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Abstract: It is widely believed that an environmental tax (price regulation) and cap-and-trade (quantity regulation) are equally efficient in controlling pollution when there is no uncertainty. We show that this is not the case if some consumers (firms, local governments) are morally concerned about pollution and the pollution price is inefficiently low for political reasons. Emissions are lower and material welfare is higher with price regulation. Furthermore, quantity regulation gives rise to dysfunctional incentive and distribution effects. It shifts the burden of adjustment to the poor and discourages voluntary efforts to reduce pollution, while price regulation makes these efforts effective.

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1 Introduction

There is unanimous agreement among economists that the most efficient way to mitigate climate change is to "put a price on carbon". There is some controversy on whether to do this with a carbon tax or an emissions market (cap-and-trade). Usually, this debate focuses on the nature of the underlying uncertainty. With a carbon tax the price of emissions is fixed, but there is uncertainty regarding the emission reduction. With an emissions market the quantity of emissions is fixed, but there is uncertainty about the resulting price. The trade-off between price and quantity regulation depends on the relative costs associated with these uncertainties (Weitzman, 1974).

There is another, orthogonal difference between price and quantity regulation. Cap-and-trade discourages all other abatement efforts that environmentally concerned consumers, firms, or governments are willing to engage in. If some market participants voluntarily reduce their emissions, e.g. by investing in a solar panel, by buying energy-efficient appliances, or by using the train rather than a short-distance flight, they cannot affect the total amount of emissions. Their behavior reduces the demand for emission rights while the supply is fixed – determined by the number of emission permits. This causes the permit price to fall until other consumers or producers buy more emission rights, fully offsetting the initial reduction. This is not the case with price regulation. If there is a fixed carbon tax, any additional climate action is effective in reducing CO_2 emissions. Thus, price regulation may be preferable because it complements the many voluntary contributions that environmentally concerned citizens are prepared to engage in, while quantity regulation makes them ineffective.

In this paper, we assume that some consumers are morally concerned consequentialists (e.g. Utilitarians), who are willing to reduce their consumption of the polluting good if their behavior affects the total level of emissions. Furthermore, we assume that there is a political constraint on the emission price. No matter whether this price is a carbon tax or a permit price determined by cap-and-trade, it cannot be higher than an upper bound because a higher price would cause political unrest. We show that under these two assumptions price regulation yields lower emissions than quantity regulation because only price regulation induces morally concerned consumers to consume less of the polluting good. These lower emissions translate into higher material social welfare. But there is also a downside to price regulation. Morally concerned consumers suffer from violating a social norm. This is not the case with quantity regulation. A consumer who knows that her actions cannot have any effect on total emissions does not have to be morally concerned about her actions. Thus, if the disutility from norm violation is taken into account, the effect on total social welfare depends on how high these moral costs are.

In Section 3 we relax the assumptions of rationality and consequentialism. Some consumers do not understand the different implications of price and quantity regulation, and some have non-consequentialist moral convictions. We look at the interaction of selfish consumers and two different types of morally concerned consumers: consequentialists ("Utilitarians") as described above and deontologists ("Kantians"), who consider it their moral duty to follow an ethical norm no matter what the consequences. Kantians behave in the same way under price and under quantity regulation. They are observationally equivalent to "naïve" Utilitarians, i.e. to consequentialists who do not understand that with an emissions market their actions cannot affect total emissions. We ask how a political (or educational) campaign that increases the share of morally concerned consumers (or reduces the share of naïve consumers) affects the utility of the different groups. With price regulation an increase of morally concerned consumers reduces emissions and benefits selfish and morally concerned consumers. With quantity regulation an increase of the share of Kantian consumers leaves total pollution unaffected but reduces the emissions price. This benefits selfish consumers, while Kantian consumers are harmed. In this case nobody has an interest in explaining to naïve Utilitarians how the emissions market works.

In Section 4 we look at the distributional consequences of price and quantity regulation. We assume that there are two groups of consumers, rich and poor, and that the rich have a lower marginal utility of money (income) than the poor. With quantity regulation consumers only care about the price of the polluting good, because they cannot affect total emissions. Thus, if the marginal utility of money is small for the rich, they will not reduce their consumption by much, so the poor have to bear the lion's share of the emissions reduction. With price regulation, both consumer groups are motivated in addition by moral concerns. Thus, both groups will reduce their consumption and bear the burden of emissions reductions more equally.

With cap-and-trade morally concerned consumers could buy and delete emission rights and thereby effectively compensate their CO_2 emissions. In Section 5, we allow for this possibility and show that our previous results are qualitatively unchanged. Only consumers with very strong moral convictions buy permits to compensate for their emissions, all others do not. Even compensating consumers consume more of the polluting good under quantity than price regulation.

In the formal model we restrict attention to the consumption decisions of individual consumers. However, consumers also affect the decisions of firms and governments. For example many firms declared that they want to become "carbon neutral" within a few years. Similarly, (regional) governments engage in significant efforts to reduce carbon emissions in addition to carbon pricing. Presumably, firms and governments want to cater to morally concerned customers, owners, and voters. Section 6 concludes by showing that these additional efforts are wasted under quantity regulation, but can yield a significant contribution to mitigate climate change with price regulation.

