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**Unequal emissions – unequal policy impacts: how do different areas of CO2 emissions compare?[[1]](#footnote-1)**

**Abstract**

Distributional implications of climate change mitigation policies relate to important questions about fairness: which groups bear the highest burdens – or receive the greatest assistance – from these policies and how does this relate to their contribution to emissions? It is already well established that general carbon taxes are likely to have regressive impacts – placing higher relative burdens on poorer than on richer households – and it is often argued that these effects can be reversed, for example through rebate schemes or equal per capita carbon allowances. But does this hold equally for home energy, transport, indirect emissions? And which role do household characteristics other than income and household size play for the distribution of benefits and burdens from mitigation policies? This chapter provides an overview of mitigation policies and examines potential distributional implications across different emission domains. The analysis is based on a dataset of household CO2 emissions that the authors derive from UK expenditure data. It shows that mitigation policies that only target home energy emissions are least equitable from a distributional point of view, not only in terms of differences among income groups but also in relation to other household characteristics.

**Introduction**

It is increasingly clear that radical policies to mitigate anthropogenic climate change (hereafter “mitigation policies”) are urgently required as its impacts are already threatening food security, damaging ecological systems and creating new social inequalities, for example related to severe weather events. Such impacts are set to worsen and contribute to mass migration, resource conflicts and other catastrophic outcomes if greenhouse gas emissions from human activities continue to accelerate. An important element of mitigation policies will be to reduce the combustion of fossil fuels, and thus the release of carbon dioxide (CO2), the greenhouse gas which contributes the most to current warming.

From a social policy perspective, an important question is how mitigation policies can be designed such that unjust distributional effects are, so far as possible, avoided. This requires proportionality in terms of people’s financial capacities as well as in terms of their relative contribution to emissions. This is important both from a fairness perspective and for the public acceptability of such policies. Acceptability is likely to influence the likelihood that governments adopt them, as is borne out by the available policy research ([Bristow et al., 2010](#_ENREF_12)).

Such policies are unlikely to be implemented without a new global agreement on climate change mitigation. The current UNFCCC process would only implement such an agreement by 2020 at the earliest under the “Doha Gateway” set up at the latest COP meeting ([Ritter and Casey, 2012](#_ENREF_55)). This tortuous and hesitant process contrasts sharply with the urgency of emissions cuts pressed by leading scientists ([Anderson and Bows, 2008](#_ENREF_3); [Hansen et al., 2013](#_ENREF_38)). It is nonetheless useful to analyse the range of policy instruments which could be used to reduce CO2 emissions, for example to reduce the likelihood that uncertainty about policy instruments and their distributional implications contributes to inaction.

Carbon taxes are generally perceived to be regressive, that is, putting larger burdens on poor than on rich households relative to their income, because this is a general feature of taxes levied on consumption ([Johnstone and Serret, 2006](#_ENREF_42); [Metcalf and Weisbach, 2009](#_ENREF_47)). While several previous studies ([AEA and Cambridge Econometrics, 2008](#_ENREF_2); [Boyce and Riddle, 2007](#_ENREF_10); [DEFRA, 2008](#_ENREF_20)) have shown that regressive effects can be reversed through equal per capita carbon trading schemes or schemes in which revenues from mitigation policies are redistributed to the population, others have questioned the fairness of these schemes ([Posner and Weisbach, 2010: ch. 6](#_ENREF_53); [Starkey, 2008](#_ENREF_61)). In particular, they highlighted the possibility that some groups in society might have higher emissions due to “structural circumstances” rather than “expensive tastes” ([Dworkin, 1981a](#_ENREF_28), [b](#_ENREF_29); [Starkey, 2012: 15](#_ENREF_62))[[2]](#footnote-2). For example, a need for higher spatial heating use obtains for the elderly and for those living in colder areas. From a social policy perspective, this is relevant in several ways: firstly, which household characteristics other than income are important for the responsibility or “need” for emissions? If there are groups with higher emission “needs”, would this justify additional support to these groups, for example in form of infrastructure investment or financial compensation to cope with the cost of emission reduction? We address these questions by examining potential distributional implications of mitigation policies, considering a range of household characteristics whilst controlling for income and household size.

Further, much is currently under-explored about how emissions vary with characteristics across domains, as most relevant studies usually just focus on one area of emissions. If emission domains are compared, descriptive analysis tends to be applied that does not control for income or other factors (e.g. [Brännlund and Nordström, 2004](#_ENREF_11); [DEFRA, 2008](#_ENREF_20); [Feng et al., 2010](#_ENREF_33); [Halvorsen, 2009](#_ENREF_37); [Hassett et al., 2009](#_ENREF_40); [Klinge Jacobsen et al., 2003](#_ENREF_43); [Labandeira and Labeaga, 1999](#_ENREF_44); [White and Thumim, 2009](#_ENREF_70)). A comparison of emission domains is also important for examining questions such how the regressiveness of carbon taxes differs and whether equal per capita rebates reverse regressiveness equally for all areas. By directly comparing potential distributional implications within one analysis, one can be more confident to separate out what is really distinctive about an emissions category as variation arising from differences in data sources and time periods is avoided.

The chapter is structured as follows. Section two provides a brief overview of mitigation policies and debates around distributional implications. Section three describes the data and methods applied. Section four examines and compares potential distributional implications of different hypothetical mitigation policies. Here we focus on a simple £100 per tonne of carbon tax scheme and a ‘tax and rebate’ scheme which re-distributes the entire tax revenue on a *per capita* basis. Section five concludes and discusses limitations.

1. **Background: mitigation policies and distributional implications**

In economic terms, climate change is market failure caused by anthropogenic greenhouse gas emissions, which are “negative externalities” (costs falling on third parties to transactions) arising from production and consumption. Hence governance is required to reduce emissions, usually seen as intervention by a national government. Here, one can distinguish traditional regulation from economic instruments ([Helm, 2005](#_ENREF_41)). For many commentators, economic instruments are an essential part of policies to reduce greenhouse gas emissions because they offer increased flexibility and scope, and, hence, cost-efficiency over a purely regulatory, “command and control” approach. However, economic instruments are sometimes criticized because they put a price on a commons, the earth’s atmosphere. That is, they create property rights over a previously unowned gift of nature, which was, in principle, freely accessible to all. Another point of contention is that some rich people will be able to maintain their high carbon lifestyles as they are able to pay a higher price for their consumption. However, within schemes that set a strict overall cap on emissions this will not be possible for the generality of the rich. For the bulk of emission reductions would need to be based on a cut-back of their consumption, which is disproportionately responsible for emissions. In short, we acknowledge considerable ethical concerns about, and potential shortcomings of, market-based mitigation policies. However, it is plausible that they form part of any viable plan to avoid dangerous climate change, since emissions cannot be regulated away overnight.

Carbon taxes and cap and trade schemes are the two main classes of economic instruments discussed. Both effectively put a price on emissions, creating financial incentives to switch to low-impact lifestyles and production methods. The key difference between the two is that environmental taxes – often termed ‘Pigouvian taxes’ – levy a charge on environmentally damaging activity, whereas cap and trade works by fixing the amount of the activity. For example, suppose less petrol needs to be sold in order to reduce the emissions its burning causes. A tax would be raised on sales, in the expectation that the resulting price increase would reduce consumption. The price increase will equal at most the value of the tax. However, it is uncertain how consumers respond to the tax: will they substantially reduce their consumption of petrol or will they just pay a higher price? The resulting reduction in emissions is thus unknown. In contrast, the cap part of cap and trade would limit the annual amount of petrol available to the economy, whilst the resulting price increase would depend on the level of consumer demand.

Mitigation instruments can apply at different levels of economic activity: up-, mid- or downstream in the chain of production running from natural resource extraction down to the end user. An upstream scheme would apply a tax or emissions cap to the production and / or import of fossil fuels into the economy, thus achieving broadest coverage whilst minimising the number of actors included in the scheme and the related administrative costs. Examples are the proposals for upstream carbon taxes ([Hansen, 2009](#_ENREF_39)), Cap and Dividend ([Barnes, 2003](#_ENREF_7)), Cap and Share ([AEA and Cambridge Econometrics, 2008](#_ENREF_2); [FEASTA, 2008](#_ENREF_32)), the Kyoto2 scheme ([Tickell, 2008](#_ENREF_66)), or Sorrel’s upstream trading scheme that fits around European Union Emissions Trading Scheme (EU ETS) ([Sorrell, 2010](#_ENREF_60)). A mid-stream scheme would apply to companies outside the primary energy sector producing goods and services. The largest existing cap scheme, the EU ETS, is an example, which applies, broadly, to energy using installations above a certain size. Downstream schemes apply to individuals, and in some variants businesses, who would have carbon accounts and trade permits themselves ([DEFRA, 2008](#_ENREF_20); [Fleming, 2007](#_ENREF_34)).

