Private provision of public goods under quantity regulation: Cap-and-trade schemes limit green consumerism

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Abstract

Private provision of public goods can only supplement government provision if individual actions affect the level of the public good. Cap-and-trade schemes reduce the overuse of common resources such as a stable climate or fish stocks by imposing a binding cap on total use by regulated agents. Any private contribution provided by means of e.g. green consumerism or life-style choices within such a scheme only impacts on who uses the resource but leaves total use unaffected. Perfect neutralisation of marginal contributions is a key design element of cap-and-trade schemes. As real world cap-and-trade policies like the EU Emission Trading System have incomplete coverage, understanding what they cover is crucial for individuals aiming to contribute. Basing consumption decisions e.g. on physical rather than effective carbon emissions is likely to increase total emissions.

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1 Introduction

Climate change mitigation is a global, intergenerational public good that seriously challenges established governance concepts. It is currently provided by international agreements, national governments and voluntary private contributions but because of its nature and scale international agreements have usually been considered key in effectively addressing the problem. However, the apparent difficulty in achieving substantial and effective emission reductions both at the national and international level, have recently led researchers from several disciplines and politicians and NGOs to more closely consider the potential of contributions made by individuals and households as part of their consumption and life-style choices. There is substantial evidence that a substantial share of the population is intriniscally motivated to contribute to climate change mitigation and does so when given the chance. Examples are subscriptions to 'green' electricity tariffs (Kotchen and Moore 2007, Jacobsen et al. 2012, Costa and Kahn 2013), purchases of hybrid cars (Ozaki and Sevastyanova 2011), grocery shopping (Perino et al. 2013) and a general willingness-to-pay to purchase carbon offsets (Diederich and Goeschl 2013). There is a drive to understand how these voluntary contributions can be increased by non-price interventions (Abrahamse et al. 2005, Allcott and Mullainathan 2010, Allcott 2011) and researchers[1], governments[2] and NGOs[3] provide lists of actions advising households in reducing their carbon footprint. In the context of grocery shopping, carbon footprint labels provide the information necessary for consumers to take into account the climate impacts of their consumption choices (Vandenbergh et al. 2011). While still in their infancy, several large corporations like Coca Cola and UK's Tesco supermarket have tested them. Common standards to compute life-cycle carbon footprints exist in the UK (PAS 2050) and are currently under development internationally (ISO 14067).

While it is clear that private provision alone cannot solve the climate change problem, it

[1] Gardner and Stern (2008), Vandenbergh et al. (2008), Dietz et al. (2009)

[2] See e.g. the U.S. Environmental Protection Agency's 'What You Can Do' (*http : //www.epa.gov/climatechange/wycd/index.html*, accessed: 9^{th} July 2013) and the European Commissions 'Take Control!' (*http : //ec.europa.eu/clima/sites/campaign/control/takecontrol$_e$n.htm*, accessed: 9^{th} July 2013) campaigns.

[3] e.g. Greenpeace's carbon footprint reduction tool kit (*http : //www.greenpeace.org/er − ship/en/Galley/Activist − toolkits/*, accessed: 9^{th} July 2013).

is widely believed to be an important part of the solution. Ostrom (2010, 2012) advocates actions being taken at many different levels including both national and international cap-and-trade programmes and changes in household behaviour and Vandenbergh et al. (2008) and Dietz et al. (2009) explicitly regard changes in consumption and life-style choices as complements to cap-and-trade schemes. Cap-and-trade schemes for greenhouse gas (GHG) emissions are opperating in the European Union, in North America as part of the Western Climate Initative (WCI) and the Regional Greenhouse Gas Initative (RGGI).[4] Australia will convert what currently in effect is a carbon tax into a cap-and-trade scheme in 2015 and China has started the first of a number of city-level cap-and-trade programmes for carbon emissions in June 2013 to gain experience for a future national scale programme[5].

Given the trend to extend the use of both cap-and-trade schemes and policies stimulating voluntary behavioural change, it is important to understand how these two mechanisms to reduce GHG emissions interact. In this paper I will make a first step toward developing such an understanding. Combining a simple behavioural economics model of consumer choice with basic environmental economics I investiage the static effects of green consumerism in the presence of a cap-and-trade scheme. The interactions between quantity based government intervention and voluntary contributions to the public good have profound - and mostly unintended - impacts on the effectivity of both forms of provision. A key result is that policies aimed e.g. at reducing domestic electrivity consumption (Allcott and Mullainathan 2010, Allcott 2011) can have profoundly different effects inside and outside a cap-and-trade scheme. Outside such a scheme, they are likely to reduce total GHG emissions. However, if the power sector's carbon dioxide emissions are covered by a cap-and-trade scheme (which is the case in all of the real world schemes mentioned above), then the exact opposite holds and total emissions are likely to increase if the intervention is 'successfull' due to an economy-wide rebound effect. But the interaction also works the other way round as the introduction of a cap-and-trade scheme might strictly increase total emissions.

[4]Participating states RGGI: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (*http://www.rggi.org/*). US states and Canadian provinces participating in WCI: Arizona, British Columbia, California, Manitoba, Montana, New Mexico, Ontario, Oregon, Quebec, Utah, and Washington (*http://www.westernclimateinitiative.org*).

[5]See Qui (2013)

It is important to note that none of the underlying effects is caused by negative interactions between public and private provision in general such as the crowding out of private contribution by government provision (Warr 1982, Bergstrom et al. 1986) or the crowding out of intrinsic motivation (Frey and Jegen 2001, Bowles 2008). The effects presented are very closey tied to specific design features of cap-and-trade schemes and would be very different under a carbon tax. However, at least one key result can be extended substantially. Any government intervention aimed at reducing GHG emissions overlapping with a cap-and-trade scheme such as feed-in tariffs for renewables, minimum prices for emissions by certain sectors within the scheme[6] or bans on incandescent light bulbs[7] will trigger a rebound effect that tends to increase total GHG emissions.

2 The Model

The reason is straightforward: The binding cap on GHG emissions imposed by the tradable permit scheme neutralises any direct effect the reduction in electricity demand by some consumers might have. However, there are important indirect effects. The reduced demand for electricity shifts the demand function for emission allowances or permits to the left. Given the fixed supply, this reduces the permit price and hence reduces the total sum of money spend on goods covered by the cap-and-trade scheme.

Moreover, how exactly cap-and-trade and green consumerism interact crucially depends on whether or not consumers understand the basic principles of emissions trading and the coverage of the specific scheme operating in their region.

Based on the assumption that intrinsically motivated or 'green' citizens care about the impact of their consumption and life-style choices on total GHG emissions,

I show that, the conversion of an emissions tax into an emission trading scheme (i.e. the Australian case) increases demand for products from regulated sectors by green consumers, if consumers understand the basic principles of both regulatory interventions and are aware of their coverage. This is because they realise that consumption of these goods no longer

[6] The UK has introduced a minimum price on carbon dioxide emissions from electricity producers in 2013.