Our paper is related to three strands of the literature: First, there is a large literature on the efficient regulation of negative externalities (Baumol and Oates, 1988). This literature goes back to Pigou (1920) who first proposed a (Pigouvian) tax (price regulation) to internalize the externality. The idea of quantity regulation through cap-and-trade is implicit in Coase (1960) and spelled out formally by Montgomery (1972). In a seminal paper Weitzman (1974) compares price and quantity regulation in a model with uncertainty regarding the costs and benefits of abatement.[1] His analysis has been extended in many directions, e.g. to stock pollutants (Hoel and Karp, 2002), commitment and flexibility (Requate, 2005), and political economy issues (Helm, 2005). Surveys on this literature are offered by Hepburn (2006) and Goulder and Schein (2013).[2] To the best of our knowledge, our paper is one of the first to consider how the presence of morally concerned consumers affects this trade-off.

Second, there is a literature discussing the interaction of different policy instruments

[1]The optimal mixture of the two instruments is analyzed, among others, by Roberts and Spence (1976), Pizer (2002), Mandell (2008), and Ambec and Coria (2013).

[2]Goulder (2013), Schmalensee and Stavins (2017) and Narassimhan et al. (2018) provide overviews and evaluations of real world cap-and-trade systems.

(Fankhauser et al., 2010; Goulder et al., 2012). This literature shows that different policy measures can be (perfect) substitutes, so adding one instrument to another may have very little or no effect. For example, if a pollution tax is imposed on a good that is already covered by cap-and-trade regulation, than the tax will be fully offset by a reduction of the permit price and does not have any additional effect on aggregate emissions (Goulder, 2013). Perino (2015) considers a general equilibrium model with two sectors, one of which is regulated by cap-and-trade. He shows that voluntary climate action may increase total emissions due to leakage to the other sector that is regulated by a tax. While this literature studies the interaction of different instruments in an inefficient policy mix, we consider the interaction of one type of regulation (either price or quantity regulation) with the moral preferences of consumers. We analyze how the intrinsic (moral) motivation of climate-conscious consumers is affected by the chosen policy instrument and how it affects the efficiency of the regulation.

Finally, our paper is related the behavioral and experimental economics literature. Pollution and climate change is a leading examples of a public good problem. There is an extensive literature in experimental economics showing that social preferences mitigate public good problems. Many experimental subjects are willing to give up own resources in order to help others.[3] This literature also shows that some informal and formal institutions can increase and sustain cooperation (Ostrom, 1990; Fehr and Gächter, 2000). In our paper, consumers do not have social preferences about the consumption or income of others but moral concerns about the environment. They suffer if their own consumption departs from the social norm. Therefore, closer related to our work is the economic literature on how social norms affect behavior (Benabou and Tirole, 2006; Krupka and Weber, 2013; Bénabou et al., 2018). In particular, several empirical papers of that literature show that social norms have an important impact on decisions affecting the environment (Nyborg et al., 2006; Allcott and Rogers, 2014; Schwirplies and Ziegler, 2016; Jakob et al., 2017). In a lab experiment, Ockenfels et al. (2019) directly investigate whether an emissions tax performs better than a cap-and-trade system for reducing carbon emissions. They find that an emissions tax yields more abatement than cap-and-trade, which confirms our theoretical results. Finally, there is a discussion on whether markets erode social responsibility and moral concerns (Sandel, 2012; Falk and Szech, 2013; Bartling et al., 2015; Sutter et al., 2020). In our paper, it is not the market per se that affects

[3]For surveys of this literature see Ledyard (1995) and Chaudhuri (2011).

moral behavior but the type of market mechanism. We consider two market instruments, price and quantity regulation, and show that price regulation fosters moral behavior, while quantity regulation renders it irrelevant.

2 The Basic Model

Consider an economy with two goods, good X which pollutes the environment and good Y which involves no externalities. The government wants to mitigate the negative externalities of X and can either impose a consumption tax (price regulation) or introduce an emissions market where a fixed number of emission permits is traded (quantity regulation). In a standard model without uncertainty price and quantity regulation are equivalent.

We deviate from the standard model by introducing two assumptions. First, we assume that there is a political constraint on the emission price. No matter whether the emission price is determined by a tax or by an emissions market, it cannot exceed an upper bound $\bar{p}$. An emission price higher than $\bar{p}$ is politically infeasible because it induces political unrest and instability. This is a major concern in the political debate about carbon pricing.[4] Second, we assume that consumers have moral concerns about pollution. They incur a moral cost if their emissions harm the environment and are willing to voluntarily reduce their consumption of good X. In the basic model, we assume that all consumers are "moral consequentialists" (e.g. Utilitarians) who base the moral judgment of an action on its consequences.