Within cap and trade schemes, options exist as to how emission permits are allocated – all of which have different distributional impacts. Initial carbon budgets can be allocated to the participants in the scheme either free of charge, through auctioning, or through a mix. For example, in the European Union Emissions Trading scheme (EU ETS), permits have largely been given away for free to companies in the participating sectors, depending on their previous and estimated future emissions. This approach is called ‘grandfathering’. It is widely believed that this leads to windfall profits for companies as they will pass the opportunity cost of using a permit onto customers, or sell a considerable volume of their allocated permits. In other words, grandfathering is likely to have regressive effects ([Shammin and Bullard, 2009](#_ENREF_57); [Sijm et al., 2006](#_ENREF_59)). In contrast, auctioning the permits makes the polluters pay whilst the distributional effects depend on the capabilities of the targeted industries to pass on the costs and the availability of alternatives to these goods for consumers. Furthermore, auctioning emission permits to the participants creates a revenue stream for the permit seller.

The seller of auctioned permits in mid- or upstream schemes is usually assumed to be a national government, but permits could also be allocated initially to citizens or trusts, who then sell to the audited companies. Examples of this alternative approach include the Cap and Share, and Cap and Dividend schemes. The differences between schemes with initial allocation to governments and these approaches are very important, but beyond the scope of this article.[[3]](#footnote-3) We focus here on the capacity of the revenue to counter-balance possible regressive effects of mitigation policies, rather than the institutional details underlying its allocation.

2.1 Distributional implications

Regressivity is a general feature of taxes on consumption, and therefore one would expect carbon taxes to be regressive. This expectation also carries through to various types of cap and trade schemes. Overall, the literature on the distributional effects of mitigation policies confirms this prior view (e.g. [Dresner and Ekins, 2006](#_ENREF_25); [Metcalf and Weisbach, 2009](#_ENREF_47); [Parry, 2004](#_ENREF_50); [Serret and Johnstone, 2006](#_ENREF_56)). However, there are exceptions to this rule depending on the source of pollution that is targeted and how the revenue arising from the policy is used. We will review results from previous studies on carbon taxes, before discussing the ways in which revenue from mitigation policies can be used and their distributional implications.

There is a general consensus that taxes on home energy use are regressive if the revenue from those taxes or charges is not redistributed to the citizens ([Baranzini et al., 2000](#_ENREF_5); [Barker and Köhler, 1998](#_ENREF_6); [Dresner and Ekins, 2006](#_ENREF_25)). The effects of such taxes, covering electricity and heating fuels, are particularly regressive because home energy use is relatively evenly distributed across income deciles (at least in industrialised countries) as shown below in the results section. This means that low income households spend much higher shares of their income on home energy than richer households ([Dresner and Ekins, 2006](#_ENREF_25); [Druckman and Jackson, 2008](#_ENREF_26); [Wier et al., 2005](#_ENREF_71)).

Schemes which put a price on carbon emissions further upstream, for example through a tax on total carbon emissions or a cap and trade scheme that applies only to those who introduce fossil fuels into the market, have an effect not only on downstream energy prices but also on *all* other goods and services due to the higher price of the energy used in their production. Since overall expenditure including that on consumer goods generally increases less than proportionally with income (see, for example, ONS ([2009](#_ENREF_49)), table A9, for the UK case), upstream mitigation policies are therefore likely to have additional regressive effects. These will be substantial because indirect emissions comprise around half of UK households’ overall emissions (52.9 % in our study).

The results are more varied when it comes to carbon taxes on transport or motor fuels. Several studies state that motor fuel taxes place higher burdens on middle income households than on poor or rich households ([Blow and Crawford, 1997](#_ENREF_8); [Poterba, 1990](#_ENREF_54)). For the UK, Dresner and Ekins ([2004](#_ENREF_24)) found that taxes on motor fuels or vehicles have progressive effects considering the whole population but regressive effects amongst motorists (see also [Klinge Jacobsen et al., 2003](#_ENREF_43); [Tiezzi, 2005](#_ENREF_67)).

Some studies compare the distributional effects of mitigation policies for different domains such as home energy and transport. For example, Barker and Köhler ([1998: 398](#_ENREF_6)) provide regressivity ratios separately for taxes on home energy, petrol and total CO2 emissions for 11 EU countries including the UK; Hassett and Mathur ([2009](#_ENREF_40)) examine the distribution of tax burdens over income groups separately for CO2 taxes on direct and indirect emissions in the United States; and Wier et al. ([2005](#_ENREF_71)) compare the distribution of burdens from an upstream CO2 tax to one on direct energy only over income groups for Denmark. Klinge Jacobsen et al. ([2003](#_ENREF_43)) compare impacts of a motor fuel and home energy tax for Denmark using Gini coefficients and distributions over different household groups but without controlling for income. These studies find that taxes on home energy emissions are more regressively distributed than taxes on transport emissions. However, they concentrate on distribution over income, and do not consider the role of other household characteristics.

The literature summarised above shows that if the revenue from carbon taxes or carbon trading schemes are not earmarked for redistribution to citizens, they are highly likely to have regressive effects, with the possible exception of schemes that only include transport emissions. But the distributional outcomes of mitigation policies crucially depend on how the revenues are used and distributed. Revenues arise, for example, through carbon taxes or if emission permits within trading schemes are (partly) auctioned. Three options for redistributing revenues are salient in the literature, though such options could also be combined in different proportions.

1) The revenue can be used to finance measures that further reduce greenhouse gas emissions or support behavioural adaptation, as proposed by Tickell (2008). For example energy efficiency measures through home insulation programmes, investments into renewable energy or public transport subsidies, training and R&D can be supported. The distributional effects depend on who is benefiting from those programs. For example, means-tested home insulation schemes like the Warm Front programme in the UK benefit low income households, and subsidies for public transport currently primarily benefit low income urban households. Policies that aim to expand renewable energy, in contrast, can have regressive effects if they work through financial incentives to (already wealthy) homeowners. ([e.g. see Monbiot, 2010 on the distributional implications of the feed-in tariffs for solar electricity](#_ENREF_48)).

2) The revenue from taxes or auctions under cap and trade schemes can be partly or fully redistributed to the population and / or industry by reducing other existing taxes. This is frequently discussed in the environmental economics literature as the ‘double dividend’ hypothesis. This proposes that environmental taxes generate dual benefits. Whilst the tax creates incentives to reduce the activities which give rise to negative externalities, the revenue generated can be ‘recycled’ for any other purpose, including the reduction of taxes on income or capital, which are often portrayed as discouraging economic activity by mainstream economics, or VAT which is regressive. If the entire revenue is earmarked to decrease/remove other taxes, the tax reform is termed ‘revenue neutral’, meaning that the costs of the new source of revenue are completely compensated through the reduction of other taxes or charges. However, one problem with the double dividend hypothesis is that the revenue from green taxes should decline over time if the tax is working, for example if carbon emissions are reduced from present levels. If this is the case, total government revenue would be shrinking, creating a need to increase other types of taxes.

Studies on the effects of reducing social security contributions, taxes on income, or VAT so far show mixed results, demonstrating that distributional implications of such measures cannot be generalised but depend on the specifics of the existing tax and benefit system and double dividend reforms introduced. For example, the German “eco-tax” involved a reduction of the contribution to pension insurance. This increased regressive effects as the reduction mainly benefited middle income households but disadvantaged low income, unemployed and pensioner households ([Bach et al., 2002](#_ENREF_4); [Bork, 2006](#_ENREF_9)). Conversely, studies on the reduction of income tax in the US report progressive effects if taxes on low incomes are reduced more than those on higher incomes (e.g. [Grainger and Kolstad, 2008](#_ENREF_36); [Metcalf, 1999](#_ENREF_46); [Metcalf and Weisbach, 2009](#_ENREF_47)). Labandeira et al.’s ([2009](#_ENREF_45)) study of a revenue-neutral reduction of VAT in Spain as a compensating mechanism also showed progressive effects. A second option is for the revenue to be returned to citizens by increasing specific social security benefits, for example, child benefit or means-tested benefits such as tax credits or income support. With this option, regressive effects can be considerably reduced or even reversed as several studies have demonstrated ([Baranzini et al., 2000](#_ENREF_5); [Dresner and Ekins, 2006](#_ENREF_25); [Ekins and Barker, 2001](#_ENREF_30); [Ekins and Dresner, 2004](#_ENREF_31)).