[7] The European Union started to phase-out incandescent light bulbs for use in households in 2009.

affects total GHG emissions: they are capped after all. Whether this increases or decreases total emissions depends on the relative prices and pollution intensities of regulated and unregulated products. However, if the unregulated goods are sufficiently cheap/clean, then the introduction of a sufficiently lax cap-and-trade scheme with incomplete coverage can result in an increase in total emissions. Given that real world cap-and-trade schemes tend to allocate emission allowances somewhat generously, this clearly is bad news.

On the other hand, I find that if consumers do not understand the implications of cap-and-trade schemes, total emissions are higher than if they do. This result highlights the importance of information and education making voluntary contributions effective.

Public goods are usually provided either by voluntary contributions, government interventions or both. Governments can increase the supply of public goods either directly by providing a certain quantity or by incentivising private provision via matching or tax break schemes. In both cases it is crucial to take the response by individuals into account as government subsidies might crowd out private contributions (Warr 1982, Bergstrom et al. 1986) and seemingly minor differences in the design of schemes intended to stimulate private contributions can have substantial impacts (Eckel and Grossman 2003).

Models of 'warm glow' giving (Andreoni 1989, 1990) or of moral or intrinsic motivation (Brekke et al. 2003) assume that people might not only care about the aggregate level of provision but also about their individual contribution to the public good. These models are better able to accommodate empirical findings such as a smaller crowding-out effect of subsidies and levels of private provision that tend to be substantially larger than predicted by models of 'pure altruism', regardless of group size.[8] Warm glows or intrinsic motivation effectively convert a pure public good into an impure one.[9]

This paper is relevant for both pure and impure altruism but in the context of large scale public goods like climate change mitigation the effects described are only of relevant scale for intrinsically motivated agents. I investigate how a particular form of government intervention - the introduction of a cap-and-trade scheme - impacts on the private provision

[8] Andreoni (1988) shows that in a model of pure altruism private contributions converge to zero in very large groups.

[9] For models of private provision of impure public goods see e.g. Cornes and Sandler (1984a).

of a public good like the reduction of greenhouse gas (GHG) emissions or the reduction of over-fishing that are mainly affected by negative contributions. Both examples have in common that they involve large group sizes (in terms of consumers, billions in the former and often millions in the latter), that there is some evidence of intrinsic motivation in the form of green consumerism and that they are frequently subject to cap-and-trade type regulation. The EU Emission Trading System (EU ETS) is the largest cap-and-trade scheme covering almost half of all GHG emissions in participating countries. There are currently two cap-and-trade schemes in operation in North America: the Regional Greenhouse Gas Initiative (RGGI) in the east of the US[10] and the Western Climate Initiative (WCI) in the western US and Canada[11]. While RGGI focuses on emissions from electricity production, the WCI in addition includes other energy intensive industries and from 2015 is planned to include transportation, residential and commercial fuel uses covering about 90% of GHG emissions of member states. Australia will convert its recently introduced emissions tax into a cap-and-trade scheme in 2015. Total allowable catches (TAC) and individual transferable quota (ITQ) type regulations are cap-and-trade schemes applied to fisheries in order to reduce over-fishing and are employed in Australia, Canada, Iceland, New Zealand, the U.S. and other countries.

Cap-and-trade schemes have an innate feature that is of particular relevance in the context of private provision of public goods. The government sets a binding upper bound on negative contributions to the public good, parcels them into permits or quotas and allows trading. This mechanism effectively converts a public good or externality problem into one of cost minimisation. The immediate implication of cap-and-trade is therefore that any marginal change in emissions by one regulated source is perfectly offset by one or more other regulated sources. The very institution of cap-and-trade makes the aggregate cap on say GHG emissions of regulated sources exogenous, but renders the response by other parties participating in the scheme endogenous and perfectly predictable in the aggregate. This

[10]Participating states are: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (*http://www.rggi.org/*).

[11]The WCI includes the following US states and Canadian provinces: Arizona, British Columbia, California, Manitoba, Montana, New Mexico, Ontario, Oregon, Quebec, Utah, and Washington (*http://www.westernclimateinitiative.org*).

holds as long as the aggregate cap is indeed binding.

Institutionalised neutralisation of marginal contributions under a cap-and-trade scheme renders efforts to privately improve the provision of the public good futile if these contributions take place within the scheme. To illustrate this point consider the replacement of an incandescent light bulb (or any other electric appliance) with an energy-efficient one. As all existing cap-and-trade schemes for GHG emissions include electricity generation, this replacement has no impact on total GHG emissions by sources within the scheme because any emissions reduced at one source will be neutralised by a corresponding increase in emissions elsewhere and vice versa. The neutrality of marginal contributions in cap-and-trade schemes is well established in the analysis of regulations, e.g. to stimulate generation of renewable energy, overlapping with a cap-and-trade scheme[12] and has also been discussed in the context of green consumerism (Twomey et al. 2012) but so far no formal treatment of the latter exists.

A cap-and-trade scheme with full coverage would therefore make private contributions to the public good via consumption or life-style choices (green consumerism) impossible. However, none of the real world incarnations of cap-and-trade are currently anywhere near full coverage. The EU ETS for example focuses on aviation and big stationary sources such as electricity production and energy intensive industries. All other sectors including road transport, agriculture and all those with a low energy intensity are not covered. They account for more than half of GHG emissions in participating countries.

Incomplete coverage requires that intrinsically motivated citizens are aware of the neutralising effect and which emissions are covered by the cap-and-trade scheme and which are not. Otherwise they will misallocate their efforts to contribute to the public good. Consider the example of aviation. A green consumer might opt to travel by bus instead of by plane in order to reduce the GHG emissions of her trip. This has the desired effect if that trip takes place in the US. However, in the EU, taking the bus is likely to increase total GHG emissions compared to the flight.[13] The simple reason being that any additional emissions

[12]See e.g. Requate (2009), Böhringer and Rosendahl (2010), Fischer and Preonas (2010).

[13]Note that there are dedicated allowances for the aviation sector (so called EUAAs) that cannot be used by stationary sources. However, airlines can use 'standard' allowances (EUAs). Given that the aviation sector is predicted to grow and hence to be a net buyer of allowances, marginal emissions by airlines will be

caused by the flight are fully neutralised (potentially even twice if the individual chooses to buy additional offsets offered by most airlines when buying tickets) while those of a bus journey are not.

