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REPORT

DESIGNING CARBON TAXATION TO PROTECT LOW-INCOME HOUSEHOLDS

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Would it be possible to increase carbon taxes on household energy use and transport, while protecting low-income households from negative impacts?

There are strong policy arguments for removing environmentally perverse subsidies and introducing carbon taxation to incentivise efforts to reduce carbon emissions. Green tax reform would shift taxes away from productive activity such as income and employment, towards harmful activity such as pollution. The difficulty from the perspective of social justice is that green taxes are not like income tax; they do not directly relate to the ability to pay.

This project:
- looks at whether it is possible to achieve a progressive approach to carbon taxation;
- examines how to design a revenue-neutral carbon tax on household energy use and transport, with a focus on safeguards to protect low-income households from losing money overall;
- concludes that it is possible to protect the majority of low-income households, and almost all recipients of means-tested benefits, from the negative impact of a carbon tax through an appropriately designed compensation package.

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CONTENTS

List of figures

List of tables

EXECUTIVE SUMMARY

At present, much taxation is placed on income, employment and other productive activity. Green tax reform would shift taxes away from this productive activity towards harmful activity such as pollution.

There are strong policy arguments for removing environmentally perverse subsidies and for introducing carbon taxation to incentivise efforts to reduce carbon emissions. The difficulty from the perspective of social justice is that green taxes are unlike income tax; they do not directly relate to the ability to pay. This project has therefore examined whether it is possible to achieve a progressive approach to carbon taxation. Specifically, it examines how to design a revenue-neutral carbon tax on household energy use and transport, with a focus on safeguards to protect low-income households from losing money overall.

Different sources of carbon are currently treated very differently in the tax system. Petrol and diesel are highly taxed; the household use of energy is taxed at only 5% VAT rather than the standard rate of 20% VAT; aviation fuel is untaxed under the 1944 Chicago Convention.

The taxation of household energy is particularly controversial because expenditure on energy is highly regressive (low-income households spend a higher proportion of their income on energy than richer households) and because of concerns about fuel poverty. However, carbon taxation is widely recognised to be essential for the transition to a low-carbon society as taxing household energy at a lower rate than most other forms of expenditure is the largest implicit subsidy to fossil-fuel use in the UK economy. Such subsidies are distortionary, encouraging energy consumption and discouraging energy conservation and measures to reduce emissions that contribute to climate change.

The aim of this project has been to examine possible ways to structure the detailed design of changes to taxes and benefits. These involve increasing taxes on household use of energy and on some forms of transport, and using the revenues to increase tax allowances and benefits, such that the tax-benefit package remains revenue-neutral overall, enabling low-income households to be protected as far as possible from losing money.

This study has used the Centre for Sustainable Energy's (CSE) Distributional Impacts Model for Policy Scenario Analysis (DIMPSA) to model the energy consumption and expenditure of UK households, and the Institute for Fiscal Studies' (IFS) model TAXBEN to calculate the effect of changes in taxes, tax allowances and benefits. Both models use underlying data from the Living Costs and Food (LCF) survey. CSE's DIMPSA model has been extended, through another project funded by the Joseph Rowntree Foundation (JRF), to include estimates of household carbon emissions from surface transport, derived from the National Travel Survey (NTS) data, and aviation, from Civil Aviation Authority Air Passenger Survey (CAA APS) data. The modelling in this study looks forward to 2017/18 and takes into account the effects of existing policies and, as far as possible, future policies that are already planned. The 2017/18 dateline was chosen because that is when Universal Credit will come fully into force.

The carbon taxes examined in this project are carbon pricing for household energy and transport, and extending VAT on household energy bills. The desire to price carbon in order to reduce carbon emissions led the government in the 2011 Budget to introduce a 'carbon price floor' (CPF) from 2013. The CPF will apply to the fossil-fuel inputs to electricity generation and will entail a carbon tax on these inputs, such that when this is added to the price of emissions permits under the EU Emissions Trading Scheme, there will be a minimum price for carbon emissions. This will start at £16 per tonne in 2013, rising linearly to £30 per tonne by 2020, and the cost will be passed on to end users through their bills.