3) A final option is to return the revenue from mitigation policies directly to individuals or households as a lump sum. There is a substantial literature discussing this option ([Barker and Köhler, 1998](#_ENREF_6); [CEC, 1992](#_ENREF_15); [Dinan and Rogers, 2002](#_ENREF_22); [Ekins and Barker, 2001](#_ENREF_30); [Parry, 2004](#_ENREF_50); [West and Williams, 2002](#_ENREF_69)). In the United States, a ‘carbon tax and 100% dividend’ proposal has recently been promoted by climate scientist James Hansen ([2009](#_ENREF_39)). An equal per capita rebate or free allocation of emission permits (which is distributionally equivalent) is also integral to Personal Carbon Trading (PCT) ([DEFRA, 2008](#_ENREF_20)), Cap and Share ([FEASTA, 2008](#_ENREF_32)) and Cap and Dividend proposals ([Barnes, 2003](#_ENREF_7)). Under PCT, individuals receive equal per capita tradable carbon allowances. Under Cap and Dividend, an independent climate trust would auction off the permits to upstream fossil fuel producers or importers and redistribute equal per capita rebates to the citizens. Under Cap and Share, an independent trust would allocate each citizen with an equal share of the nation’s emission permits which they can then sell via banks or post offices. Fossil fuel producers or importers would have to buy the permits to cover the carbon content of the products that they intend to sell on the market.

Studies which examined the distributional effects of equal per capita permit or rebate schemes usually conclude that this option has strongly progressive effects on average when applied to total or direct emissions ([AEA and Cambridge Econometrics, 2008](#_ENREF_2); [Barker and Köhler, 1998](#_ENREF_6); [DEFRA, 2008](#_ENREF_20); [Dinan and Rogers, 2002](#_ENREF_22); [Parry, 2004](#_ENREF_50); [Starkey and Anderson, 2005](#_ENREF_63)). This means that low income households will gain more (lose less) financially as a share of their income than high income households. For example, in a Cap and Share or Cap and Dividend scheme, any individual who consumes less than the average per capita allocation will gain from the rebate/revenue ([AEA and Cambridge Econometrics, 2008](#_ENREF_2); [Boyce and Riddle, 2007](#_ENREF_10)). As low income households usually generate relatively low emissions, they may gain financially from the scheme. Even if gains were equal across the income distribution, they would be larger as a share of income for poorer than for richer households. If poorer households gain more in absolute terms than richer households, the distributional effect will be strongly progressive in relative terms.[[4]](#footnote-4) However, questions have been raised regarding the fairness of equal per capita schemes as they are not taking higher “needs” for emissions that some people in society may have into account (e.g. [Posner and Weisbach, 2010: ch. 6](#_ENREF_53); [Starkey, 2008](#_ENREF_61); [Starkey, 2012](#_ENREF_62)). Whilst a discussion about a distinction between needs and wants when it comes to emissions goes beyond this chapter, our analysis of relationships between a whole range of household characteristics and emissions will help identify those with higher emission needs which may need to be addressed through complementary policies.

Furthermore, the studies outlined above estimate effects of mitigation policies either within a single area or for total emissions. There are no studies we are aware of that compare the distributional implications, taking a range of household characteristics into account, of per capita rebate schemes for different areas of emissions. Do equal per capita schemes reverse regressiveness in all areas? What are potential implications for different types of households arising from equal per capita schemes related to different areas of emissions? We will examine these questions below.

1. **Data and limitations**

3.1 Data

For the UK there is currently no representative CO2 emissions dataset at the household level available. Research on the distribution of emissions across households thus relies on other data sources to estimate household emissions. In this paper, we convert rich information on households’ expenditure into CO2 estimates. Our household expenditure data derive from the UK Living Costs and Food Survey (LCF) for the years 2008 and 2009 and its predecessor, the Expenditure and Food Survey (EFS), for the years 2006 and 2007 which, merged, provide us with a total household sample size of 24,446. The LCF/EFS is an annual survey, covering detailed information on expenditure for a large number of consumer items and services according to the UN *Classification of Individual Consumption According to Purpose* (COICOP) and a range of socio-economic variables. We convert households’ expenditure into CO2 emission estimates using the following methods.

For *home energy* we use Tables 2.2.3 and 2.3.3 of the Quarterly Energy Prices statistics by the Department for Energy and Climate Change ([DECC, 2011a](#_ENREF_16), [b](#_ENREF_17)) which provides us with information on annual domestic electricity and gas prices per kWh, including standing charge and VAT, for three payment methods and each electricity/gas region. Since the LCF/EFS includes variables on payment method and region, we can estimate units of energy consumption separately for piped gas and electricity. In addition, our home energy CO2 estimates include emissions from heating oil, bottled gas, and coal and wood which comprise 9.8% of the UK households’ home energy CO2 emissions estimate. Here we use Sutherland[[5]](#footnote-5) tables to convert expenditure into units of consumption.

For *transport* we estimate litres of motor fuel (petrol and diesel) consumedusing AA statistics ([AA, 2006-2009](#_ENREF_1)) of monthly motor fuel prices for each government region. For public transportwe estimatekilometres travelled employing information on average annual passenger miles for train, tube, bus and coach journeys from the National Travel Survey (NTS) for Great Britain ([DfT, 2011: table NTS0305](#_ENREF_21)) and the Northern Ireland Travel Survey for Northern Ireland ([DRDNI, 2011: table 3.1](#_ENREF_23)). Flight emissions are estimated by approximating flight kilometres merging information from the LCF/EFS survey on the number of person flights per household within the UK, Europe and outside Europe with average mileage for flights to these destinations calculated using the NTS and the International Passenger Survey.

DECC CO2 conversion factors ([DECC and DEFRA, 2011](#_ENREF_19)) provided for different fuels and modes of transport are then applied to units of home energy and litres of motor fuels consumed, as well as kilometres travelled by mode of transport, to estimate CO2 emissions.

To estimate *indirect emissions*, we use the Resources and Energy Analysis Programme (REAP) database which provides estimates of total CO2 emissions arising from consumption by UK households of 56 COICOP categories in 2006 ([Paul et al., 2010](#_ENREF_52)). These data are employed to generate CO2 per pound expenditure factors for 50[[6]](#footnote-6) consumption categories which we apply to household expenditure to estimate emissions. Expenditure data for 2007-9 are deflated to 2006 prices using Consumer Price Index Statistics for each of the consumption categories. For further details see Büchs and Schnepf ([2013a](#_ENREF_13)).

3.2 Limitations

Estimating emissions based on household expenditure is limited in several ways. Firstly, the data available to us in the LCF/EFS and external statistics cannot account for some of the heterogeneity of emissions in the “real world”. For example, neither the LCF/EFS or the DECC home energy price statistics provide information on the tariff that a household is subscribed to; for public transport tickets and flights, the provider of the service and type of ticket (first or second class, reductions for pre-booking or railcards) are unknown; and for other consumer items we have no information on brands. This might also lead to a slight overestimation of emissions by rich people because they might, on average, purchase more expensive products even though the actual product might have similar or even lower emissions. Choosing high profile brands for example, may often involve “paying for the name”, in which case cheaper products may involve equivalent emissions. Local organic produce from the farmers market will tend to be more expensive compared to that from a supermarket, shipped round the world and cooled over long periods, but less emissions intensive ([Girod and De Haan, 2010](#_ENREF_35)). However, due to a lack of detailed data on embedded emissions of individual goods and services, the estimation of the size of this effect remains limited.

Another limitation results from the ‘infrequency of purchase problem’. The LCF/EFS collects expenditure data through a survey, with interview questions covering quarterly or annual expenditure for more infrequent purchases such as electricity and gas bills, cars, season tickets and package holidays. However, some more frequent expenditure items are only collected through two-week diaries kept by each household member. For all these expenditures, some aspects of the data will be affected by the ‘infrequency of purchase’ problem. For some items we can estimate the extent of the problem, for example, we know that, based on the two-week diary, only 1.2% of households have an expenditure on flights, whilst 41% of households state in the survey that they had at least one flight in the past 12 months (consequently, we use the survey, not the expenditure data, to estimate flight emissions). Furthermore, according to the LCF/EFS, 18.2% of households with a vehicle have not purchased any petrol during the diary window whilst data from the National Travel Survey indicate that only around 0.1% of households with a vehicle have not driven their vehicle within the last year.