Many recommendations by government agencies[14] and NGOs[15] on how to reduce one's carbon footprint are inappropriate in the EU and to some extent also in the other regions of the world operating a cap-and-trade scheme. Reducing the number of flights, installing energy efficient light bulbs and many other recommended actions have no or a much lower direct impact on total GHG emissions and depending on the alternatives chosen might actually have increase total emissions. The same holds for carbon footprint labels like those used by the UK Carbon Trust or calculated based on Publicly Available Specification (PAS) 2050.[16] They report life-cycle emissions of products and do not differentiate between emissions covered by the EU ETS and those that are not. Consumption decisions influenced by those labels are very likely to be misguided.[17] Consumers caring about either total GHG emissions or their own contribution to total GHG emissions that understand how a cap-and-trade scheme works only take emissions not covered by the scheme into account. They might still have very good reasons to buy energy efficient light bulbs, but directly reducing

covered by EUAs and hence the partial separation of the two schemes is unlikely to be relevant. One caveat is in order. While carbon dioxide emission emissions are unaffected, the fact that planes fly at high altitudes means that there are non-carbon effects associated with emissions by planes. How much this adds to their global warming potential, depends crucially on the time scale considered, but seems to be relatively small if time scales of more than a hundred years are considered (Forster et al. 2006).

[14]Examples are the 'a world you like' campaign by the EU ($http://world-you-like.europa.eu/en/explore/$, accessed 15.01.2013) and the 'What can I do?' website of the UK Department of Energy & Climate Change ($http://www.decc.gov.uk/en/content/cms/tackling/saving_energy/individual/individual.aspx$, accessed 15.01.2013)

[15]Examples include advice by the Carbon Trust's Empower Savings Calculator ($http://www.carbontrust.com/resources/tools/empower-savings-calculator$, accessed 15.01.2013), the National Energy Foundation ($http://www.nef.org.uk/actonCO2/ecotravelling.asp$, accessed 15.01.2013) and Climate Care ($https://www.climatecare.org/climate/low-carbon-living/$, accessed 15.01.2013)

[16]PAS 2050 can be downloaded at $http://shop.bsigroup.com/en/forms/PASs/PAS-2050$ (accessed 15.01.2013).

[17]Perino et al. (2013) provide evidence from a field experiment that UK grocery shoppers take the UK Carbon Trusts carbon footprint label into account.

GHG emissions is not one of them.[18] This has absolutely nothing to do with any of its technical characteristics but is exclusively due to the regulatory framework. Also note that this effect does not require any preferences to change and that it is neither a response to the public provision itself nor to the fact that emissions are priced.[19] It merely assumes that consumers understand how a cap-and-trade scheme works, i.e. that there is a cap on regulated emissions that is unaffected by their shopping and lifestyle choices.[20]

This paper studies the effect of cap-and-trade schemes on private contributions in a world were regulation is second-best due to incomplete coverage and potentially a lack of stringency. Section 4 makes comparisons with taxes of the same coverage and stringency. There is no neutralisation of marginal contributions under a tax scheme and hence no crowding out. The level of private contributions and their distribution over sectors in the economy differs between instruments. Heyes and Kapur (2011) have recently compared price and quantity based regulation with altruistic agents but they focus on uniform emission standards that are not transferable between individuals. They therefore do not capture the crowding-out effect caused by institutionalised neutralisation which is at the heart of this paper.[21] Section 5 shows that the failure to understand how a cap-and-trade scheme works or equivalently basing decisions on both regulated and unregulated emissions as recommended by government agencies, NGOs and established carbon footprint labels is likely to increase total emissions.

3 Green consumerism and regulatory interventions

There is a large number of consumers N who derive utility from the consumption of two private goods x and y. Emissions are caused in the production of both private goods.

[18]There might be indirect effects on GHG emissions, e.g. via an impact on future emission caps. But they are likely to be small compared to the alleged direct impact.

[19]Hence, the response by consumers is neither crowding-out in the sense of Bergstrom et al. (1986), nor motivation crowding as in Frey and Jegen (2001), Bowles (2008) or Perino et al. (2013).

[20]The cap is of course not truly exogenous as consumers can also influence the political process as citizens, see e.g. Malueg and Yates (2006). This is not explicitly modelled here in order to focus on the impact of cap-and-trade schemes on private provision of the public good and green consumerism.

[21]There is an extensive literature comparing price and quantity based regulation including e.g Weitzman (1974), Montero (2002), Requate and Unold (2003), Krysiak (2008).

$\alpha \in [0,1[$ is the emission intensity of good x and y causes one unit of emissions per unit of output. Hence, x is the cleaner good.

The utility function is assumed to be

$$u^i = v(x^i, y^i) - m^i l^i, \tag{1}$$

where v is the utility derived from consumption (with $v_k > 0$, $v_{kk} < 0$ with $k = \{x, y\}$ and $v_{xy} \geq 0$) and l^i are the emissions of individual of type $i \in \{plain, green\}$. Own emissions cause a disutility of m^i per unit to individual of type i due to intrinsic or moral motivation, where m^i is exogenously given. $N^{green} \in [1, N]$ consumers are intrinsically motivated or "green" and experience a warm glow associated with their own emissions ($m^{green} = m > 0$). The $N - N^{green}$ "plain" individuals do not experience a special disutility from emissions ($m^{plain} = 0$). For simplicity consumers are assumed to be identical in all other aspects. Note that since I focus on green consumerism in the context of public goods like a stable climate that involve very large groups, I refrain from modelling the direct benefits of the public good or the 'pure altruist' dimension as it has been labelled in the literature on giving. This is in line with results by Andreoni (1988) showing that the Nash contribution of plain individuals is best approximated by zero.[22]

The exact nature of the warm glow, namely whether the preferences are defined over the change in aggregate emissions E caused by the individual's purchasing decisions (net emissions), or whether they are defined over the emissions that can be physically attributed to the individual regardless of whether they actually add to total emissions or not (gross emissions), is of particular concern here. Formally the two concepts can be written as

$$l^i_{net} = \frac{\partial E}{\partial \left(\alpha x^i + y^i\right)}, \tag{2}$$

$$l^i_{gross} = \alpha x^i + y^i, \tag{3}$$

This will be relevant in what follows as the regulatory regime might affect l_{net} but not l_{gross}. To illustrate this point consider a cap-and-trade scheme with full coverage. It would

[22] All results derived below also hold for consumers that only care about the total level of the public good and do not experience a warm glow. But in the context of large scale public goods like climate stability, this effect is negligible.

imply that $l_{gross} > l_{net} = 0$ since aggregate emissions are fixed by the cap on emissions and independent of the consumption choices of the individiual. Nevertheless, even under a cap-and-trade scheme with full coverage, there will be emissions that are directly attributable to the individual's consumption choices as long as at least one good is consumed in strictly positive quantities. The distinction between net and gross contributions has not been raised in the original models of warm glow (Andreoni 1989, 1990). However, Crumpler and Grossman (2008) experimentally compare net and gross contributions (where gross contributions have no impact on aggregate provision, like in the example with a full-coverage cap-and-trade scheme) to show that warm glow giving might indeed be based on whether or not a contribution has 'my name on it' rather than it 'making a difference'. In what follows I will discuss both cases. In the remainder of this and the next section I will assume that green consumers care about their net emissions and in section 5 the case of preferences over gross emissions is considered.