As we will show, with these two assumptions, there is a difference between price and quantity regulation. With price regulation a morally concerned consumer can reduce overall pollution by consuming less than what she would consume without moral concerns.[5] With quantity regulation this is not the case. On an emissions market the total quantity of emissions is fixed by the number of pollution permits. If some consumers reduce their consumption, the demand for emission permits is reduced and the permit price falls until other consumers consume more, exactly offsetting the initial reduction. A rational ("sophisticated") consumer

[4] The opposition to higher gas taxes in the US and the "yellow vests movement" in France are prominent examples.

[5] Even with price regulation the reduction of total emissions need not be one-to-one if there is indirect leakage; see e.g. Sinn (2008). This effect is ignored in the following.

understands this and knows that a reduction of her consumption has no impact on overall pollution. Thus, an emissions market renders her moral concerns irrelevant.

We model this as follows. There is a continuum of consumers of mass one. Good X is produced on a perfectly competitive market at constant marginal cost $c > 0$. The quantity of good X is measured such that one unit of consumption yields one unit of pollution. In addition, there is a pollution price p per unit of the good that is either imposed by the government through a tax or through an emissions market that gives rise to an emission price. Thus, the total price of good X is $c + p$. The price of the numeraire good Y is normalized to 1. Let x and y denote the quantities consumed of goods X and Y, respectively, and m the income of the representative consumer. Revenues from pollution pricing $p\bar{x}$ are redistributed lumpsum, so her budget constraint implies that $y = m + p\bar{x} - (c + p)x$. Her (quasi-linear) utility function is

$$U = v(x) + m + p\bar{x} - (c + p)x - D(\bar{x}) - \beta^R[x - x^o]^+ \ , \qquad (1)$$

where $v'(x) > 0$ and $v''(x) < 0$.[6]

A consumer suffers from the environmental damage $D(\cdot)$ that is caused by aggregate consumption $\bar{x} = \int_0^1 x(i)di$, with $D'(\cdot) > 0$ and $D''(\cdot) > 0$. Let $v'(0) > c + D'(0)$. Because there is a continuum of consumers, each consumer ignores the effect of his consumption on $\bar{x}$.

The consumer also suffers a moral cost if she consumes more than the social norm x^0 prescribes, i.e. her utility is reduced by $\beta^R[x - x^o]^+$, where $[x - x^o]^+ = \max\{x - x^o, 0\}$ and $R \in \{P, Q\}$. With price regulation the consumer affects total pollution, so $\beta^R = \beta > 0$, while with quantity regulation she cannot affect total pollution, so $\beta^Q = 0$.[7] For simplicity we assume that the agent's utility loss is a piecewise linear function of the norm violation.

Define $\hat{x}(z)$ implicitly by $v'(\hat{x}) \equiv z$ for all $z \geq 0$. Thus, $\hat{x}(z)$ with $\hat{x}'(z) < 0$ denotes a consumer's demand as a function of the perceived cost of consuming X, which may incorporate, next to the price, also the moral cost of consumption. Moreover, we assume that the wealth

[6] In an online appendix we show that the main results continue to hold for more general utility functions.

[7] A consequentialist should feel morally responsible for the environmental damage that she imposes on all other consumers even if her impact on total pollution is small in the sense that it cannot be felt by any single consumer. For example, the harm imposed by one additional ton of CO_2 on all other people in the world is equal to the social cost of carbon, while the harm imposed on oneself is negligible. For supportive philosophical arguments see Tiefensee (2019) .

m is sufficiently high so that consumption of the numeraire good Y is always strictly positive. This implies that m is a constant shift parameter in the utility function, which we will ignore in the following.

The social norm x^o is determined endogenously. We assume that it is a weighted average of the morally appropriate consumption level x^* (defined below) and the average actual consumption level $\bar{x}$, i.e.,

$$x^o = \alpha x^* + (1 - \alpha)\bar{x} \ . \tag{2}$$

If $\alpha = 1$ the norm is fully injunctive and says that everybody should consume the socially efficient quantity x^* that maximizes material social welfare

$$W^M = v(\bar{x}) - c\bar{x} - D(\bar{x}) \ . \tag{3}$$

So x^* is uniquely defined by

$$v'(x^*) = c + D'(x^*) \ . \tag{4}$$

If $\alpha = 0$ the norm is purely descriptive, i.e. the consumer suffers if she consumes more of X than everybody else does.

The social planner (regulator) wants to maximize social welfare by imposing an emission price p. The revenues of emission pricing are redistributed lumpsum to consumers. It could be debated whether social welfare is just material social welfare as defined in (3) or whether it should also include the feelings of utility losses due to norm violations. We will see that this does not make a difference in a first best world, but it is important if the first best cannot be implemented. We will always discuss the effects on both, material and total social welfare, where the latter is defined by

$$\begin{aligned} W &= v(\bar{x}) - (c+p)\bar{x} - D(\bar{x}) - \beta^R[\bar{x} - x^o]^+ + p\bar{x} \\ &= W^M(\bar{x}) - \alpha\beta^R[\bar{x} - x^*]^+ \ . \end{aligned} \tag{5}$$

Lemma 1. *Total social welfare (5) and material social welfare (3) are both maximized by consumption level x^*.*

Proof. For $\bar{x} = x^*$, $W^M(\cdot)$ is maximized and $\alpha\beta^R[\bar{x} - x^*]$ is minimized. Thus, x^* maximizes $W(\cdot)$. □

If the carbon price is not constrained, both regulations can implement the first best.