For our CO2 *transport estimate* this problem most clearly affects motor fuels and public transport which contribute 74.3% of our total transport CO2 estimate (the rest deriving from flights for which we use the survey’s interview-based measure) and 16.2% of our total UK household CO2 estimate. For *home energy*, the problem is less relevant with expenditure on heating fuels collected through the diary such as oil, bottled gas, coal, wood and peat contributing only 2.6% of total emissio­ns, prepayment electricity only used by 15% of households, and gas pre-payments by 12.2% of households with access to mains gas. All *indirect CO2 emission* estimates are based on diary data. Whilst proportions of households with zero expenditure can be high for individual categories, none of the households has zero expenditure on the sum of items that are included in indirect emissions (see Table 1).

Does the infrequency of purchase problem affect our analysis? All previous studies using expenditure data for estimating CO2 emissions implicitly or explicitly ([DEFRA, 2008: 13](#_ENREF_20)) assume that CO2 estimates based on diary data provide unbiased estimates of population *mean values*, as zero expenditure from infrequently purchased items should be compensated by expenditures higher than the actual consumption rate of those households who stock up during the diary period. However, *measures of dispersion* and inequality such as standard deviation and Gini coefficients are likely to be overestimated (especially so for subcategories such as motor fuels and possibly flights[[7]](#footnote-7)). For this reason, we use ratios of mean emissions comparing different income quintiles rather than the Gini coefficient for examining emissions inequality and distributional implications of mitigation policies. In the last section, we present OLS regression results. Since there will be measurement error affecting the dependent variable, standard errors of coefficients are likely to be inflated.

1. **Results**

4.1 CO2 emissions in the UK by emission category

Table 1 shows mean and median household CO2 emissions for our pooled sample. Median UK total household emissions are 17.1 tonnes of CO2 per year whilst the mean is 20.2 tonnes, showing a positively skewed distribution. Home energy emissions constitute 25% of total emissions, and transport 22%, including flight emissions that contribute 6% on average to households’ total emissions (equating to 1.3 flights per household). The remaining 53% consist of indirect emissions incorporated in other goods and services.

4.2 Inequality of emissions

We know from previous research that emissions are unequally distributed across UK households (see section 2 above) but how does this compare for different areas of emissions? Table 2 shows measures of variation and inequality for home energy, transport, indirect and total emissions. The coefficient of variation (CV), which is the ratio of the standard deviation to the mean, is a standardised measure of the dispersion of a variable. Total, home energy and indirect emissions show similar levels of dispersion with CVs of 61.8, 63.5 and 66.8 respectively, whilst transport emissions are more dispersed with a CV of 102.2. However, since the CV is affected by the infrequency of purchase problem, it is likely to be inflated, particularly for transport emissions. Column 4 shows mean emissions for households in the lowest income quintile which can be compared with mean emissions for households in the highest income quintile in column 5. Since sample sizes are fairly large with almost 4,900 households per quintile we can assume that these mean figures are not substantially influenced by infrequency of purchase. Column 6 shows the ratio of mean emissions for the highest and lowest income quintiles, demonstrating that transport emissions are most unequally, and home energy emissions most equally, distributed.

[Figures 1 and 2 here]

Figures 1 and 2 graph the distribution of emissions over equivalised income deciles, confirming that emissions in all areas are unequally distributed and increasing with income. The 25% of households with the lowest incomes only emit 11% of all transport emissions, 14% of indirect and 15% of total emissions, whilst the richest emit 42%, 38% and 37% respectively. However, for home energy, the poorest 25% emit 20% of all emissions, whilst the richest 25% emit 30%.

This illustrates the very large contribution that richer households make to overall emissions. If all households restricted themselves to CO2 emissions equal to those of the poorest 25%, average UK household emissions would decrease from 20.2 to about 12.1 tonnes and total annual UK household emissions from 513 to 306 million tonnes. If achieved by 2020 and compared to a baseline of 586 million tonnes in 1990 ([DECC, 2012](#_ENREF_18)), this would equate to a reduction by 48% to the 1990 baseline - much more drastic than the currently envisaged reduction of 20% by 2020 that the European Union is subscribed to. Thus, there are clearly potentially serious issues over fairness if low income households are penalised by mitigation policies.

4.3 Distributional implications of mitigation policies

To quantify potential distributional implications, we first calculated the tax burden from a hypothetical tax of £100 per one tonne of carbon dioxide emission. The tax burden is expressed as a proportion of equivalised household income. Figure 2 suggests that taxes are regressive for all emission domains, apart from transport where they appear to be nearly neutral. Households in the lowest equivalised income decile would lose an estimated 6% of their income from taxes on home energy, 8% for indirect, 2% for transport and 15% for taxes on total emissions. This compares to 1%, 3%, 1% and 5% respectively for households in the highest equivalised income decile.

As discussed above, it is assumed in the literature that the regressiveness of carbon taxes can be reversed, for example by redistributing the tax revenue to the population on a per capita basis. To estimate distributional implications we estimate “net rebates”. This is achieved by substracting the tax burden from the rebates that each household received (based on the number of adults, and possibly children, in a household) and expressing this as a proportion of disposable household income. The net rebates necessarily have a mean of zero. Figure 3 shows the estimated distributional outcome of such as scheme and suggests that regressive effects can indeed be reversed for total, indirect and transport emissions whilst income effect seem very marginal for home energy emissions across the income distribution. It is striking that relatively large net financial gains[[8]](#footnote-8) for the lowest income groups can be achieved by carbon tax and rebate policies, given sufficient emissions coverage, with only modest percentage costs to the higher income groups. The lowest decile are estimated to gain, on average, by 8% of their mean income, whilst the top decile are estimated to be less than 2% worse off financially. This reflects a steep gradient in underlying income in addition to the gradient in emissions across income deciles.

This can be examined further using the Suits index for tax progressivity which compares the cumulative distribution of the tax burden to the cumulative income distribution ([Suits, 1977](#_ENREF_65)). Since the Suits index can be calculated based on mean emissions and mean income per income decile, it is less affected by the infrequency of purchase problem than the Gini coefficient that is sometimes used to examine changes in income inequality before and after a tax or benefit reform. The Suits index lies between -1 (extreme regressivity) and +1 (extreme progressivity), and is shown in table 3. This confirms that taxes on home energy have most regressive effects, followed by taxes on total emissions.

[Table 3 here]

Conversely, taxes on transport emissions are near neutrally distributed or even progressive for flight emissions. The remainder of the table presents the *change* of the income ratio comparing the highest and lowest income quintiles *after* different mitigation policies are applied, including the £100 carbon tax, an equal per adult tax and rebate (T&R) scheme and an equal per adult T&R scheme that also includes half a rebate per child. Positive figures indicate that income inequality rises after the policy is applied and vice versa. However, sizes of the change in income ratios are affected by the size of the tax burden which, in our model, differs across emission domains due to different quantities of emissions per domain. To achieve comparability across emission domains, we can imagine that the tax is applied to equal quantities of CO2 in each area by scaling changes in income ratios for home energy, transport and indirect emissions up based on the proportion that they contribute to total emissions in the right-hand side of the table. For example, since home energy emissions constitute 25% of total emissions, the ratio change is scaled up by a factor of 4.

Results suggest that T&R schemes on home energy reduce income inequality only very marginally whilst those applied to transport emissions have stronger progressive effects. This is an interesting result as it may question the effectiveness of equal per capita home energy schemes ([DEFRA, 2008](#_ENREF_20); [Parry and Williams, 2010](#_ENREF_51)). Furthermore, the scheme that includes allowances for children suggests stronger progressive effects across all emission domains than the scheme that only distributes rebates to adults.

Most of the existing work on distributional implications of mitigation policies focusses on income. However, household characteristics other than income may well play an important role in influencing distributional outcomes of mitigation policies, including age, employment status, education and rural/urban location. To examine the relationship between other household characteristics and distributional impacts, we estimated mean net rebates from a £100 per tonne of CO2 adult-only T&R scheme and tested whether means differ for specific groups (see table 4). A difference in the role of household size for different areas of emissions is evident: whilst two-adult households lose significantly more from adult-only T&R schemes on total and transport emissions than one-adult households, the opposite is true for home energy. However, economies of scale also become relevant for total and transport emissions for households with three or more adults. Furthermore, households with children receive significantly lower net rebates than households without children who ‘gain’ on average for all schemes. This pattern reverses if the scheme allocates half a lump sum rebate to each child (results not shown).