In the absence of any regulatory intervention to restrict pollution, the budget constraint is given by

$$x^i + py^i = w, \tag{4}$$

where w is the consumer's income and p the (relative) price of good y. In what follows the focus is on cases where the budget constraint is binding for all consumers. This cannot be taken for granted as green consumers naturally restrict consumption by internalising at least part of the pollution externality and because $\alpha > 0$ all consumption causes pollution. The condition for consumption to be constrained by budget is $v_x(x^{green*}, y^{green*}) - \alpha m > 0$ where x^{green*} and y^{green*} are the quantities consumed by green consumers in equilibrium. The larger m, the less likely is it that the budget constraint is binding.[23]

If there is no regulatory intervention to restrict emissions, the provision of the public good relies entirely on private provision by green consumers. Demand for goods x and y by consumer of type $i = \{plain, green\}$ is given by maximising (1) subject to (4) and

[23] There might well be individuals with very high levels of intrinsic motivation for which an exogenous budget constraint might not be binding. However, in a richer model, the budget constraint is of course endogenous and they would hence reduce their hours worked making the budget constraint binding again. In any case, the group of people for which this is an issue is likely to be relatively small.

$l_{net}^{i,un} = l_{gross}^{i,un} = \alpha x^i + y^i$. In the unregulated case there is no difference between net and gross emissions assuming that the Nash conjecture holds and all consumers take the actions of all others as given when making their own choice. The familiar conditions determining $x^{i,un}$ and $y^{i,un}$ are

$$p = \frac{v_y\left(x^{i,un}, y^{i,un}\right) - m^i}{v_x\left(x^{i,un}, y^{i,un}\right) - \alpha m^i}, \tag{5}$$

$$w = x^{i,un} + p y^{i,un}, \qquad i = \{plain, green\}. \tag{6}$$

Note that $m^{plain} = 0$.

3.1 Cap-and-trade

While cap-and-trade schemes are in theory able to fully solve the externality problem, all real world examples both implemented and proposed are clearly imperfect. They tend to focus on large, stationary sources but exclude emissions from e.g. road transport and agriculture. The EU Emission Trading System (EU ETS) for example covers about half of GHG emissions in participating countries including large scale electricity and heat generation, energy intensive industries like aluminium and steel production and inner-European flights. Even if the emission cap would be second-best optimal for regulated sectors, private provision of GHG abatement still has substantial scope to improve welfare in unregulated sectors. Moreover, the EU ETS has been plagued by over-provision of allowances, even leading to an effective collapse of the scheme toward the end of Phase I (2005 - 2007). The price for allowances in the EU ETS and RGGI are currently much lower than common estimates of the social costs of carbon emissions. One might therefore conclude that even in regulated sectors a bit of green consumerism might do good.

However, green consumerism within sectors regulated by a cap-and-trade scheme has no immediate impact on aggregate emissions as long as the cap is binding. Any abatement conducted in regulated sectors has no (direct) impact on aggregate emissions. Cap-and-trade schemes are all about allocating a given amount of emissions such as to minimise abatement costs. The environmental impact is decided ex-ante by the stringency of the cap and all decisions at the micro-level, whether by firms, governments or consumers, are irrelevant for total emissions from regulated sources unless they directly affect the cap or the cap ceases to be binding. Hence, when green consumers choose their consumption bundle they can no longer take the actions of all other consumers as given, as that would conflict with the requirement to take as given what is given (the cap on aggregate emissions in the dirty sector). In a small group setting this would require to look at potentially complex strategic effects, but in a large group context it seems warranted to ignore an individual's effects on aggregate variables - with the exception of l_{net} as intrinsic motivation effectively works like a magnifying glass and introduces an asymmetry in weighing the impacts of own versus others' actions.[24]

Next I formalise these features of a cap-and-trade scheme with incomplete coverage. Partial coverage is captured by assuming that only emissions associated with the production of good y are included in the cap-and-trade scheme. Emissions from production of x remain unregulated. Recall that x is the cleaner good and thereby this is in line with the fact that the EU ETS and other schemes focus on emission-intensive sectors.

The aggregate cap on emissions C is assumed to be exogenous for the purposes of the subsequent analysis. From an individual consumers' perspective this is clearly justified in the short run. However, the drop in the allowance prices induced by green consumerism in regulated sectors might trigger further reductions in the cap in future periods, but this effect is not only hard to quantify but also orthogonal to the focus of this paper as the presence and size of this indirect effect is likely to be independent of the direct effect on emissions highlighted in this paper.

The inclusion of the dirty good in a cap-and-trade scheme drives a wedge between net and gross emissions. Consumption of the dirty good by an individual now has no impact on aggregate emissions. Net emissions are therefore

$$l_{net}^{i,c\&t} = \alpha x^i, \qquad i = \{plain, green\}. \tag{7}$$

It is important to note that this does not reflect a change in preferences (so-called motivation crowding) or a response to the total level of public good provided. Green consumers merely take into account the very nature of a cap-and-trade scheme which causes l_{net} to differ

[24] For a discussion of non-Nash conjectures in the early literature on private provision of public goods see Cornes and Sandler (1984b) and Sugden (1985).

from l_{gross}. The key is therefore that green consumers care about l_{net} rather than l_{gross}. The value of m^{green} is assumed to remain unaffected by both presence and type of the policy intervention. Experimental evidence suggests that motivation crowding might indeed be an issue when a price on emissions is introduced even if this only induces a small price change in consumption goods (Perino et al. 2013). However, I am not aware of a clear conjecture or evidence that this crowding effect would differ depending on whether the price on emissions originates from an emission tax or a tradable permit scheme. Without such an instrument specific effect, all results are robust to the consideration of changes in m^{green} as long as it remains strictly positive.

If the cap is binding, emission allowances are traded at a positive price γ. The budget constraint becomes

$$x^i + (p+\gamma)y^i = w, \qquad i = \{plain, green\} \tag{8}$$

The permit constraint is

$$(N - N^{green})y^{plain} + N^{green}y^{green} \leq C, \tag{9}$$

and attention is restricted to cases where (9) is binding.

Demand for goods x and y by consumer of type $i = \{plain, green\}$ is given by maximising (1) subject to (7) - (9). The conditions determining $x^{i,c\&t}$ and $y^{i,c\&t}$ under cap-and-trade are

$$\begin{aligned} p+\gamma &= \frac{v_y\left(x^{i,c\&t}, y^{i,c\&t}\right)}{v_x\left(x^{i,c\&t}, y^{i,c\&t}\right) - \alpha m^i}, & (10)\\ w &= x^{i,c\&t} + (p+\gamma)y^{i,c\&t}, \qquad i = \{plain, green\} & (11)\\ C &\geq (N - N^{green})y^{plain,c\&t} + N^{green}y^{green,c\&t}, & (12) \end{aligned}$$

which is a system of five equations and five unknowns. Note that again $m^{plain} = 0$.