Lemma 2. *If the emission price is unconstrained, the first best can be implemented by*

(a) either price regulation that sets the emission price to $p^* \in [D'(x^*) - \beta,\ D'(x^*)]$*,*

(b) or quantity regulation that restricts the number of emission permits to $\bar{E} = x^*$*.*

Proof. The result readily follows from the maximization of U and the definition of x^*. □

Now, suppose that there is a political constraint on the emission price.

Assumption 1. *The social planner is constrained to implement an emission price* $p \leq \bar{p} < D'(x^*) - \beta$*.*

In this second best world the social planner will choose $p = \bar{p}$ if he opts for price regulation, and he will set $\bar{E}$ such that the endogenous price on the emissions market $p(\bar{E}) = \bar{p}$. Importantly, even though the emission price is the same, total emissions are different.

Proposition 1. *Under Assumption 1, optimal price regulation implements an emission level* $x^P = \hat{x}(c + \bar{p} + \beta)$ *that is inefficiently high but strictly smaller than the level of emissions* $x^Q = \hat{x}(c + \bar{p})$ *under optimal quantity regulation, i.e.*

$$x^* < x^P < x^Q \ . \tag{6}$$

Proof. A consumer demands $\hat{x}$ defined by

$$v'(\hat{x}) = c + \bar{p} + \beta^R < c + D'(x^*). \tag{7}$$

Thus, $x^* < x^P = \hat{x}(c+\bar{p}+\beta) < x^Q = \hat{x}(c+\bar{p})$ because of the concavity of $v(\cdot)$. Under quantity regulation the planer sets $\bar{E} = \hat{x}(c + \bar{p})$. □

The different resulting quantities directly affect the welfare comparisons.

Proposition 2. *Material social welfare (3) is unambiguously higher with price regulation than with quantity regulation, i.e.*

$$W^M(x^P) > W^M(x^Q) \ . \tag{8}$$

The difference in material welfare is strictly increasing in β,

$$\frac{d(W^M(x^P) - W^M(x^Q))}{d\beta} > 0. \tag{9}$$

Total social welfare (5) is higher with price than with quantity regulation if and only if

$$W^M(x^P) - W^M(x^Q) > \alpha\beta[x^P - x^*] \ . \tag{10}$$

This is the case if the social norm is sufficiently descriptive (α *sufficiently small).*

Proof. By Proposition 1, $x^Q > x^P > x^*$ which implies $W^M(x^Q) < W^M(x^P) < W^M(x^*)$. Moreover,

$$\frac{d(W^M(x^P) - W^M(x^Q))}{d\beta} = \underbrace{\hat{x}'(c + \bar{p} + \beta)}_{<0} \underbrace{[v'(x^P) - c - D'(x^P)]}_{<0} > 0. \tag{11}$$

By (5) total social welfare is higher under price than quantity regulation iff

$$\begin{aligned} W(x^P) = W^M(x^P) - \alpha\beta[x^P - x^*] \quad &> \quad W(x^Q) = W^M(x^Q) \\ \Leftrightarrow \quad W^M(x^P) - W^M(x^Q) \quad &> \quad \alpha\beta[x^P - x^*]. \end{aligned} \tag{12}$$

Note that x^P and x^Q are independent of α. Thus, if $\alpha \to 0$ inequality (12) holds. □

An important advantage of quantity regulation is that consumers do not have to be morally concerned about their actions, so there are no moral costs. With price regulation consumers suffer from the fact that their consumption affects total pollution and that it exceeds x^0. If the norm is purely descriptive ($\alpha = 0$), consumers do not suffer any moral cost, because everybody behaves as they do. Thus, if α is sufficiently small, price regulation dominates.

The effect of β on total welfare is less clear. A decrease in β reduces the moral suffering under price regulation, but it also reduces the incentives of consumers to consume less. Thus, both sides of inequality (12) are reduced and the total effect is ambiguous.

3 Selfish, Kantian and Naïve Consumers

Welfare economics is based on the assumptions of rational choice and consequentialism, so it is natural to start out with a model in which all consumers are fully rational and moral consequentialists. However, in the real world many consumers are not familiar with the functioning of an emissions market and may fail to understand that their behavior cannot affect total emissions. They are "naïve" in the sense that they do not see any difference between price and quantity regulation. Furthermore, consumers who are morally concerned need not be consequentialists. Many consumers are better described as deontologists (e.g. Kantians) who aspire to follow an ethical rule or a moral duty, independently of what the consequences of this action are.[8] For example, in the public debate we often observe moral imperatives such as "You shall not fly", but we rarely observe the statement "You may use the plane on flights within Europe, because they are covered by the EU Emissions Trading System, but you shall not fly in the US".

