implies

$$\frac{d\pi(\kappa^o, p^o; \omega)}{d\omega} = -\kappa^o D(0, p^o) < 0.$$

Since $\pi(\bar{\kappa}, p^o; 0) > \pi(\kappa^*, p^*; \lambda)$ from Equation (A.3) and $\pi(\kappa^o, p^o; \omega)$ decreases in ω, there exists $\bar{\omega}$ such that $\pi(\kappa^o, p^o; \omega) > \pi(\kappa^*, p^*; \lambda)$ for $\omega \in [0, \bar{\omega})$, which means that the firm can benefit from adopting a climate neutral strategy when the offsetting costs are sufficiently low.

From Proposition 3, we know that stronger climate concerns reduce profit in the benchmark case absent carbon offsets. Therefore, stronger climate concerns make the adoption of an offset strategy more attractive to marketers. □

Proof of Proposition 5. We follow the convention and define welfare as the sum of consumer surplus and profit. Consumer surplus is obtained by adding up the utilities from buyers and non-buyers:

$$
\begin{aligned}
S(\kappa, p; \lambda) &= \int_{p+z(\kappa;\lambda)}^{\infty} [v - p - z(\kappa;\lambda) - E] dF(v) + \int_{0}^{p+z(\kappa;\lambda)} [-E] dF(v) \\
&= \int_{p+z(\kappa;\lambda)}^{\infty} [v - p - z(\kappa;\lambda)] dF(v) - E \\
&= \int_{p+z(\kappa;\lambda)}^{\infty} v dF(v) - pD(\kappa, p; \lambda) - \Phi(\kappa), \qquad \text{(A.9)}
\end{aligned}
$$

where the third equality uses the definition of demand in Equation (2), the definition of the market externality in Equation (3), and where $\Phi(\kappa) \equiv \kappa D(\kappa, p; \lambda)$ denotes the firm's overall level of emissions. Adding the consumer surplus in Equation (A.9) and the profit in Equation (4) yields welfare:

$$
W(\kappa, p; \lambda) = \int_{p+z(\kappa;\lambda)}^{\infty} v dF(v) - c(\kappa) D(\kappa, p; \lambda) - \Phi(\kappa). \qquad \text{(A.10)}
$$

Drawing on Spence (1975), let $\overline{\pi}(\kappa) = \max_p \pi(\kappa, p; \lambda)$ and $\overline{W}(\kappa) = \max_p W(\kappa, p; \lambda)$. The ratio of maximized profit to maximized welfare is defined as

$$
\beta(\kappa) = \frac{\overline{\pi}(\kappa)}{\overline{W}(\kappa)}.
$$

Taking logs and differentiating, it follows that

$$
\frac{\beta'(\kappa)}{\beta(\kappa)} = \frac{\overline{\pi}'(\kappa)}{\overline{\pi}(\kappa)} - \frac{\overline{W}'(\kappa)}{\overline{W}(\kappa)}.
$$

Now let κ^* denote the profit-maximizing choice of the carbon footprint. By definition, $\overline{\pi}'(\kappa^*) = 0$, so that

$$
\frac{\beta'(\kappa^*)}{\beta(\kappa^*)} = -\frac{\overline{W}'(\kappa^*)}{\overline{W}(\kappa^*)}.
$$

Thus, the carbon footprint exceeds the socially optimal level if $\beta'(\kappa^*) > 0$ and conversely, which implies that the marketer's choice of the carbon footprint is not necessarily consistent with corporate social responsibility.

Adopting an offset strategy is consistent with corporate social responsibility if it increases welfare compared to the no-offset strategy. To this end, consider an offset market in which an offset provider compensates emissions at variable cost $\phi\omega\kappa^o D(p^o)$, where $\phi \in [0,1]$ is an efficiency parameter, and fixed cost $F > 0$. In this scenario, welfare is obtained by adding up consumer surplus and the profits from the firm and the offset provider:

$$W(\kappa^o, p^o; \omega) = \int_{p^o}^{\infty} v dF(v) - c(\kappa^o) D(p^o) - \phi\omega\kappa^o D(p^o) - F. \quad \text{(A.11)}$$