3.2 Emissions taxes

A second instrument available to reduce GHG emissions is a carbon tax. Australia has recently introduced a tax on carbon emissions (which will be converted into a cap-and-trade scheme in 2015), Germany taxes petrol and to some extent electricity based on associated

GHG emissions and in April 2013 the UK imposed a tax (binding price floor) of GBP 16 per ton of CO_2 (scheduled to rise to GBP 30 in 2020 and GBP 70 in 2030) on GHG emissions in electricity production. Again, coverage of these schemes is limited and the appropriateness of their stringency debatable. By and large emission taxes suffer from the same imperfections in implementation as cap-and-trade schemes as they can only cover emissions that can be easily measured and verified. However, in contrast to cap-and-trade schemes, taxes do not pre-determine aggregate emissions in regulated sectors but set a pre-determined price for a unit of emissions instead. Hence, green consumerism affects aggregate emissions in the standard way so that $l^{i,tax}_{net} = l^{i,tax}_{gross} = \alpha x^i + y^i$. The consumer's budget constraint is $x^i + (p+\gamma)y^i = w$, i.e. the same as with a cap-and-trade scheme, where γ is now the tax rate.

Demand for goods x and y by consumers of type $i = \{plain, green\}$ under taxes is given by the following conditions

$$p + \gamma = \frac{v_y\left(x^{i,tax}, y^{i,tax}\right) - m^i}{v_x\left(x^{i,tax}, y^{i,tax}\right) - \alpha m^i}, \tag{13}$$

$$w = x^{i,tax} + (p+\gamma)y^{i,tax}, \qquad i = \{plain, green\}. \tag{14}$$

Note that $m^{plain} = 0$. There are two differences between the conditions under taxes and permits. The first is that in (13) but not in (10) green consumerism is relevant for good y. The second difference is the permit constraint (12) which is only relevant in the cap-and-trade scheme, as the price of emissions is set exogenously under an emissions tax. In the tax case consumption choices by individual consumers are independent of each other as they are only linked through prices which here are treated as exogenous. In the cap-and-trade scheme, however, the permit constraint reflects the neutralising aspect of this regulatory approach directly linking choices by individuals.

4 Comparison of instruments

This section compares consumption and emission levels under cap-and-trade to those under an emissions tax. For that purpose the emissions tax is set equal to the equilibrium price of permits. This makes sure that consumers face the same set of prices and that any difference can be attributed to the impact of the cap-and-trade scheme on private provision of the public good by green consumers. Plain consumers' consumption choices are the same under both instruments as they only care about relative prices which by assumption are held constant. The difference in consumption levels for green consumers is driven by them caring about the impact of their consumption choices on total emissions and the fact that consumption of good y is emission-neutral under a cap-and-trade scheme but not under an emissions tax. This is reflected by the absence of m in the numerator of (10) while m appears in the numerator of (13). Since $v_{xx} < 0$, $v_{yy} < 0$ and $m > 0$ it follows that

Proposition 1 *(Demand by green consumers) Green consumers consume less of the relatively clean good, i.e.* $x^{green,c\&t}(\gamma) < x^{green,tax}(\gamma)$*, and more of the relatively dirty good, i.e.* $y^{green,c\&t}(\gamma) > y^{green,tax}(\gamma)$*, under a cap-and-trade scheme than under an emissions tax. This holds for all* $\gamma > 0$ *and hence for all levels of the aggregate cap on emissions* C*.*

The proof is given in the appendix. Figure 1 illustrates Proposition 1. Consumption by green consumers under a cap-and-trade scheme is given by black lines. Consumption by green consumers under an emissions tax are represented by grey lines.

Note that Figure 1 is drawn in a way that the equilibrium permit price approaches zero at the right end of each panel and is strictly positive and strictly increasing as one moves towards the left. Consumption under taxes converges to the unregulated level (shown as a horizontal grey dashed line) when the price of emissions approaches zero. This can be easily verfied by comparing conditions (5) - (6) and (13) - (14).

In contrast, under a cap-and-trade scheme only the budget constraint converges towards the one in the unregulated case. An individual's emissions in sector y are still fully neutralised and hence green consumers ignore them in their consumption choices, affecting how they value the dirty good at the margin. As derived above demand for the dirty good by green consumers y is higher under cap-and-trade than under an equivalent emissions tax. This implies that

Proposition 2 *(Permit price with cap at unregulated level) The permit price is strictly positive when the cap imposed on the dirty sector is equal to unregulated emissions in that sector.*

The proof is given in the appendix but the intuition for this result is straightforward. Because private provision of reduction of greenhouse gas emissions is crowded-out by a cap-and-trade scheme in the regulated sector, the demand for dirty goods increases when such a scheme is introduced (Proposition 1). With an emission cap at the unregulated level of emissions (represented by 1.0 on the horizontal axis in Figure 1), the permit constraint is binding because the demand curve for dirty goods y has been shifted upwards by the introduction of a cap-and-trade scheme. Permits are hence a scarce resource with a strictly positive value. The permit price drops to zero only when the cap on emissions exceeds the unregulated level significantly.

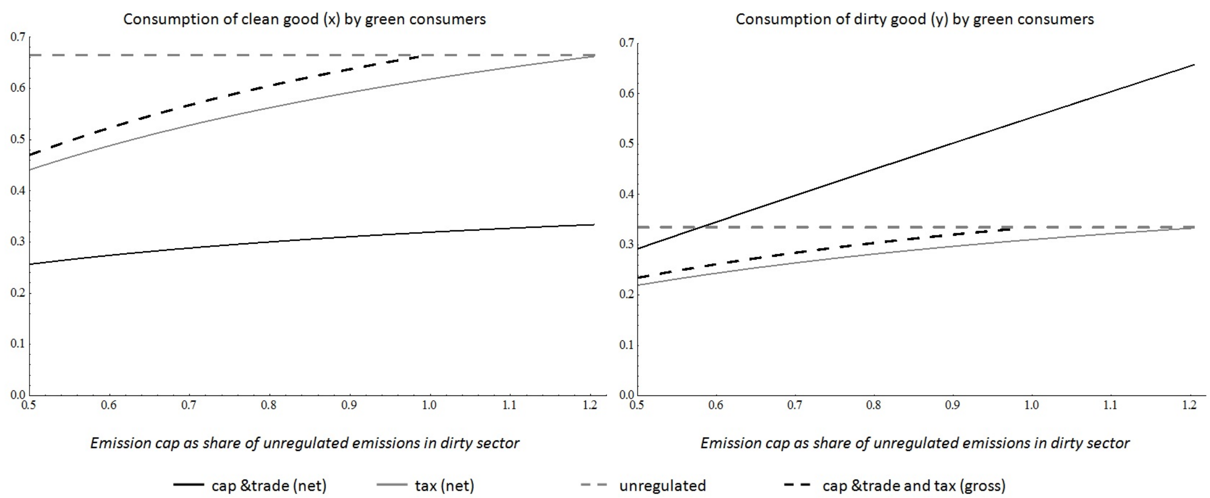

Figure 1: Consumption of goods x (left panel) and y (right panel) by green consumers as a function of the stringency of the cap-and-trade scheme.