[Table 4 here]

The results also show an interesting relationship between age and distributional outcomes. Previous research has shown that the relationship between age and emissions takes on an inverse u-shape, apart from home energy emissions which rise with age ([Büchs and Schnepf, 2013b](#_ENREF_14)). This is confirmed when we compare mean net rebates: on average, households with reference persons aged 35-65 receive significantly lower net rebates, and those with reference persons aged 65+ significantly higher ones, compared to households with reference persons under 35. In contrast, the oldest age group ‘loses’ more than the other two groups for home energy schemes. Education also makes a difference to the financial implications of this scheme: Those with highly educated reference persons (defined as attending full-time education for 16 or more years) receive significantly lower net rebates than households in which no-one attended full time education for longer than is compulsory in the UK (11 years).

Rural households (defined as those in settlements of fewer than 10,000 inhabitants) receive lower net rebates than ‘urban’ households (households in all other areas), apart from schemes that apply to flights and public transport only, where there is no significant difference. Workless households (defined as households with at least one person of working age but without any person in employment) receive significantly higher net rebates than households in which at least one person of working age is in employment. Female headed households receive significantly higher net rebates than male headed households for schemes that apply to total and transport emissions, but lower rebates for schemes that apply to home energy emissions. Whilst households with ‘non-white’ reference persons receive significantly higher rebates than other households in most cases, they lose out from schemes that only apply to flights. It is possible that this reflects a need to visit relatives overseas. Finally, whilst poor rural households with vehicles lose on average from T&R schemes that apply to motor fuels and home energy, they lose significantly less than rich rural households with vehicles and they gain from all other schemes.

Even though some groups are estimated to gain on average from T&R schemes as demonstrated above, a certain proportion of households with these characteristics will still lose financially from these schemes as they emit more than the rebate that they are allocated. Table 5 provides an overview of the estimated proportion of households in each group ‘losing’ from an adult-only T&R scheme across the different emission domains. This confirms that, on average, considerably lower proportions of low income, older, childless, female headed, low educated, urban and workless households ‘lose’ from these schemes than their counterparts. However, the proportion of households ‘losing’ from these schemes can still be considerable, for example, amongst low income households, 21.1% are estimated to ‘lose’ from a scheme on total emissions, 42.5% in relation to a home energy emissions scheme and 18.7% within a scheme targeting motor fuels. Furthermore, there are some exceptions to the general pattern that higher proportions of well-situated households ‘lose’ from T&R schemes, particularly for schemes on home energy emissions for which higher proportions (around half) of households with older reference persons, female headed households and ‘low educated’ households ‘lose’ than their counterparts.

[Table 5 here]

Clearly, many of these household characteristics are related, such as high income and high education or rural location and car ownership. Which characteristics still make a significant difference to households’ estimated net rebates from a T&R scheme after income and other factors are held constant can be examined using multivariate regression analysis. In the remainder of this chapter we present results from OLS regression of net rebates from a £100 per tonne T&R adult-only scheme on total, home energy and transport.[[9]](#footnote-9) Results are shown in Table 6.

[Table 6 here]

The first three columns show models that only include income and household size as independent variables, columns 4 to 8 present models that include a range of other household characteristics. All models exclude missings to make the results comparable, apply sampling weights and use robust standard errors to address heteroskedasticity. Error terms were not perfectly normally distributed but results were robust to the exclusion of regression error outliers without significant changes in coefficients. The models presented here include regression outliers.

The results confirm that an increase in income (here represented as annual disposable income divided by 10,000) is associated with losses from a T&R scheme. A comparison of results after standardizing the values of the dependent variables confirmed that effect sizes are greatest for schemes on total emissions and lowest for home energy (results not shown). Results in table 6 also show that each additional adult in the household is associated with further gains from an adult-only T&R scheme due to economies of scale. Children tend to be associated with ‘losses’ from these schemes. If children receive half an allowance each, each additional child is associated with gains after controlling for other factors (regression results for these models not shown).[[10]](#footnote-10)

Interestingly, high education (households in which at least one member attended full time education for 16 or more years) remains associated with significant losses, compared to households in which none of the members attended post-compulsory full time education. This holds for T&R schemes across all emission domains after controlling for income and other factors.

Female-headed households lose significantly more from schemes on total and home energy emissions than male-headed households. Workless households tend to ‘win’ from schemes on total and transport emissions compared to households in employment but do not significantly differ from their counterparts in relation to home energy schemes.

Rural households lose from all types of T&R schemes, suggesting that they use more energy for heating their homes and for travelling than urban households, after controlling for income, education, housing and vehicle ownership. However, rural location is no longer significant in the full model that also controls for dwelling and heating type as well as home ownership (columns 7 and 8 in table 6). This suggests that higher home energy emissions of rural households are largely accounted for by a higher proportion of detached houses and oil central heating in rural areas. As one would expect, additional numbers of bedrooms and owning a car reduce net rebates from T&R schemes on all types of emissions because they relate to higher emissions from home energy and transport, controlling for other factors. The ‘full’ model of rebates on total and home energy emissions also indicates that owning an accommodation outright or through a mortgage reduces the net rebate compared to households who are renting, holding all other factors constant.

**5 Conclusion and Discussion**

Comparing estimated distributions of burdens from carbon taxes and net rebates from T&R schemes across emission domains in the UK provides several insights. According to income ratios, transport emissions were most unequally distributed in the sample, followed by indirect, total and home energy emissions. We also found that carbon taxes on transport are less regressive than taxes on total or home energy emissions, confirming findings from other studies (e.g. [Barker and Köhler, 1998](#_ENREF_6); [Klinge Jacobsen et al., 2003](#_ENREF_43)). Taxes on flight emissions were slightly progressive based on the Suits index and near neutral using changes in income ratios whilst taxes on motor fuels remained to be regressive. This contrasts to findings by Barker and Köhler ([1998: 398](#_ENREF_6)) and Dresner and Ekins ([2004](#_ENREF_24)) who found taxes on motor fuels to be neutral or progressive in the UK. This may well be because car ownership amongst low income households was still much lower in the mid to late 1990s. In 1995, NTS data record just under 40% of sampled households in the lowest income quintile as owning cars, but by 2008 this had risen to 60% ([Stokes and Lucas, 2011](#_ENREF_64)).

Our results also confirm that T&R schemes, generally speaking, have progressive distributional effects, based on a comparison of income inequality before and after applying the T&R schemes. However, this was less clear for the home energy scheme which was surprising given that per capita schemes have been advocated for reversing regressive effects of home energy taxes ([DEFRA, 2008](#_ENREF_20); [Parry and Williams, 2010](#_ENREF_51)). T&R schemes on total and transport emissions also appeared to be slightly more progressive if allowances for children were included.

Furthermore, employing multivariate analysis suggests that household characteristics other than income and household size have important, independent associations with distributional outcomes and may thus need to be considered in the design of mitigation or other complementary policies as they may indicate greater emissions “needs” or responsibilities for emissions – including rural location, type of heating and dwelling, age, worklessness, gender and high education. This adds weight to the point so far most forcefully raised by Starkey ([2008](#_ENREF_61); [2012](#_ENREF_62)) that equal per capita allowances or rebates may not be fair as they do not take these responsibilities and/or “needs” into account. Whilst (especially upstream) per capita schemes are perhaps least costly from an administrative point of view, they may need to be complemented by additional schemes that offer compensation to people who have higher emissions due to circumstances beyond their own choice.

Due to several limitations, results presented in this chapter need to be treated with caution:

* Distributional implications across emission domains are compared by applying the same tax rate in each area. If the degree of regressiveness or progressiveness is compared across emission domains, results might differ if different tax rates are applied to different areas.
* We only applied a very simple method of simulating distributional outcomes by focussing on the change in household income after the tax or T&R scheme is applied. More detailed simulation exercises would also introduce the complexities of the existing tax and benefit system and could examine how changes based on mitigation policies interact with other changes in the tax and benefit system.
* In relation to T&R schemes we referred to financial ‘gains’ and ‘losses’ from these schemes. However, a declining upstream cap on emissions would have to be set if emission reduction targets are to be met, or equivalently an increasing level of CO2 taxation over time. ‘Gains’ from these schemes, in these circumstances, need not translate into overall higher consumption or increases in material living standards. This is because the economy would be shrinking overall to the extent that alternative energy sources and efficiency gains are not fully substituting for fossil energy. Monetary income from the scheme might not be falling, but money is, ultimately, only a claim on goods and services produced. The limitation of our analysis here is intrinsic to static microsimulation, which allows a detailed analysis of instantaneous effects at the cost of assuming unchanged behaviour.
* Due to the infrequency of purchase problem outlined above, some measures of distribution or inequality are likely to be inflated, particularly for transport related emissions, as set out in the text.