The project created two scenarios for modelling an increase of taxation on household energy: the first envisages the extension of the CPF to the household consumption of gas and non-metered fuels ('small carbon tax'),[1] which would also be passed on to end users; the second adds to this CPF extension an increase in the VAT rate on household energy to 20% (which we call the 'large carbon tax' as shorthand, although the VAT increase is not a true carbon tax). We selected this increase rather than a pure carbon tax because the lower rate of VAT for household energy is a tax subsidy for energy use and carbon emissions – the major environmentally perverse subsidy in the UK. For each of these household energy scenarios, there was the further option to include an additional carbon tax at the same level as the CPF on transport fuels and on aviation emissions,[2] making four (2x2) scenarios in all:

- Scenario 1: CPF on gas and non-metered fuels only ('small carbon tax without transport')
- Scenario 2: CPF on gas and non-metered fuels, and VAT rate increase on household energy ('large carbon tax without transport')
- Scenario 3: CPF on gas, non-metered fuels and transport ('small carbon tax with transport')
- Scenario 4: CPF on gas, non-metered fuels and transport, and VAT rate increase on household energy ('large carbon tax with transport').

The team modelled these changes as happening in 2017–18: this coincides with the full introduction of Universal Credit. The analysis does not take into account changes announced in Budget 2012 (in particular the increase in the personal allowance that will take place in 2013–14); this does not substantively affect the conclusions of the analysis, as the distributional impact of the higher Income Tax Personal Allowance and benefit amounts will be much the same irrespective of the base system to which they are applied.

The team designed a series of compensation packages using some of the projected revenues from the taxes to address the impacts of the tax scenarios on low-income households. The compensation packages involve reforms to Universal Credit, in particular increasing the basic amount of Universal Credit and lowering the rate at which it is withdrawn as income rises. Note that the increase in the Income Tax Personal Allowance takes up almost all of the revenue in the case of the small carbon tax applied only to gas and non-metered fuels, and that there is no increase in Universal Credit.

It is important to note that these compensation packages are intended to be illustrative: the aim of the research team was to minimise the number of low-income 'losers' in a way that did not favour a particular household type over another (for example, the research team did not particularly aim to minimise the number of losing low-income pensioners or lone-parent households at the expense of other low-income groups). A government that wished to introduce a carbon tax would have its own distributional objectives; the analysis here is simply intended to show that the introduction of a carbon tax need not disproportionately impact on low-income households if the revenues from the carbon tax are used to fund an appropriate compensation package.

It is important to bear two caveats in mind. Firstly, TAXBEN assumes full take-up of means-tested benefits. This means that in practice there will be more low-income losers than we estimate in our results, where full take-up does not occur. Clearly, the take-up rate of the new Universal Credit will be crucial in determining how important a factor this will be. Existing means-tested benefits and tax credits for those of working age already have relatively high rates of take-up, often in excess of 90% – at least for those on lower incomes.[3] The government hopes that Universal Credit will have a higher take-up rate as it is a single benefit that families can continue claiming whether they are in or out of work. However, Pension Credit has a lower rate of take-up, particularly among pensioners with small amounts of private income. It is therefore likely that more lower-income pensioners will lose out from the introduction of a carbon tax than we estimate here. Secondly, the analysis does not take account of individuals changing their labour market or other behaviours in response to either the introduction of the carbon tax or an increase in means-tested benefits.

The small carbon tax without transport and its associated compensation package has a very different overall distributional impact to the other variants and their compensation packages. This is because increasing the income tax allowance takes up most of the revenue from the small carbon tax without transport, whereas the package with larger tax revenues leaves much more revenue to increase the means-tested benefits that go to lower-income groups. The reason for that is because the first package was designed to achieve the stated government policy of increasing the Income Tax Personal Allowance to £10,000 a year.

By contrast, in the other three scenarios the larger amount of revenue gained in taxation enables increases in Universal Credit and Pension Credit similar in size to the gains wealthier households receive from the increase in the Income Tax Personal Allowance, with the effect that, on average, households on lower incomes gain quite significantly. Revenue neutrality means that this gain is balanced by average losses in higher-income households, although because their incomes are much higher the losses are much smaller as a percentage of income.

The small carbon tax without transport (carbon price floor on gas and non-metered fuels only) is relatively small in magnitude, so relatively few households are affected by more than one pound per week. Even those who lose by more than a pound a week in low-income deciles do not lose much more. Losers are predominantly found in lower-income rather than higher-income groups; this is because, as explained previously, these groups gain little from the increase in the Income Tax Personal Allowance that forms the majority of the compensation package for the small carbon tax without transport.

The other tax scenarios, with larger carbon taxes and their associated compensation packages, have relatively fewer households who are broadly unaffected. Most low-income households gain from these packages, and most high-income households lose. As the compensation packages are deliberately skewed towards lower-income households, this is unsurprising.