The neutralisation of private contributions to the public good also affects the aggregate level of emissions (see Figure 2). To highlight this I focus again on the case where the price of emissions converges to zero. All equilibrium conditions and hence consumption choices and emissions under a tax converge to that without regulation. Under a cap-and-trade scheme, the budget constraint again converges to the unregulated case, but green (not plain) consumers choose a different point (one with a higher y and a lower x) on the budget line as they no longer experience a warm glow by reducing emissions associated with y (see Proposition 1). Such a movement along a given budget line implies that

Proposition 3 *(Total emissions) Total emissions are higher under a cap-and-trade scheme than under an emission tax (or in the absence of regulation) if the price of emissions is close to zero and if the dirty good is sufficiently cheap ($p < \frac{1}{\alpha} > 1$).*

The proof is given in the appendix.

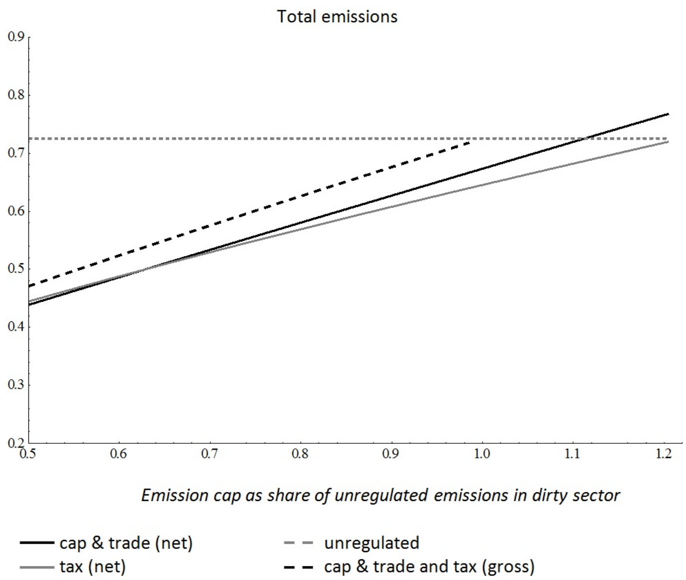

Figure 2: Total emissions as a function of the stringency of the cap-and-trade scheme.

The neutralisation of individual efforts to contribute to the provision of the public good in a cap-and-trade scheme is of particular relevance if the permit price is very low. This currently is the case in the EU ETS with the price per ton falling below 4 EUR in January 2013. In such a case total emissions potentially are higher than in the absence of any regulation.

5 Consumers caring about gross contribution

Now let us briefly consider what happens if green consumers base decisions on their gross rather than their net contribution and the dirty sector is again regulated by a cap-and-trade scheme.[25] Gross emissions l_{gross} include all emissions physically associated with consumption

[25]Recall that under an emissions tax there is no difference between net and gross emissions and hence behaviour is not affected by this distinction.

ignoring neutralisation occurring within a cap-and-trade scheme. This is the case if they care about their net contribution but are unaware - as is arguably the case at the moment for a substantial share of consumers - that consumption choices within cap-and-trade sectors are emission-neutral at least as far as direct effects are concerned. Alternatively, consumers might fully understand the regulatory framework, but their preferences are defined over full carbon footprints of their consumption choices rather than the actual change in total GHG emissions.[26] In both cases they effectively follow advise by governments and NGOs on how to reduce carbon footprints and in their shopping choices consider carbon footprint labels based on life-cycle GHG emissions (such as those based on PAS 2050 and used by the UK supermarket chain Tesco and Coca-Cola).

The equilibrium conditions are hence

$$
\begin{aligned}
p+\gamma &= \frac{v_y\left(x^{i,c\&t}, y^{i,c\&t}\right) - m^i}{v_x\left(x^{i,c\&t}, y^{i,c\&t}\right) - \alpha m^i}, && (15)\\
w &= x^{i,c\&t} + (p+\gamma)y^{i,c\&t}, \qquad i = \{plain, green\} && (16)\\
C &\geq (N - N^{green})y^{plain,c\&t} + N^{green}y^{green,c\&t}, && (17)
\end{aligned}
$$

which are equivalent to the conditions under cap-and-trade when consumers care about net emissions with the important exception that here (10) is replaced by (13). This has a number of implications. The first is that the permit price is zero at a cap equal to the unregulated level of emissions. Hence, Proposition 2 does not carry over to the case where green consumers base their consumption choices on gross rather than net emissions. The black dashed lines in Figure 1 both stop at 1.0 and quantities consumed coincide with the unregulated levels as at this point the cap-and-trade scheme has neither an impact on how consumers trade-off goods nor on the budget constraint. It is also straightforward to show that consumption by green consumers of the dirtier (cleaner) good is decreasing (increasing) in the m in the numerator of (15) while holding the m in the denominator constant. Hence, green consumers buy more of the cleaner good if they base their consumption choices on gross rather than net contributions under a cap-and-trade scheme. By doing this they increase their unregulated emissions, and decrease their demand for regulated emissions - inducing

[26]Crumpler and Grossman (2008) provide experimental evidence that this might be the case in the context of giving to a charity.

plain consumers to buy more of the dirty good as the price of emissions is lower.

Proposition 4 *(Emissions when consumers consider gross contributions) If green consumers take their gross emissions rather than only those outside a cap-and-trade scheme into account total emissions increase compared to the case where they only consider their net emissions. This only ceases to hold if:*

- *total emissions in the net emission scenario are at or above those in the unregulated case (see Proposition 3). This implies that the permit constraint exceeds the level of unregulated emissions in the dirty sector and the cap is therefore not binding in the gross emission scenario, or*
- *the unregulated sector x is perfectly clean ($\alpha = 0$) and coverage of the cap-and-trade scheme therefore complete.*

The proof is given in the appendix. Figure 2 illustrates the increase in total emissions.

One qualification is in order. The strong result that emissions always strictly increase when consumers base decisions on gross emissions does not necessarily carry over to situations where there are more than two goods. For example, if there are several goods covered by the cap-and-trade scheme with different emission intensities consumers considering gross emissions might substitute the one with the lower emission intensity for the one with the higher one. As emissions from both goods are neutralised with in the cap-and-trade scheme, such a switch does not affect total emissions. In the current model the result is driven by a negative correlation between the gross emissions of a product and its net emissions. Overall this is likely to hold for real world cap-and-trade schemes as they tend to focus on energy intensive industries. It is therefore not only possible but likely that considering gross instead of net emissions on average results in an increase of total emissions.