**TABLES and FIGURES**

**Table 1: Mean and median annual household CO2 emissions in tonnes, % of total emission and % of households not having emissions by emission area**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Median CO2, tonnes** | **Mean CO2, tonnes** | **Standard error mean, tonnes** | **% of total CO2 emissions** | **% of households without emissions** |
| **Home energy total of which** | **4.48** | **5.11** | **0.03** | **25.3** | **5.7** |
| *Gas* | 2.35 | *2.49* | 0.02 | 12.3 | 22.8 |
| *Electricity* | 1.84 | *2.09* | 0.01 | 10.4 | 8.1 |
| *Other home energy* | 0.00 | *0.53* | 0.03 | 2.6 | 93.2 |
|  |  |  |  |  |  |
| **Transport total of which** | **2.97** | **4.40** | **0.04** | **21.8** | **15.2** |
| *Motor fuels* | 1.60 | *2.38* | 0.03 | 11.8 | 36.4 |
| *Flights* | 0.00 | *1.13* | 0.02 | 5.6 | 59.0 |
| *Public transport* | 0.00 | *0.89* | 0.02 | 4.4 | 50.2 |
|  |  |  |  |  |  |
| **Indirect total of which** | **8.69** | **10.67** | **0.08** | **52.9** | **0.0** |
| *Indirect home energy and motor fuel emissions* | 2.23 | *2.60* | 0.02 | 12.9 | 9.0 |
| *Food* | 1.33 | *1.53* | 0.01 | 7.6 | 0.7 |
| *Catering/hotels* | 0.69 | *1.11* | 0.01 | 5.5 | 11.6 |
| *Cars & repairs* | 0.05 | *0.4* | 0.01 | 2.0 | 39.5 |
| *Recreation* | 0.33 | *0.77* | 0.03 | 3.8 | 3.7 |
| *Clothing* | 0.23 | *0.66* | 0.01 | 3.3 | 32.6 |
| *Furniture, appliances, tools* | 0.13 | *0.67* | 0.01 | 3.3 | 32.1 |
| *Personal care* | 0.17 | *0.38* | 0.01 | 1.9 | 12.3 |
| *Other indirect* | 1.53 | *2.54* | 0.03 | 12.6 | 0.0 |
|  |  |  |  |  |  |
| **Total** | **17.13** | **20.18** | **0.13** | **100.0** | **0.0** |

Note: Estimation of emissions is based on the LCF/EFS 2006-2009, sample size 24,446 households in the UK.

**Table 2: CO2 emissions and inequality**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 |
|  | **Mean** | **Median** | **CV** | **Mean CO2 low income** | **Mean CO2 high income** | **20/80 ratio** |
| **Total** | 20.18 | 17.13 | 72.42 | 11.47 | 30.94 | 2.70 |
| **Indirect** | 10.67 | 8.69 | 86.69 | 5.79 | 16.84 | 2.91 |
| **Home energy** | 5.11 | 4.48 | 77.97 | 3.97 | 6.32 | 1.59 |
| **Transport** | 4.40 | 2.97 | 113.21 | 1.70 | 7.79 | 4.57 |

Note: CV stands for coefficient of variation. Column 4 shows mean emissions for the lowest income quintile, based on equivalised income. Colum 5 shows mean emissions for the highest income quintile. Column 6 shows the ratio of mean emissions of the top and bottom income quintiles.

**Figure 1: Distribution of annual household emissions over equivalised income deciles**

Note: Sample size 24,446

**Figure 2: The distribution of annual CO2 tax burdens over equivalised income deciles**

Note: The 1st and 99th percentile of the income distribution are excluded to reduce bias from income outliers. The tax burden relates to carbon taxes of £100 per tonne, expressed as % of annual disposable household income.

**Figure 3: the distribution of net allowances from a carbon tax and rebate scheme, % of disposable income**

Note: the 1st and 99th percentiles of the income distribution are excluded to minimise bias from income outliers. The net rebates are calculated by subtracting the CO2 tax to be paid by each household from their equal per adult allocation of tax rebates. The net rebate is expressed as % of annual disposable household income.

**Table 3: change of the gini coefficient of income inequality before/after tax and ‘tax and rebate’ (T&R) schemes; Suits index for the CO2 taxes.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Suits index** | **Difference of 20/80 income ratio after policy** | | | | | |  |
|  |  | Unscaled | | | Scaled | |  | *Scaling factor* |
|  | Tax | Tax | T&R adult | T&R 0.5 child | Tax | T&R adult | T&R 0.5 child |  |
| **Total** | -0.08 | 1.20 | -0.54 | -0.64 | 1.20 | -0.54 | -0.64 | *1.0* |
| **Indirect** | -0.06 | 0.48 | -0.35 | -0.41 | 0.91 | -0.66 | -0.77 | *1.9* |
| **Home energy** | -0.19 | 0.39 | -0.01 | -0.04 | 1.55 | -0.05 | -0.16 | *4.0* |
| **Transport** | 0.02 | 0.08 | -0.24 | -0.26 | 0.38 | -1.10 | -1.21 | *4.6* |
| **Motor fuels** | -0.01 | 0.06 | -0.12 | -0.13 | 0.48 | -1.01 | -1.12 | *8.5* |
| **Public transport** | 0.04 | 0.01 | -0.05 | -0.05 | 0.33 | -1.13 | -1.25 | *22.7* |
| **Flights** | 0.07 | 0.01 | -0.07 | -0.08 | 0.23 | -1.26 | -1.36 | *17.9* |

Note: The Suits index compares the distribution of income to the distribution of the tax burden over equivalised income deciles. A negative sign means the tax is regressive, a positive sign means it is progressive, 0 is neutral. It reaches from 1 to -1.  
Changes in income inequality in response to mitigation policies are examined by comparing the ratio of mean income of the highest income quintile to that of the lowest income quintile after deducting tax burdens or net rebates from equivalised household income. Positive figures indicate an increase in income inequality, negative figures a decrease. The scaled 20/80 income ratio changes are multiplied by a factor reflecting the proportion of an emissions sub-category of total emissions. For example, home energy emissions make up about 25% of total emissions. The income ratio difference is thus multiplied by 4 to make it comparable to the one for total emissions.

**Table 4: Comparison of mean net annual rebates of a £100 per tonne of CO2 adult-only scheme, £ pounds**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | total | *se* | he | *se* | transport | *se* | mf | *se* | flights | *se* | pt | *se* |
| Adult 1 | -49.3 | | *10.3* | -95.1 | *3.7* | 54.3 | *3.3* | 31.2 | *2.1* | 16.3 | *1.5* | 6.8 | *1.6* |
| Adult 2 | **-140.2** | | *16.7* | **-7.1** | *4.4* | **-51.2** | *5.5* | **-22.1** | *3.1* | **-19.2** | *2.9* | **-9.9** | *2.4* |
| Adult 3 | **442.8** | | *35.3* | **189.1** | *9.6* | 32.9 | *13.3* | **-3.4** | *9.1* | 23.8 | *6.9* | 12.4 | *5.4* |
| Children | -305.0 | | *22.7* | -36.7 | *5.9* | -69.8 | *7.6* | -49.0 | *4.4* | -13.9 | *4.2* | -6.8 | *3.2* |
| No children | **126.1** | | *12.3* | **15.2** | *3.7* | **28.8** | *4.0* | **20.3** | *2.5* | **5.7** | *2.0* | 2.8 | *1.7* |
| Age <35 | 55.9 | | *22.0* | **80.2** | *6.0* | -22.1 | *8.2* | 2.4 | *4.9* | -15.5 | *4.2* | -9.1 | *3.5* |
| Age 35-65 | **-169.5** | | *16.7* | **-9.1** | *4.4* | **-64.1** | *5.5* | **-40.3** | *3.4* | -14.6 | *2.8* | -9.2 | *2.3* |
| Age > 65 | **314.0** | | *16.5* | **-42.2** | *5.8* | **152.0** | *3.9* | **83.0** | *2.4* | **42.6** | *2.0* | **26.4** | *1.8* |
| Low income | 487.2 | | *14.8* | 21.4 | *5.7* | 180.2 | *4.2* | 92.8 | *2.8* | 51.7 | *2.3* | 35.7 | *1.4* |
| High income | **-807.6** | | *23.8* | **-68.1** | *6.8* | **-269.7** | *8.5* | **-111.3** | *5.3* | **-92.1** | *5.1* | -66.4 | *4.4* |
| High education | -475.2 | | *29.3* | -15.5 | *7.7* | -183.6 | *9.5* | -65.9 | *5.7* | -77.8 | *5.4* | -39.9 | *4.5* |
| Low education | **219.6** | | *13.3* | 5.9 | *4.1* | **83.3** | *4.2* | **34.6** | *2.7* | **32.6** | *1.9* | **16.1** | *1.8* |
| Rural | -302.7 | | *25.1* | -100.5 | *9.1* | -65.3 | *7.9* | -79.3 | *5.2* | 5.8 | *3.7* | 8.2 | *3.0* |
| Urban | **92.7** | | *13.7* | **33.5** | *3.3* | **17.9** | *4.5* | **23.6** | *2.5* | -3.2 | *2.4* | -2.4 | *1.9* |
| Workless | 442.7 | | *21.9* | 37.5 | *7.6* | 158.5 | *6.4* | 93.7 | *3.8* | 41.0 | *3.5* | 23.8 | *2.6* |
| Employed | **-62.7** | | *12.7* | **-5.3** | *3.6* | **-22.5** | *4.1* | **-13.3** | *2.5* | **-5.8** | *2.2* | **-3.4** | *1.8* |
| Female | 51.1 | | *13.9* | -26.7 | *4.5* | 46.8 | *4.7* | 32.3 | *2.8* | 14.2 | *2.3* | 0.3 | *2.1* |
| Male | **-32.1** | | *15.9* | **16.8** | *4.2* | **-29.4** | *5.0* | **-20.3** | *3.1* | **-9.0** | *2.7* | -0.2 | *2.1* |
| "White" | -32.5 | | *12.4* | -7.1 | *3.5* | -2.3 | *4.0* | -5.2 | *2.4* | 3.7 | *2.0* | -0.7 | *1.6* |
| Ethnic minority | **382.3** | | *38.5* | **83.9** | *11.4* | 27.8 | *13.7* | **62.9** | *8.4* | **-43.5** | *7.9* | 8.4 | *5.2* |
| Poor rural motorists | 113.7 | | *46.6* | -110.3 | *22.7* | 79.5 | *14.3* | -12.7 | *9.7* | 53.4 | *7.0* | 38.8 | *6.8* |
| Rich rural motorists | **-1172.4** | | *52.3* | **-194.4** | *18.4* | **-347.3** | *17.0* | **-220.5** | *11.2* | **-75.6** | *8.9* | **-51.2** | *8.3* |