Despite this, however, the compensation packages do not eliminate low-income losers completely, demonstrating how difficult it is to completely compensate all low-income households when a carbon tax is introduced. The main reason for this is that in these compensation packages there are some low-income households that will not be eligible for Universal Credit or Pension Credit – almost all of those entitled to Universal Credit do not lose out overall from the introduction of the large carbon tax (with or without the transport tax). In some cases this is because they have considerable savings or other assets which mean they are not entitled to Universal Credit, perhaps suggesting that they have only a temporarily low income. In others, it is because they are households of students, who are generally not entitled to benefits. Overall, however, it is possible to protect the vast majority of low-income households from the negative impact of a carbon tax through an appropriately designed compensation package.

Analysis based on a fairly complex statistical methodology, Chi-squared Automatic Interaction Detector (CHAID) analysis, then looked in detail at which kinds of households (grouped into categories called 'nodes') gain or lose. The main 'losing' nodes are dominated by working higher-income couples with or without children in larger properties, not eligible for Universal Credit, but with high household fuel and transport emissions. Being higher-income households, the fact that they are losing out is less of a concern from a social justice point of view, but could be a politically sensitive issue given the nature of these groups ('hard-working' adults and families). In the modelling, we have tried to protect low-income households, meaning that most of them gain from the packages we have simulated. That inevitably means that there have to be higher-income losers to keep each package revenue-neutral.

To explore the sensitivity of the results to changes in underlying trends for energy demand, and the fact that some households will use energy-efficiency measures to make their homes warmer rather than save energy (called 'comfort-taking'), the team undertook some additional analysis and found that the difference was not large enough to have a significant effect on our results.

Due to concerns raised in advance of the modelling that using changes in Income Tax Personal Allowance, tax credits and the benefits system might not be sufficient to adequately compensate low-income households for higher energy and transport taxes, other approaches were also investigated. These included exemptions from higher taxes on household energy for households in receipt of certain benefits – rather like the system that currently exists for free school meals – or concessions for rural areas. However, on the basis of this research, it has been concluded that compensation through tax and benefits would be sufficiently effective, and that the administrative complexity of the exemptions investigated could not be justified by their extra distributional benefits. The Rural Fuel Duty

Reduction Pilot Scheme, which reduces fuel duty by 5p a litre on remote Scottish islands and the Scilly Isles, could be extended to remote areas of the Highlands as well, but it would not be practical to extend it to rural areas more widely because of the risk of people driving to such areas especially to fill up with cheaper fuel.

The main conclusion of the project is that if the government wishes to use taxation to help reduce CO_2 emissions, it should not be dissuaded from doing so by distributional considerations provided that at the same it applies appropriate compensation measures. This report shows that it is possible to protect the vast majority of low-income households (though not all) and almost all recipients of means-tested benefits from the negative impact of a carbon tax through an appropriately designed compensation package.

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1 PROJECT RATIONALE

Under the 2008 Climate Change Act, the government is legally obliged to reduce emissions of carbon dioxide (CO_2) and other greenhouse gases that contribute to climate change by 80% from 1990 levels by 2050, with reductions in the intervening period being made according to five-yearly 'carbon budgets'. There are two principal ways of reducing carbon emissions from the household sector, which are the focus of this project.

One way is to increase the energy efficiency of homes, so that people can keep warm using less energy. UK governments have had policies in this area for a number of years, and the average energy efficiency of homes has increased. Further policies – most notably the Green Deal and the Energy Company Obligation – are the subject of current consultation and legislation. These are important policies, but their detail is largely outside the scope of this project, though they are mentioned when they are relevant to its main analysis.

The other principal way of achieving cuts in carbon emissions (from all sectors) is to use public policy to put a price on carbon – indeed, carbon pricing is widely recognised to be essential for the transition to a low-carbon society – and this, and the implications for low-income households, provide the main focus of this project.

At the level of the EU, carbon pricing is achieved through the EU Emissions Trading Scheme (EU ETS), and the government has supplemented this with a number of other taxes related to energy or carbon emissions, including the Climate Change Levy and the Carbon Price Floor (CPF).

The CPF is a policy instrument intended to ensure that electricity generators face a minimum price for the carbon contained in any fossil fuels that they burn, in order to encourage them to use and invest in low-carbon technologies. The CPF is made up of the price of the permits in the EU ETS plus a carbon tax on the fossil-fuel inputs to power generation, applied each year at a rate to ensure that the overall price of carbon for the fuels burned in power stations rises steadily from £16 per tonne CO_2 (/t CO_2) in 2013 to £30/t CO_2 in 2020. In addition to giving an incentive to power generators to use low-carbon technologies, this carbon price will be passed through to the electricity prices faced by consumers, encouraging them to buy more efficient appliances and generally use less electricity, reducing further the emissions and other damaging environmental effects from power generation.