The comparison between a tax and a cap-and-trade scheme when consumers base their decisions on gross emissions is straightforward: they are equivalent. Both budget constraints and how consumers value the goods at the margin are the same under the two types of regulation. This again hinges on the assumption that the emission tax rate equals the equilibrium permits price. Note that since the latter is reduced compared to the case where consumers consider net emissions, the curves representing consumption by green consumers and total emissions under a tax in Figures 1 and 2 respectively, changes as well and coincides with the corresponding curves for cap-and-trade. This also implies that if consumers base their decisions on gross emissions, the choice of instrument has no impact on private provision of the public good.

Cap-and-trade schemes reduce private efforts of GHG control when green consumers realise that emissions caused in regulated sectors are fully neutralised. This results in higher aggregate emissions than under an equivalent tax if the dirtier good is sufficiently cheap and the cap on dirty sector emissions sufficiently lenient. However, if green consumers are oblivious to or disregard the offsetting effects of the cap-and-trade scheme aggregate emissions are higher than if they base decisions on net emissions whenever the cap is binding in both scenarios. Emissions in this case are higher than when they only consider net emissions because green consumers misallocate their restraint between sectors and cause too many unregulated emissions which in contrast to regulated emissions are not neutralised.

6 Conclusions

Cap-and-trade schemes fundamentally change how an individual can affect aggregate provision of a public good. By imposing a binding upper bound on e.g. emissions and allowing trading, it is no longer consistent to believe that one's own decisions will not affect emissions by others. Cap-and-trade schemes institutionalise perfect neutralisation of marginal contributions made in the sectors covered by the scheme. Someone caring either about the total level of the public good (pure altruism) or her individual contribution to the total level (impure altruism) should therefore disregard any contribution made within a cap-and-trade scheme. A cap-and-trade scheme fully crowds out voluntary contribution within the system.

The EU Emission Trading System (EU ETS) is the most prominent - but by no means the only - example of a cap-and-trade scheme. Carbon footprint labels such as those calculated based on PAS 2050 that include both regulated and unregulated emissions are misleading for consumers that care about the impact of their consumption choices on total emissions in the current period. Green consumers that base their consumption decisions on these labels unwittingly emit more than if they would only consider emissions not covered by the EU ETS. The same holds for following advise by both governments and environmental NGOs on how to reduce carbon footprints as they so far do not differentiate between emissions occurring within or outside cap-and-trade systems.

With a cap-and-trade scheme in place, green consumers are left with three options to reduce total GHG emissions. First, they can reduce emissions not captured by the scheme, e.g. by driving less or by eating less red meat. Second, they can influence the political process via voting and lobbying to reduce the cap on regulated emissions. Third, they can buy allowances (or other types of offsets) and retire them and thereby have a direct impact on total GHG emissions.[27]

But it is not only green consumers that are vulnerable to failing to understand the full implications of a cap-and-trade scheme. The European Commission - the same institution that governs the EU ETS - claims that its recent ban of incandescent light bulbs "will reduce emissions of carbon dioxide by 15 million tons each year."[28] This is wrong. Any emissions saved in electricity production will be emitted by another sector participating in the EU ETS - or the electricity will be used to do other things.

It is important to note that the neutralisation of abatement efforts within a cap-and-trade scheme does not preclude the presence of positive indirect or long-term effects on total emissions. It might be argued that any voluntary abatement or restraint reduces the permit price which might make future reductions in the cap politically more feasible. At the same time consumption and life-style choices might help to change habits and social norms that in the long-run make it easier to achieve more ambitious environmental targets. This paper merely points out some of the short-run costs (e.g. in terms of increased aggregate emissions) these strategies might have.

[27] Malueg and Yates (2006) compare lobbying and retiring of permits by consumers. Citizen involment in permit markets is also studied by Ahlheim and Schneider (2002) and Eshel and Sexton (2009). For models of demand for offsets in the presence of impure public goods see Kotchen (2005, 2006, 2009). Within the EU ETS retiring of emission allowances is offered e.g. by the charity Sandbag.org (*www.sandbag.org.uk*). The RGGI features a formal retiring scheme for allowances to create a direct impact on total emissions when consumers switch to electricity produced by renewable sources. See also Twomey et al. (2012).

[28] $http://ec.europa.eu/news/energy/090901_en.htm$, accessed on 15.01.2013.

The ineffectiveness of both private efforts and supplementary policies to reduce GHG emissions within a cap-and-trade scheme are of particular relevance when the price for emission allowances is much lower than estimates of the marginal damages caused by these emissions. Arguably this is currently the case in both the EU ETS and the RGGI. EU ETS emission allowances were traded at about 4 EUR per metric ton in early 2013 while RGGI allowances were auctioned off at just below 2 USD per short ton in December 2012. Both are only a fraction of the estimated social costs of CO_2 emissions. This is problematic for two reasons: Firstly, as shown above, very low permit prices risk increasing total emissions compared to no regulation. Secondly, low prices indicate that the cap on emissions is too lax. Additional reduction efforts by consumers and governments have the potential to increase social welfare. Them not being effective is therefore more of a tragedy when a cap-and-trade scheme is too lax compared to a situation when it fully internalises the social costs of emissions in the sectors covered, i.e. is second-best.

It is interesting to note that green consumerism is rendered partially ineffective in exactly those regions of the world where it is most prevalent: Canada, Europe, and the East and West coast of the US - with Australia to follow in 2015. The relatively strong representation of environmental preferences in the political sphere has - by the choice of regulatory instrument - substantially limited how these same preferences can impact in market settings.

The effects identified here are not limited to the particular way private contributions are modelled. Using alternative specifications like reciprocity (Sugden 1984) would have very similar effects. Reciprocity is impossible within a cap-and-trade system, unless voluntary sacrifices are so large as to render the cap non-binding. But this is also true under the specification used in this paper.

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A Appendix

A.1 Proof of Proposition 1

The equilibrium conditions for the emissions tax (13) and (14) consist of two 2x2 systems of equations. One for plain and one for green consumers with no interaction between them, because all prices are fixed. To allow comparison between the two regulatory schemes the price for emissions is assumed to be the equilibrium permit price under the cap-and-trade scheme. Note that the conditions for plain consumers is the same as those under a cap-and-trade scheme. Hence the equilibrium quantities are the same under a tax and cap-and-trade if all prices are the same. For green consumers the budget constraint remains unaltered but the marginal rate of substitution has changed due as emissions of the dirty good were not considered under cap-and-trade but have a internalised marginal cost m under an emissions tax. The equilibrium quantities under tradable permits hence do not satisfy (13) and (14) for green consumers. Rewriting the two conditions by adding an exogenous parameter ρ in front of the m in the numerator one obtains a generalised version that contains both the cap-and-trade conditions ($\rho = 0$) and those for the emissions tax

$(\rho = 1)$.

$$p + \gamma = \frac{v_y - \rho m^i}{v_x - \alpha m^i}, \tag{A.1}$$

$$w = x^i + (p+\gamma) y^i, \qquad i = \{plain, green\}. \tag{A.2}$$

Using the implicit function theorem and Cramer's rule it is straightforward to show that

$$\frac{\partial x^{green}}{\partial \rho} = -\frac{m(p+\gamma)}{(p+\gamma)^2 v_{xx} - 2(p+\gamma)v_{xy} + v_{yy}} > 0 \tag{A.3}$$

$$\frac{\partial y^{green}}{\partial \rho} = \frac{m}{(p+\gamma)^2 v_{xx} - 2(p+\gamma)v_{xy} + v_{yy}} < 0 \tag{A.4}$$

Hence $x^{green,c\&t}(\gamma) < x^{green,tax}(\gamma)$ and $y^{green,c\&t}(\gamma) > y^{green,tax}(\gamma)$.