Since the offset cost $\omega\kappa^o D(p^o)$ is simply a transfer from the firm to the offset provider and cancels out in the welfare calculation. Clearly, a climate neutral strategy is economically efficient if the cost of carbon removal $\phi\omega\kappa^o D(p^o) + F$ is sufficiently low compared to the climate damage that results from the organizational carbon footprint under a no-offset strategy, given by $\Phi(\kappa^*)$. □

Proof of Proposition 6. The firm maximizes profit if and only if its carbon footprint and price selections satisfy the following Kuhn-Tucker conditions (the multipliers $\mu_i \geq 0$ are associated with the inequality constraints):

$$D(\kappa^r, p^r) + (p^r - c(\kappa^r)) D_p(\kappa^r, p^r) - \mu_3 \Phi_p(\kappa^r, p^r) = 0 \quad \text{(A.12)}$$

$$-c'(\kappa^r) D(\kappa^r, p^r) + (p^r - c(\kappa^r)) D_\kappa(\kappa^r, p^r) + \mu_1 - \mu_2 + \mu_3 \Phi_\kappa(\kappa^r, p^r) = 0 \quad \text{(A.13)}$$

$$\mu_1 \kappa^r = 0, \quad \mu_2(\kappa^r - \overline{\kappa}), \quad \text{and} \quad \mu_3(\Phi(\kappa^r, p^r) - R) = 0.$$

We denote the unique constrained profit-maximizing marketing activities by (κ^r, p^r). Assuming that the carbon constraint is binding and that $0 < \kappa^r < \overline{\kappa}$, the firm raises κ above the level that would be optimal absent the carbon regulation if $\Phi_\kappa(p, \kappa) < 0$. Instead, if $\Phi_\kappa(p, \kappa) > 0$, it is optimal for the firm to lower the carbon footprint in response to the regulation. □

Proof of Proposition 7. If marketers meet the carbon cap, the cost of regulation (CR) is given by the difference between the actual profit and the expected profit under the carbon regulation:

$$\Delta\pi^R \equiv \pi^* - [\rho\pi^r + (1-\rho)\pi^*] = \rho(\pi^* - \pi^r).$$

Instead, if marketers purchases carbon allowances, the CR is given by the difference between the actual profit and the expected profit net of the cost to offset the emissions:

$$\Delta\pi^k \equiv \pi^* - [\rho(\pi^* - \varpi(\Phi(p^*,\kappa^*) - R)) + (1-\rho)\pi^*] = \rho\varpi(\Phi(p^*,\kappa^*) - R).$$

The firm chooses the option that yields the higher expected profit. Thus, the expected profit impact of regulation is given by $\rho\min\{\pi^* - \pi^r, \varpi(\Phi(p^*,\kappa^*) - R)\}$. □

Proof of Proposition 8. To understand the impact of a carbon tax, consider an interior solution and suppose that $\pi_{\kappa t} > \min\left\{\frac{\pi_{\kappa p}\pi_{pt}}{\pi_{pp}}, \frac{\pi_{\kappa\kappa}\pi_{pt}}{\pi_{p\kappa}}\right\}$. Totally differentiating the (necessary and sufficient) first-order conditions and applying Cramer's rule yields

$$\frac{d\kappa^*(t)}{dt} = -\frac{\pi_{pp}\pi_{\kappa t} - \pi_{\kappa p}\pi_{pt}}{\pi_{pp}\pi_{\kappa\kappa} - \pi_{\kappa p}\pi_{p\kappa}} \tag{A.14}$$

and

$$\frac{dp^*(t)}{dt} = -\frac{\pi_{\kappa\kappa}\pi_{pt} - \pi_{p\kappa}\pi_{\kappa t}}{\pi_{pp}\pi_{\kappa\kappa} - \pi_{\kappa p}\pi_{p\kappa}}. \tag{A.15}$$

The expression in the denominators of (A.14) and (A.15) is the determinant of the Hessian matrix of $\pi(p,\kappa)$, which is positive under the concavity assumption. Assuming that π_{pp}, $\pi_{\kappa p}$, and π_{pt} are negative, the carbon footprint is decreasing in the tax rate t if $\pi_{\kappa t} > \frac{\pi_{\kappa p}\pi_{pt}}{\pi_{pp}}$ (which is the case if $\pi_{\kappa t}$ is not too negative, as assumed). Further assuming that $\pi_{\kappa\kappa} < 0$, the price is increasing in t if $\pi_{\kappa\lambda} > \frac{\pi_{\kappa\kappa}\pi_{pt}}{\pi_{p\kappa}}$, a condition that is assumed to hold.