In this section, we allow for different moral convictions and degrees of rationality. We assume that fraction $1 - \lambda$ of consumers are selfish and have no moral concerns. They simply maximize their material utility. The remaining fraction λ consists of two types of morally concerned consumers – consequentialists as in Section 2 and deontologists – who follow an ethical norm. We assume that deontologists are equally morally strict as consequentialists, so they follow the same social norm $x^o = \alpha x^* + (1 - \alpha)\bar{x}$, but, to a deontologist this social norm applies no matter what the consequences. For concreteness, we will call consequentialists "Utilitarians" and deontologists "Kantians". Furthermore, there are naïve Utilitarians who do not understand the functioning of an emissions market and believe that any reduction of their emissions reduces total emissions by exactly this amount. In our model Kantian consumers and naïve Utilitarian consumers are observationally equivalent. We assume that the share of Kantians and naïve Utilitarians in the population is $\lambda^K \geq 0$ and the share of sophisticated Utilitarians is $\lambda^U \geq 0$, $\lambda^K + \lambda^U = \lambda < 1$. Let $x^s(p) = \hat{x}(c + p)$ and $x^m(p) = \hat{x}(c + p + \beta)$ be the "selfish" and the "moral" consumption, respectively.

With price regulation all morally concerned consumers behave in the same way and choose consumption level $x^m(\bar{p})$, while selfish consumers choose $x^s(\bar{p})$, with $x^m < x^s$. This gives rise to total emissions $\bar{x}^P = (1 - \lambda)x^s + \lambda x^m$ and to social norm $x^o = \alpha x^* + (1 - \alpha)[x^s - \lambda(x^s -$

[8] Kantian decision makers are also analyzed by Roemer (2010) and Alger and Weibull (2016).

$x^m)]$.[9] With quantity regulation sophisticated Utilitarian consumers have no moral concerns and choose the same consumption level $x^s(p)$ as selfish consumers. Only Kantian and naïve Utilitarian consumers choose the moral consumption level $x^m(p)$. Thus, total consumption and pollution is given by $x^Q(p) = (1-\lambda^K)x^s(p) + \lambda^K x^m(p)$. The social planner will set the quantity of emission permits $\bar{E}$ such that $\bar{E} = x^Q(\bar{p})$ which gives rise to emission price $\bar{p}$. Thus, with price regulation total pollution is smaller than with quantity regulation, $x^P < x^Q$, and material efficiency is higher, as in Section 2.

The focus of this section is on the effects of a political or educational campaign that changes the composition of the population. For example, a new report of the IPCC or a political movement (e.g. "Fridays for Future") may raise the awareness of climate change and turn some selfish consumers into morally concerned consumers. The government could also make an effort to better explain the functioning of an emissions market to the public, thereby reducing the share of naïve consumers. Because these campaigns change the preferences of some part of the population, we cannot compare total social welfare before and after the policy change. However, we can assess how consumers who did not change their type are affected, which gives rise to important distributional effects.

Proposition 3 (Price regulation)**.** *Suppose that the share of morally concerned consumers, λ, increases. With price regulation all consumers (both selfish and moral) who did not change their type benefit from the conversion of some selfish to moral consumers.*

Proof. An increase of λ reduces the consumption of those selfish consumers that have been turned into moral consumers. It does not affect the consumption decisions of consumers who did not change type. The effect on aggregate consumption is:

$$\frac{\partial \bar{x}^P}{\partial \lambda} = -[x^s - x^m] < 0.$$

[9]This assumes that $x > x^o$ for all morally concerned consumers, which is the case if α is sufficiently large:

$$\alpha > \frac{\hat{x}(c+\bar{p}) - \hat{x}(c+\bar{p}+\beta)}{\hat{x}(c+\bar{p}) - x^*}.$$

The effect on utility of selfish and moral consumers is:

$$\frac{\partial U_S}{\partial \lambda} = \underbrace{[-D'(\bar{x}) + \bar{p}]}_{<0 \text{ by Ass. 1}} \underbrace{\frac{\partial \bar{x}^P}{\partial \lambda}}_{<0} = -\left[-D'(\bar{x}) + \bar{p}\right][x^s - x^m] > 0, \tag{13}$$

$$\frac{\partial U_K}{\partial \lambda} = \underbrace{[-D'(\bar{x}) + \beta(1-\alpha) + \bar{p}]}_{<0 \text{ by Ass. 1}} \underbrace{\frac{\partial \bar{x}^P}{\partial \lambda}}_{<0} = -\left[-D'(\bar{x}) + \beta(1-\alpha) + \bar{p}\right][x^s - x^m] > 0. \tag{14}$$

□

If a selfish consumer gets morally concerned, she consumes less and total pollution is reduced. The consumption choices of selfish and moral consumers who did not change their type are unaffected, but both types benefit from the reduction of pollution. There is also a negative effect on all consumers because tax revenues go down and less money can be redistributed. Furthermore, moral types are adversely affected because the social norm gets stricter. However, under Assumption 1, these effects are dominated by the positive effect of less pollution.