A.2 Proof of Proposition 2

If the price of emissions approaches zero (from above) the equilibrium conditions under a tax (13) and (14) and the unregulated case (5) and (6) converge. Hence quantities consumed and sector emissions converge as well. Using Proposition 1 shows that as the permit price converges to zero, the total quantity consumed of the dirty good and hence dirty sector emissions are always strictly higher under a cap-and-trade scheme than under a tax. The price for permits is therefore strictly positive at the unregulated level of dirty sector emissions and drops to zero only at a cap strictly above the unregulated level of dirty sector emissions.

A.3 Proof of Proposition 3

Moving along the budget constraint requires that $\frac{\partial x}{\partial y} = -(p+\gamma)$. The effect on individual emissions e are $\frac{\partial e}{\partial y} = \alpha \frac{\partial x}{\partial y} + 1 = 1 - \alpha(p+\gamma)$. With γ approaching zero this is positive if $p < \frac{1}{\alpha} \geq 1$.

A.4 Proof of Proposition 4

To assess the impact on emissions when green consumers care about gross contributions in a cap-and-trade scheme we re-write the system (10) - (12) by again adding the parameter ρ. This is different from the proof for Proposition 1 as we are looking now at the 5x5 cap-and-trade system of equations and not at the 2x2 tax one.

$$p + \gamma = \frac{v_y^{green} - \rho m}{v_x^{green} - \alpha m}, \tag{A.5}$$

$$
\begin{aligned}
p+\gamma &= \frac{v_y^{plain}}{v_x^{plain}}, && \text{(A.6)}\\
w &= x^{green} + (p+\gamma)y^{green}, && \text{(A.7)}\\
w &= x^{plain} + (p+\gamma)y^{plain}, && \text{(A.8)}\\
C &\geq (N - N^{green})y^{plain} + N^{green}y^{green}, && \text{(A.9)}
\end{aligned}
$$

where $v_j^i = v_j(x^i, y^i)$ and $v_{jk}^i = v_{jk}(x^i, y^i)$ with $j,k \in \{x,y\}$ and $i \in \{plain, green\}$. Using the implicit function theorem, Cramer's rule and the fact that emissions in the dirty sector are capped at C the effect of a change in ρ on total emissions E is

$$
\begin{aligned}
\frac{\partial E}{\partial \rho} &= \alpha\left[\frac{\partial x^{plain}}{\partial \rho} + \frac{\partial x^{green}}{\partial \rho}\right]\\
&= \alpha m \frac{(p+\gamma)A^{plain}C - N^{green}[(p+\gamma)y^{green} + y^{plain}]B^{plain} - (p+\gamma)(N - 2N^{green})v_x^{plain}}{\Omega} \qquad \text{(A.10)}
\end{aligned}
$$

where $\Omega = -(N - N^{green})B^{green}[v_x^{plain} - A^{plain}y^{plain}] + N^{green}(v_x^{green} - \alpha m)[(p+\gamma)A^{plain} - B^{plain}] + A^{green}[B^{plain}y^{green}N^{green} + (p+\gamma)[v_x^{plain}(N - N^{green}) - A^{plain}[(N - N^{green})y^{plain} + N^{green}y^{green}]]] < 0$, $A^i = (p+\gamma)v_{xx}^i - v_{xy}^i < 0$ and $B^i = (p+\gamma)v_{xy}^i - v_{yy}^i > 0$. If $N^{green} \leq 0.5N$ then (A.10) is strictly positive. If $N^{green} > 0.5N$ then the last term in the nominator of (A.10) becomes positive and the sign of the entire expression potentially ambiguous. The conditions for the nominator to be strictly positive are

$$
\begin{aligned}
N^{green} &> \frac{(p+\gamma)v_x^{plain} - (p+\gamma)A^{plain}C}{2(p+\gamma)v_x^{plain} - [(p+\gamma)y^{green} + y^{plain}]B^{plain}} > \frac{1}{2} && \text{(A.11)}\\
&\textit{or}\\
N^{green} &< \frac{(p+\gamma)v_x^{plain} - (p+\gamma)A^{plain}C}{2(p+\gamma)v_x^{plain} - [(p+\gamma)y^{green} + y^{plain}]B^{plain}} < 0 && \text{(A.12)}
\end{aligned}
$$

The latter is irrelevant since $N^{green} \geq 0$. We therefore check the sign for the extreme case when $N^{green} = 1$, i.e. all consumers are green. In this case the system (A.5) - (A.9) collapses to

$$
\begin{aligned}
p+\gamma &= \frac{v_y^{green} - \rho m}{v_x^{green} - \alpha m}, && \text{(A.13)}\\
w &= x^{green} + (p+\gamma)y^{green}, && \text{(A.14)}\\
C &\geq y^{green}, && \text{(A.15)}
\end{aligned}
$$

which yields $y^{green} = C$, $x^{green} = w - (p+\gamma)C$ and γ implicitly defined by $p+\gamma = \frac{v_y(w-(p+\gamma)C, C) - \rho m}{v_x(w-(p+\gamma)C, C) - \alpha m}$. Differentiating the latter w.r.t. γ and ρ yields

$$
\frac{d\gamma}{d\rho} = -\frac{m}{v_{xy}C + v_x - \alpha m - C(p+\gamma)v_{xx}} < 0. \qquad \text{(A.16)}
$$

Hence, for $N^{green} = N$ it holds that

$$\frac{\partial E}{\partial \rho} = \alpha \frac{\partial x}{\partial \rho} = \alpha \frac{\partial x}{\partial \gamma} \frac{\partial \gamma}{\partial \rho} = \alpha \frac{Cm}{v_{xy} C + v_x - \alpha m - C(p+\gamma) v_{xx}} \geq 0. \tag{A.17}$$

The expression in (A.10) is therefore always positive (strictly if $\alpha > 0$) and total emissions higher when green consumers are unaware of or ignore the neutralisation induced by a cap-and-trade scheme if production of x is not perfectly clean $\alpha > 0$.

The above requires that the cap on emissions in the dirty sector is binding in both scenarios. This is not the case if the cap exceeds emissions in the dirty sector in the unregulated case. Aggregate emissions are still increasing in ρ as long as total emissions in the net emission scenario do not exceed total emissions without regulation. Proposition 3 shows that this can indeed happen if the cap is sufficiently lenient and the dirty good sufficiently cheap.