The organizational carbon footprint can be derived as

$$\Phi^*(t) \equiv \kappa^*(t) D(p^*(t), \kappa^*(t), t). \tag{A.16}$$

Differentiating (A.16) with respect to the tax rate t yields

$$\frac{d\Phi^*(t)}{dt} = \frac{d\kappa^*(t)}{dt} D + \kappa^*(t)\left(D_p\frac{dp^*(t)}{dt} + D_\kappa\frac{d\kappa^*(t)}{dt}\right), \tag{A.17}$$

where the arguments of the demand function are suppressed for convenience. Since $\frac{d\kappa^*(t)}{dt} < 0$, the first term on the right-hand side of (A.17) is negative. This implies, since $\frac{dp^*(t)}{dt} > 0$, $D_p < 0$, and $D_\kappa < 0$, that the sign of the second term is ambiguous. Therefore, the impact of a carbon tax on the organizational carbon footprint is ambiguous.

Let $\pi^*(t)$ denote the optimized profit given the tax rate t. The cost of regulation is defined as the difference between the actual profit and the expected profit under the carbon tax:

$$\Delta\pi \equiv \pi^*(0) - [\rho\pi^*(t) + (1-\rho)\pi^*(0)] = \rho\{\pi^*(0) - \pi^*(t)\},$$

where $\pi^*(0) \equiv \pi^*$ is the profit under a zero tax rate. Note that $\Delta\pi$ is positive as

$$\pi^*(0) - \pi^*(t) \; = -\int_0^t \frac{d\pi^*(y)}{dy} dy = \int_0^t \Phi^*(y) dy$$

is positive, where the last equality follows from the application of the envelope theorem and the definition of the organizational carbon footprint. □

Proof of Proposition 9. If the firm adopts the green technology, the actual profit is given by $\pi_1^* - f$. Using the CR defined in Proposition 7, the expected profit to accommodate the carbon regulation with the green technology can be derived as $\pi_1^* - f - CR_1$. Similarly, the expected profit to accommodate the carbon regulation with the existing technology is $\pi_0^* - CR_0$. Clearly, if $\pi_1^* - f - CR_1 \geq \pi_0^* - CR_0$, then the firm will adopt the green technology to increase the expected profit. □

Proof of Proposition 10. Demand for each firm i can be derived from the location of the consumer who is indifferent between buying from firm 1 and from firm 2, denoted $\hat{x}$. From the indirect utility function in Equation (8), this location solves the indifference condition $v_1(\hat{x}) = v_2(\hat{x})$. With linear mismatch, the consumer located at $\hat{x}$ segments the market, that is, consumers located to the left of $\hat{x}$ purchase from firm 1, while consumers located to the right of $\hat{x}$ purchase from firm 1. Demand of firm i can therefore be derived as

$$D_i(\boldsymbol{\kappa}, \mathbf{p}; \lambda) = \frac{1}{2} - \lambda(\kappa_i - \kappa_j) - (p_i - p_j). \tag{A.18}$$

To establish the claim, we first focus on the symmetric case where $c_1^0 = c_2^0 \equiv 1$ and set $\lambda = 1$.[9] First, we analyze the setting in which both firms adopt a no-offset strategy. The marketer of firm i then solves

$$\max_{\kappa_i, p_i; 1} \quad \pi_i(\kappa_i, p_i) = \left[p_i - (1-\kappa_i)^2\right] D_i(\boldsymbol{\kappa}, \mathbf{p}; 1), \tag{A.19}$$

where demand follows by setting $\lambda = 1$ in Equation (A.18). Simultaneously solving the (necessary and sufficient) first-order conditions yields $\kappa_i^* = \frac{1}{2}$ and $p_i^* = \frac{3}{4}$. By substitution, $\hat{x} = \frac{1}{2}$, $\pi_i^* = \frac{1}{4}$ (indicated in top-left cell in Figure 3), and $\Phi_i^* = \frac{1}{4}$. Consumer surplus for buyers of firm 1 is obtained as

$$S_1(\kappa_1, p_1; 1) = \int_0^{\hat{x}} (v - p_1 - \kappa_1 - \frac{x}{2} - E)dx \tag{A.20}$$