Consider now the case of quantity regulation and assume that the number of emission rights $\bar{E}$ is fixed.[10]

Proposition 4 (Quantity regulation)**.** *Suppose that the share of Kantian consumers, λ^K, increases . With quantity regulation total pollution is unaffected, but the pollution price goes down. Selfish consumers unambiguously benefit from the price decrease, while Kantian consumers are strictly worse off.*

Proof. If $\bar{E}$ stays fixed, an increase of λ^k reduces p by $\frac{\partial p}{\partial \lambda^k} < 0$, which affects the consumption choices of selfish and Kantian consumers. The effect on selfish consumers is

$$\frac{\partial U_s}{\partial \lambda} = \underbrace{[v'(x) - c - p]}_{=0 \text{ by definition of } x^s} \frac{\partial x^s}{\partial p} \frac{\partial p}{\partial \lambda^k} - (x^s(p) - \bar{x}) \frac{\partial p}{\partial \lambda^k} > 0, \tag{15}$$

which is positive because $x^s(p) > \bar{x}$. The effect on Kantian consumers is

$$\frac{\partial U_k}{\partial \lambda} = \underbrace{[v'(x) - \beta - c - p]}_{=0 \text{ by definition of } x^m} \frac{\partial x^m}{\partial p} \frac{\partial p}{\partial \lambda^k} - (x^m(p) - \bar{x}) \frac{\partial p}{\partial \lambda^k} < 0, \tag{16}$$

[10] An increase of the number of Kantian consumers reduces the emission price. Thus, the regulator could respond by reducing the number of emission rights. Many existing emissions markets fixed the number of emission rights for many years. For example, in the European Emissions Trading System the amount is fixed until 2030.

which is negative because $x^m(p) < \bar{x}$. □

With a fixed cap, an increase of the share of Kantian consumers cannot affect total pollution, but it does affect the permit price p. A decrease in p has three effects: It reduces the amount px that consumers have to pay for their consumption x, it reduces the lumpsum redistribution $p\bar{x}$ that each consumer gets, and it affects the individual consumption decisions. At the margin, the last effect is positive but second order due to the envelope theorem. Because selfish consumers consume more than $\bar{x}$, they benefit from the price reduction, while Kantian consumers consume less than $\bar{x}$and therefore lose out.

These propositions show that with price regulation total emissions are reduced and everybody benefits if the population gets more climate conscious. With quantity regulation only selfish consumers benefit, morally concerned consumers lose out, and there is no effect on total emissions. Furthermore, quantity regulation gives rise to perverse incentive effects. Kantian consumers have no material interest to convince selfish consumers to behave more morally and selfish consumers do not want to educate naïve Utilitarians about the functioning of the emissions market.

4 Distributional Effects

We distinguish two types of consumers, called rich (r) and poor (p), who are all moral consequentialists. The utility functions are

$$U_i = v(x) - \delta_i(c + \bar{p})x - D(\bar{x}) - \beta[x - x^o]^+ + \delta_i \bar{p}\bar{x} \ , \tag{17}$$

with $i \in \{r, p\}$ and $\delta := \delta_r < \delta_p := 1$. The rich have a lower marginal utility of money than the poor. This reflects the common observation that many wealthy people do not seem to react much to the prices of polluting goods. They do not care whether a plastic bag in the supermarket costs an additional 50 cent, they drive an SUV even if fuel consumption is more expensive, and they do not give up on vacations to far away destinations just because the flight costs a few hundred Dollars more. However, some of these rich consumers react quite sensitively to moral concerns. They do not use plastic bags to protect the environment, they buy an electric car even though it is more expensive than a car with a combustion engine, and they cut back on air travel because they suffer from “flight shame”.

Let the consumption of type $i \in \{r, p\}$ under regime $j \in \{P, Q\}$ be x_i^j. With price regulation optimal consumption of the poor and the rich is $x_p^P = \hat{x}(c + p + \beta)$ and $x_r^P = \hat{x}(\delta(c+p)+\beta)$, respectively, while with quantity regulation the poor and rich consume $x_p^Q = \hat{x}(c+p)$ and $x_r^Q = \hat{x}(\delta(c+p))$, respectively. Fraction μ of the population is poor and fraction $1-\mu$ is rich, so that the average consumption in regime $j \in \{P, Q\}$ is $\bar{x}^j = \mu x_p^j + (1-\mu)x_r^j$. Moreover, we assume that the norm is sufficiently injunctive (α sufficiently large) so that $x_p^P > x^o = \alpha x^* + (1-\alpha)\bar{x}^j$, implying that $x^o < x_p^j < x_r^j$. Here, $x^* \equiv \mu x_p^* + (1-\mu)x_r^*$, where $v'(x_i^*) = \delta_i c + D'(x^*)$.