Note: Figures in bold are significantly different to the comparator group (always the first line within each group)

**Table 5: Percentage of households ‘losing’ from an adult only tax and rebate scheme**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Total** | **Energy** | **Trans-port** | **Motor fuel** | **Flights** | **Public transport** | **n** |
| *Average* | *41.87* | *44.71* | *37.34* | *38.81* | *26.06* | *24.45* | *24,446* |
| Low income | 21.1 | 42.5 | 15.2 | 18.7 | 10.3 | 15.5 | 6,112 |
| High income | 70.7 | 50.2 | 64.7 | 57.3 | 44.0 | 39.6 | 6,112 |
| Children in hh | 54.4 | 49.2 | 44.4 | 48.7 | 26.5 | 28.5 | 7,151 |
| No children hh | 36.7 | 42.9 | 34.4 | 34.7 | 23.6 | 25.1 | 17,295 |
| Age <= 35 | 43.6 | 34.4 | 41.8 | 40.2 | 27.9 | 30.4 | 4,836 |
| Age 36 to 64 | 48.9 | 46.1 | 44.8 | 46.9 | 28.5 | 28.4 | 13,294 |
| Age>=65 | 25.8 | 49.7 | 18.2 | 20.8 | 13.4 | 17.7 | 6,316 |
| Education>=16 | 58.9 | 44.4 | 57.0 | 51.3 | 40.8 | 35.5 | 5,743 |
| Education<11 | 33.3 | 44.7 | 28.1 | 31.9 | 16.6 | 21.8 | 9,405 |
| Rural area | 50.1 | 51.2 | 44.8 | 51.5 | 23.4 | 23.3 | 4,713 |
| Urban area | 39.2 | 42.6 | 35.3 | 35.0 | 25.0 | 26.9 | 17,374 |
| Workless hh | 24.1 | 40.3 | 18.7 | 20.7 | 12.6 | 19.4 | 3,035 |
| In employment | 44.4 | 45.3 | 40.0 | 41.4 | 26.1 | 27.0 | 21,411 |
| Female head | 40.5 | 50.4 | 31.5 | 32.4 | 20.8 | 25.7 | 9,434 |
| Male head | 42.7 | 41.1 | 41.0 | 42.8 | 26.7 | 26.3 | 15,011 |
| Not white | 34.4 | 36.7 | 36.1 | 29.4 | 35.2 | 28.0 | 1,908 |
| White | 42.5 | 45.4 | 37.4 | 39.6 | 23.5 | 25.9 | 22,530 |
| Poor rural motorists | 36.6 | 50.8 | 29.2 | 42.7 | 10.7 | 13.6 | 637 |
| Rich rural motorists | 76.6 | 58.0 | 71.6 | 70.6 | 41.6 | 34.6 | 1,422 |

Note: Low income households have equivalised household income equal or below the 25th percentile, high income households are situated at or above the 75th percentile of the equivalised income distribution.