Since consumers fully internalize their climate externality ($\lambda = 1$), it follows that $E = 0$. By substitution, (A.20) reduces to $S_1^* = \frac{8v-11}{16}$, and symmetry implies that $S_1^* = S_2^*$. Welfare is obtained by aggregating consumer surplus and profit net of the organizational carbon footprint across firms:

$$W^* = \sum_{i=1}^{2} (S_i^* + \pi_i^* - \Phi_i^*) = v - \frac{11}{8}. \tag{A.21}$$

Second, we analyze the setting in which firm 1 uses an offset strategy and firm 2 uses a no-offset strategy. The marketer of firm 1 therefore solves

$$\max_{\kappa_1, p_1} \quad \pi_1(\kappa_1, p_1; \lambda) = \left[p_1 - (1-\kappa_1)^2 - w\right] \left(\frac{1}{2} + \kappa_2 - (p_1 - p_2)\right), \tag{A.22}$$

where w denote the offset cost per unit of carbon emissions. Instead, the marketer of firm 2 solves

$$\max_{\kappa_2, p_2} \quad \pi_2(\kappa_2, p_2) = \left[p_2 - (1-\kappa_2)^2\right] \left(\frac{1}{2} - \kappa_2 - (p_2 - p_1)\right). \tag{A.23}$$

Simultaneously solving the first-order conditions and substituting back into the profit functions yields $\hat{\pi}_1 = \frac{1}{144}(w(w-4)+9)^2 \equiv A$ and $\hat{\pi}_2 = \frac{1}{144}(w(w-4)-3)^2 \equiv B$ (indicated

[9] The choice of parameter values simplifies the analysis without qualitatively affecting the results. The full proof is available from the authors upon request.

in bottom-left cell in Figure 3). Since $\hat{\pi}_1 > \frac{1}{4}$ and $\hat{\pi}_2 < \frac{1}{4}$ for all $w < 1$, adopting an offset strategy is a dominant strategy for firm 1. Note that the other asymmetric outcome in which the marketer of firm 1 uses a no-offset strategy and the marketer of firm 2 uses an offset strategy can be obtained by reversing the payoffs (indicated in top-right cell in Figure 3).

Third, we analyze the setting in which both firms adopt an offset strategy. Therefore, the marketer of firm i solves

$$\max_{\kappa_i, p_i} \quad \pi_i(\kappa_i, p_i) = \left[p_i - (1-\kappa_i)^2 - w\right]\left(\frac{1}{2} - (p_i - p_j)\right). \tag{A.24}$$

Simultaneously solving the first-order conditions and substituting back into the profit functions yields $\overline{\pi}_i = \frac{1}{4}$. Since adopting an offset strategy is a strictly dominant strategy for each marketer, equilibrium play involves that both marketers use an offset strategy.

These equilibrium strategy choices are consistent with corporate social responsibility if welfare is improved over the benchmark case where both firm use a no offset strategy. Welfare under offset strategies can be derived as

$$\begin{aligned} \overline{W}^* &= \sum_{i=1}^{2}(S_i^* + \pi_i^*) + (w-\phi)\sum_{i=1}^{2}\Phi_i^* - F \\ &= v - \frac{w^2}{4} - \frac{\phi}{2}(2-w) - \frac{1}{8} - F, \end{aligned} \tag{A.25}$$

where $(w-\phi)\sum_{i=1}^{2}\Phi_i^* - F$ is the profit of the offset provider.

Carbon offsets improve welfare over the case absent offsets if and only if $\overline{W}^* \geq W^*$. Clearly, this holds if the marginal cost ϕ and the fixed cost F are sufficiently small, that is, as long as the offset technology is sufficiently cost effective. □