Comparing the consumption levels of the poor and the rich under price and quantity regulation we get the familiar result that $x_p^P(\bar{p}) < x_p^Q(\bar{p})$ and $x_r^P(\bar{p}) < x_r^Q(\bar{p})$, so total pollution is again smaller with price regulation than with quantity regulation:

$$x^P(\bar{p}) = \mu x_p^P(\bar{p}) + (1-\mu)x_r^P(\bar{p}) < \mu x_p^Q(\bar{p}) + (1-\mu)x_r^Q(\bar{p}) = x^Q(\bar{p}). \tag{18}$$

More importantly, we claim that with quantity regulation the rich reduce their consumption very little and“buy their way out” by paying the emission price, while with price regulation they do this to a lesser extent.

To analyze which group, the poor or the rich, contributes more to the reduction of emissions we compare their consumption levels to those from the *status quo ante*: to the consumption in a situation in which consumers are unaware of the environmental damage and in which there is no regulation, i.e. $\beta = 0$ and $p = 0$. These consumption levels are $x_p^a = \hat{x}(c)$ and $x_r^a = \hat{x}(\delta c)$, respectively. We define the “excess contribution of the poor” as

$$\Delta^j = [x_p^a - x_p^j] - [x_r^a - x_r^j]. \tag{19}$$

If $\Delta^j > 0$ the poor reduce consumption more than the rich in regime $j \in \{P, Q\}$ compared to the status quo ante.

Proposition 5.

(a) *With quantity regulation, the poor contribute more to the reduction of pollution than the* *rich,*

$$\Delta^Q(\bar{p}) > 0 \ , \tag{20}$$

if

$$-\frac{z\hat{x}''(z)}{\hat{x}'(z)} < 1 \ . \tag{21}$$

(b) The excess contribution of the poor is larger with quantity regulation than with price regulation,

$$\Delta^Q(\bar{p}) > \Delta^P(\bar{p}) \ , \tag{22}$$

if the demand function is convex, i.e. $\hat{x}''(z) > 0$.

Proof. Note that

$$\Delta^Q = \hat{x}(c) - \hat{x}(c+p) - [\hat{x}(\delta c) - \hat{x}(\delta(c+p)) \tag{23}$$

$$\Delta^P = \hat{x}(c) - \hat{x}(c+p+\beta) - [\hat{x}(\delta c) - \hat{x}(\delta(c+p)+\beta) \tag{24}$$

Part (a): For $\delta = 1$ it holds that $\Delta^Q = 0$. Thus, if $d\Delta^Q/d\delta < 0$, then $\Delta^Q > 0$ for all $\delta \in [0, 1)$. Note that

$$\frac{d\Delta^Q}{d\delta} = -\hat{x}'(\delta c)c + \hat{x}'(\delta(c+p))(c+p). \tag{25}$$

This derivative is negative iff

$$\delta c\hat{x}'(\delta c) > \delta(c+p)\hat{x}'(\delta(c+p)), \tag{26}$$

which is the case if $z\hat{x}'(z)$ is strictly decreasing in z for all $z \geq \delta c$. Differentiating $z\hat{x}'(z)$ with respect to z yields

$$\hat{x}'(z) + z\hat{x}''(z) < 0 \quad \Leftrightarrow \quad -\frac{z\hat{x}''(z)}{\hat{x}'(z)} < 1 \ . \tag{27}$$

Part (b): Note that $\Delta^P = \Delta^Q$ for $\beta = 0$. Thus, $\Delta^P < \Delta^Q$ for all $\beta > 0$ if Δ^P is strictly decreasing in β. Taking the derivative of Δ^P with respect to β yields:

$$\frac{d\Delta^P}{d\beta} = -\hat{x}'(c+p+\beta) + \hat{x}'(\delta(c+p)+\beta) \ . \tag{28}$$

Note that $c + p + \beta > \delta(c+p) + \beta$. The derivative is strictly negative if $\hat{x}''(z) > 0$. □

Part (a) of Proposition 5 shows that with quantity regulation poor consumers contribute more to the reduction of pollution than rich consumers under a weak condition on demand. Condition (21) is satisfied if demand is not too convex (e.g. concave or linear). The excess contribution of the poor is smaller with price than with quantity regulation if demand is convex. In fact, with price regulation it is possible that the excess contribution of the poor becomes negative, i.e. the rich contribute more than the poor. Thus, if it is desirable that the poor do not contribute much more than the rich in order to increase political support, price regulation tends to be better than quantity regulation.

An extreme example illustrating Proposition 5 is the following. Suppose there is an upper limit on the consumption of good X, $x \leq x^{max}$, and that $\min\{c+p,\ \delta(c+\bar{p})+\beta\} > v'(x^{max}) > \delta(c+p)$. This is the case if δ is small and β is large.

(i) With quantity regulation the rich do not adjust their consumption of X compared to the status quo ante at all, so all the adjustment has to be done by the poor.