**Table 6: OLS regression results of an adult-only £100 per tonne of CO2 Tax and Rebate scheme. Dependent variable = net rebate = gross rebate less carbon tax paid**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| VARIABLES | Total | Home energy | Transport | Total | Home energy | Transport | Total | Home energy |
|  |  |  |  |  |  |  |  |  |
| Income | -0.33\*\*\* | -0.03\*\*\* | -0.10\*\*\* | -0.25\*\*\* | -0.02\*\*\* | -0.08\*\*\* | -0.23\*\*\* | -0.02\*\*\* |
|  | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | (0.01) | (0.00) |
| Adult2 | 0.63\*\*\* | 0.18\*\*\* | 0.10\*\*\* | 0.78\*\*\* | 0.21\*\*\* | 0.15\*\*\* | 0.78\*\*\* | 0.22\*\*\* |
|  | (0.01) | (0.00) | (0.01) | (0.01) | (0.00) | (0.01) | (0.01) | (0.00) |
| Adult3 | 0.66\*\*\* | 0.16\*\*\* | 0.13\*\*\* | 0.74\*\*\* | 0.20\*\*\* | 0.13\*\*\* | 0.70\*\*\* | 0.19\*\*\* |
|  | (0.03) | (0.01) | (0.01) | (0.03) | (0.01) | (0.01) | (0.03) | (0.01) |
| Adult4 | 0.58\*\*\* | 0.20\*\*\* | 0.05\* | 0.63\*\*\* | 0.22\*\*\* | 0.06\*\* | 0.61\*\*\* | 0.21\*\*\* |
|  | (0.06) | (0.02) | (0.03) | (0.06) | (0.02) | (0.03) | (0.06) | (0.02) |
| Adult5+ | 0.62\*\*\* | 0.08 | 0.12\* | 0.59\*\*\* | 0.11\* | 0.10 | 0.56\*\*\* | 0.10\* |
|  | (0.19) | (0.06) | (0.07) | (0.18) | (0.06) | (0.06) | (0.18) | (0.06) |
| Child1 | -0.15\*\*\* | -0.02\*\*\* | -0.01 | -0.11\*\*\* | -0.04\*\*\* | 0.03\*\*\* | -0.12\*\*\* | -0.04\*\*\* |
|  | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) |
| Child2 | -0.21\*\*\* | -0.05\*\*\* | -0.04\*\*\* | -0.14\*\*\* | -0.03\*\*\* | -0.02\*\* | -0.14\*\*\* | -0.03\*\*\* |
|  | (0.03) | (0.01) | (0.01) | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) |
| Child3+ | -0.04 | -0.05\*\*\* | 0.02 | -0.05 | -0.04\*\*\* | 0.02 | -0.08\*\* | -0.05\*\*\* |
|  | (0.04) | (0.01) | (0.02) | (0.03) | (0.01) | (0.02) | (0.03) | (0.01) |
| Age |  |  |  | -0.03\*\*\* | -0.01\*\*\* | -0.01\*\*\* | -0.02\*\*\* | -0.00\*\*\* |
|  |  |  |  | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Age2\_100 |  |  |  | 0.02\*\*\* | 0.00\*\*\* | 0.01\*\*\* | 0.02\*\*\* | 0.00\*\*\* |
|  |  |  |  | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Agetop |  |  |  | -0.00 | -0.02\* | -0.00 | 0.01 | -0.02\* |
|  |  |  |  | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) |
| Female |  |  |  | -0.04\*\*\* | -0.02\*\*\* | 0.00 | -0.05\*\*\* | -0.02\*\*\* |
|  |  |  |  | (0.01) | (0.00) | (0.00) | (0.01) | (0.00) |
| Education 16+ |  |  |  | -0.20\*\*\* | -0.03\*\*\* | -0.06\*\*\* | -0.17\*\*\* | -0.02\*\*\* |
|  |  |  |  | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) |
| Education 12-15 |  |  |  | -0.12\*\*\* | -0.02\*\*\* | -0.02\*\*\* | -0.10\*\*\* | -0.02\*\*\* |
|  |  |  |  | (0.01) | (0.00) | (0.01) | (0.01) | (0.00) |
| Edu. missing |  |  |  | 0.05\*\*\* | 0.01 | 0.02\*\*\* | 0.05\*\*\* | 0.01 |
|  |  |  |  | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) |
| Workless |  |  |  | 0.06\*\*\* | 0.01\* | 0.03\*\*\* | 0.04\*\* | 0.01 |
|  |  |  |  | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) |
| Ethnic minority |  |  |  | 0.14\*\*\* | -0.00 | -0.02\* | 0.12\*\*\* | -0.02\* |
|  |  |  |  | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) |
| Rural |  |  |  | -0.11\*\*\* | -0.04\*\*\* | -0.03\*\*\* | -0.06\*\*\* | -0.01 |
|  |  |  |  | (0.01) | (0.01) | (0.01) | (0.01) | (0.00) |
| Rural missing |  |  |  | -0.30\*\*\* | -0.15\*\*\* | -0.02\* | -0.10\*\*\* | -0.03\*\* |
|  |  |  |  | (0.02) | (0.01) | (0.01) | (0.03) | (0.02) |
| Bedrooms |  |  |  | -0.18\*\*\* | -0.08\*\*\* | -0.02\*\*\* | -0.13\*\*\* | -0.05\*\*\* |
|  |  |  |  | (0.01) | (0.00) | (0.00) | (0.01) | (0.00) |
| No vehicle |  |  |  | 0.39\*\*\* | 0.05\*\*\* | 0.15\*\*\* | 0.32\*\*\* | 0.02\*\*\* |
|  |  |  |  | (0.01) | (0.00) | (0.00) | (0.01) | (0.00) |
| Own outright |  |  |  |  |  |  | -0.14\*\*\* | -0.05\*\*\* |
|  |  |  |  |  |  |  | (0.02) | (0.01) |
| Mortgage |  |  |  |  |  |  | -0.18\*\*\* | -0.05\*\*\* |
|  |  |  |  |  |  |  | (0.02) | (0.01) |
| Missing own |  |  |  |  |  |  | -0.10\*\* | -0.07\*\*\* |
|  |  |  |  |  |  |  | (0.04) | (0.02) |
| Detached |  |  |  |  |  |  | -0.17\*\*\* | -0.10\*\*\* |
|  |  |  |  |  |  |  | (0.02) | (0.01) |
| Semid |  |  |  |  |  |  | 0.00 | -0.04\*\*\* |
|  |  |  |  |  |  |  | (0.02) | (0.01) |
| Terraced |  |  |  |  |  |  | 0.05\*\*\* | -0.03\*\*\* |
|  |  |  |  |  |  |  | (0.02) | (0.01) |
| Flat conv. |  |  |  |  |  |  | -0.06\*\* | -0.03\*\*\* |
|  |  |  |  |  |  |  | (0.03) | (0.01) |
| Elec heat |  |  |  |  |  |  | 0.17\*\*\* | 0.06\*\*\* |
|  |  |  |  |  |  |  | (0.02) | (0.01) |
| Oil heat |  |  |  |  |  |  | -0.23\*\*\* | -0.15\*\*\* |
|  |  |  |  |  |  |  | (0.04) | (0.02) |
| Other heat |  |  |  |  |  |  | 0.18\*\*\* | 0.05\*\*\* |
|  |  |  |  |  |  |  | (0.02) | (0.01) |
| Constant | 0.51\*\*\* | -0.03\*\*\* | 0.21\*\*\* | 1.29\*\*\* | 0.36\*\*\* | 0.29\*\*\* | 1.07\*\*\* | 0.30\*\*\* |
|  | (0.01) | (0.00) | (0.00) | (0.06) | (0.02) | (0.03) | (0.06) | (0.02) |
|  |  |  |  |  |  |  |  |  |
| Observations | 22,990 | 22,990 | 22,990 | 22,990 | 22,990 | 22,990 | 22,990 | 22,990 |
| R-squared | 0.325 | 0.138 | 0.188 | 0.409 | 0.233 | 0.240 | 0.426 | 0.261 |

Note: Robust standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.   
1st and 99th percentiles of the net rebate distributions and of income are excluded to reduce influence of outliers. Error terms are not perfectly normally distributed but regression results were robust against exclusion of error outliers with no significant differences of coefficients. The results presented include regression outliers.  
Independent variables: “Income” represents annual disposable income divided by 10,000. “Adult2” identifies households with at least 2 adults, “adults3” identifies households with at least 3 adults and so forth, the same logic applies to the variables “child2” and following. “Age” provides age in years. Since the relationship between age and emissions has an inverse u-shape, an age-squared term is also used (‘age2/100 – age squared divided by 100). “Agetop” is coded 1 for households with reference persons aged 80 and over and 0 otherwise. “Education 16+” is coded 1 if at least one household member attended full time education for 16 or more years. “Education 12-15” is coded 1 if at least one household member attended education for 12 to 15 years and 0 otherwise, “Edu. missing” is coded 1 if information on education is missing. “Rural” is coded 1 for households in settlements with less than 10,000 inhabitants. “Rural missing” is coded 1 if information on rural location is missing which is mainly for households in Northern Ireland. Own outright means that the household owns the property without mortgage, “mortgage” means the property is owned through a mortgage. “Missing own” denotes that information is not available, control household is renting the property. Control household for type of dwelling is a household in a purpose build flat and the control household for the heating variables has central gas heating.

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2. The distinction between needs and wants or tastes is notoriously fuzzy and its clarification is outside of the scope of this chapter. See Starkey ([2008](#_ENREF_61)) and Druckman and Jackson ([2010](#_ENREF_27)) for a discussion on emissions needs. [↑](#footnote-ref-2)
3. The issues at stake include whether the atmospheric sink can be considered the property of national governments, whether governments can be trusted to reallocate revenues for a defined purpose rather than absorb them into general revenue, effects on public acceptance, and potentially lower costs of a scheme that would work through the existing structures of the nation state. [↑](#footnote-ref-3)
4. The distributional effects of lump-sum rebate schemes also depend on the level of the cap. PCT or Cap and Share/Dividend schemes will be progressive as long as low income households generally consume less than their initial allocation of emissions/energy. If a scheme applies internationally with the same per capita allocation across the whole scheme, its distributional effects are likely to be regressive in highly developed countries. For example, a global scheme which allocated a budget of 4 tonnes of CO2 per year to each citizen in 2006, slightly below the then world average of 4.39 tonnes CO2 per person, would have regressive effects in most industrialised countries as their average per capita emissions are much higher (in the UK, annual per capita emissions were 9.37 tonnes CO2, in the US 19 tonnes CO2 in 2006, according to the World Bank Development Indicators.). However, those schemes would be extremely progressive in less developed countries. See Wakeford ([2008](#_ENREF_68)) and Sharan ([2008](#_ENREF_58)) on the impact of a Cap and Share scheme on South Africa and India respectively. [↑](#footnote-ref-4)
5. See <http://www.sutherlandtables.co.uk/>, last accessed 24 April 2013. [↑](#footnote-ref-5)
6. The remaining six categories are estimated as described above. [↑](#footnote-ref-6)
7. The interview question asks for the number of flights taken in the previous year. The infrequency of purchase problem therefore applies to the extent that there are households who fly, but less than once per year. We assume that this is a small percentage of households, but do not have data on this figure. [↑](#footnote-ref-7)
8. The language of “gaining” and “losing” is problematic in this context because a nominal rebate surplus may not necessarily translate into ‘real’ increased consumption in an economy that is constrained by increasing emission caps, see the limitations discussed in the conclusion. [↑](#footnote-ref-8)
9. The net rebate variables are divided by 1000 to ease interpretation. The 1st and 99th percentile of the net rebate and income distribution are excluded from the regression analysis to minimise the influence of outliers. [↑](#footnote-ref-9)
10. All other patterns described above remain very similar in the model which allocates half an allowance to every child, apart from ethnic minority households’ rebates on transport emissions which are no longer significantly different to ‘white’ households. This is probably related to the significantly higher number of children in ethnic minority households (1 child on average (se 0.03) compared to 0.5 (se 0.01) for “white” households). [↑](#footnote-ref-10)