(ii) With price regulation the rich will reduce their consumption of X (even if they do not care about the pollution price $\bar{p}$) because of their moral concerns. In this case, both the rich and the poor contribute to the reduction of emissions.

These findings have some important implications. The limit on the pollution price $\bar{p}$ is usually determined by poor consumers who suffer more from higher prices than the rich. With quantity regulation the rich will continue to consume (almost) as much as they did in the status quo ante, so the total quantity of emission rights $\bar{E} = x^Q(\bar{p})$ may have to be very high to make sure that $p \leq \bar{p}$. Furthermore, the larger the fraction of the rich, the larger $\bar{E}$ has to be.

Sometimes it is argued that rich consumers have a higher β than poor consumers (because morality is a normal good). If this is the case, rich consumers may consume less than poor consumers with price regulation, but they will not do so with quantity regulation. This also provides support for a price regulation.

5 Deleting Emission Rights

If there is an emissions market, a morally concerned consumer could compensate for the emissions caused by her consumption by buying and deleting emission permits, which effectively reduces total emissions. Thus, (sophisticated) Utilitarians may have moral concerns also under a quantity regulation.[11]

Let $e \geq 0$ denote the number of emission rights that a consumer buys and deletes. This reduces her utility loss from violating the norm x^o to $\beta[x - e - x^o]^+$. A Utilitarian consumer understands that she can reduce emissions by purchasing and deleting emission rights, but not by reducing consumption. We model this as a two stage decision process. At stage two, for a given x, she maximizes her utility via the amount of permits e purchased. At stage one, she chooses her consumption x taking into account how this affects her purchase of permits. The first decision is independent of moral concerns, while for the second decision norm violation affects utility. The marginal benefit of buying emission rights is β and the marginal cost is $\bar{p}$. Thus, if β is smaller than $\bar{p}$, a morally concerned consumer will not buy any emissions rights and consumes x^s. If β is larger than $\bar{p}$, she buys as many permits so as to fully comply with the social norm, $e = x - x^0$. The consumer foresees that for every unit consumed she will buy one emission right, which increases the marginal cost of consumption to $c + 2\bar{p}$.

Proposition 6. *Suppose that morally concerned consumers can buy and delete emission rights at price $\bar{p}$. If $\bar{p} > \beta$, a Utilitarian consumer chooses x^s and does not delete any emission rights. If $\bar{p} < \beta$, she buys $x^e = \hat{x}(c + 2\bar{p})$ and deletes $e = x^e - x^o$. Note that $x^* < x^m < x^e < x^s$ for $\beta > \bar{p}$.*

Proof. Follows from the linearity of second-stage utility in e and the definition of $\hat{x}(\cdot)$. □

For heterogeneous consumers that differ in their degree of morality β, the above proposition shows that for all consumers i with $\beta_i < \bar{p}$ the analysis of the previous sections is unaffected. Consumers with $\beta_i > \bar{p}$ will make use of the option to buy emission rights. Importantly, these consumers still consume more under quantity regulation than price regulation.

[11] There are organizations offering to compensate CO_2 emissions by buying and deleting emissions rights (e.g. Carbonkiller (`carbonkiller.org/en`). See also Gerlagh and Heijmans (2019).

6 Conclusions

Many consumers are morally concerned about their carbon footprint and prepared to voluntarily reduce emissions by saving energy, investing in renewables, or changing their consumption patterns. With quantity regulation these efforts to reduce consumption do not affect total pollution and are discouraged. Under price regulation climate action by morally concerned consumers reduces total emissions. This leads to an important difference between price and quantity regulation if there is a political constraint on the pollution price.

Our analysis applies not only to consumption decisions. Many firms and (regional) governments are pressured by their customers and voters to also make substantial efforts to reduce carbon emissions. For example, Forbes (2019) lists 101 multinational companies that are committed to become carbon neutral in the near future. Similarly, many (regional) governments make significant efforts to reduce CO_2 emissions. For example, many US states impose clean energy standards to reduce non-renewable energy consumption and to increase the production of renewable energy. In the EU, several countries heavily subsidize the production of solar and wind energy. These initiatives are often on top of cap-and-trade systems, such as the Regional Greenhouse Gas Initiative (RGGI) and the Western Climate Initiative (WCI) in North America or the Emissions Trading System (ETS) in the EU, and so have little or no effect on total emissions.

Furthermore, quantity regulation gives rise to dysfunctional incentive and distribution effects. There are no incentives for Kantian consumers to convince selfish consumers to become morally concerned and for selfish consumers to educate "naïve" consumers about the functioning of cap-and-trade. It gives little incentives to the rich to curb their emissions, so most of the burden of adjustment has to be born by the poor. Climate action of morally concerned agents lowers the carbon price and thereby subsidizes consumption of those who are less environmentally conscious. In contrast, with price regulation everybody benefits if agents are motivated to take climate action. Additionally, rich and poor households have similar incentives to reduce their carbon emissions. These are powerful arguments in favor of price regulation that policy makers should take into account.

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