However, this taxation of the carbon inputs to electricity is not matched by the taxation of carbon-based fuels used by households, mainly natural gas for heating. Indeed, not only is the gas used by households not subject to a carbon tax, but it only has a 5% rate of VAT, compared to 20% VAT charged on practically all other goods and services. Aviation fuel used for international flights also cannot be taxed, because of commitments in the 1944 Chicago Convention, an international agreement to which the UK is a signatory (as are nearly all other countries). This is an implicit subsidy to household gas and aviation uses, which distorts markets (for example, the choice between untaxed gas and taxed electricity) and discourages energy conservation and investments in energy efficiency, thereby having the environmentally perverse effect of increasing emissions. There is near-universal agreement among policy makers that, in principle, such subsidies should be removed. In this case, applying the CPF and the full rate of VAT to household gas use and taxing aviation emissions provide the means of removing these subsidies.

The problem in practice with taxing the household use of energy is that low-income households spend a higher proportion of their income on this energy than do higher-income households. Such a tax would hit lower-income households disproportionately hard (i.e. would be regressive), unless they could be compensated in some way. In addition, such an uncompensated tax could increase the numbers of households in fuel poverty at a time when the government has a commitment to reduce such numbers, and indeed to eliminate fuel poverty entirely.[4] However, it is also the case that general energy subsidies, such as a lower rate of VAT, are a very inefficient way of helping low-income households; this is because most of the subsidy actually goes to higher-income households, who use more energy in absolute terms than lower-income households do.

The aim of this project was to see whether it would be possible to remove the subsidies on the household use of energy, particularly by applying the CPF and the full rate of VAT to household gas use. The subsequent revenues could then be used to fund a package of compensations through the tax and benefit system that would ensure that no (or very few) low-income households were worse off as a result. The CPF was also applied to transport fuels and on aviation emissions in order to provide a further incentive to reduce carbon emissions from transport.

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Because the Coalition Government has a pledge to raise the Income Tax Personal Allowance to £10,000 over the course of this Parliament, the team looked at the distributional effect of recycling some of the tax revenues this might generate. Increasing the Income Tax Personal Allowance would help those on moderately low incomes, but of course not those on incomes below the tax threshold. So for this latter group, additional or alternative measures to help were considered – including through the benefits system – in attempting to ensure that the higher energy price did not have a regressive effect. In addition, we looked at concessions for rural areas. The absence of the gas network in many rural locations and the lack of public transport makes per-household emissions in those areas higher than in more densely populated parts of the country.

The research has utilised the Centre for Sustainable Energy's (CSE) 'Distributional Impacts Model for Policy and Strategic Analysis' (DIMPSA) model with data on UK household energy use and emissions to simulate the impacts of the chosen taxes: a carbon tax on gas at the level of the CPF, as announced in Budget 2011; an increase in the VAT rate on household energy use from the current 5% to the standard rate of 20%; and an increase in tax equivalent to the level of the CPF on road fuels and on aviation emissions. The policy scenarios explored, and the results from the models of levying these taxes, are presented in Chapters 2 and 3.

In addition to encouraging people to reduce their energy use and emissions, the carbon tax raises revenues which, as noted above, can be used to compensate households for the extra cost of their energy. The main compensation mechanisms proposed are increasing the Income Tax Personal Allowance, increasing the State Pension and Pension Credit, and increasing payments under Universal Credit. This is the first time that this new benefit structure has been used for such analysis. The effects of these compensation mechanisms have been explored using the Institute for Fiscal Studies' (IFS) TAXBEN model, and the results of this work are described in Chapter 4.

Analysis of the results from the TAXBEN model can then indicate the 'winner' and 'loser' households from the taxation-plus-compensation scenarios. The DIMPSA model can then be used again to identify the principal relevant characteristics of the main groups of winning and losing households. The results of this analysis are given in Chapters 5 and 6. Chapter 7 discusses other ways in which low-income households that lose out even after the compensation packages could be further compensated.

The DIMPSA model estimates the impact of various energy-efficiency measures on the energy use of households, but the actual effect of these measures can differ from the modelled effect because the measures are not as effective as assumed in real life, or because of the rebound effect.[5] The use of real energy-consumption data following an intervention allows a comparison between the modelled impact and the actual performance. Chapter 8 discusses the approach taken to re-running the DIMPSA model to allow for actual in-situ performance of policy measures and the effect of this on the overall outcomes. Chapter 9 presents a sensitivity analysis for the results of the modelling, looking at the scale of the uncertainties in the output of the model and how they are affected by different sources of uncertainty in the inputs to the model, including the assumptions about rebound and the effectiveness of the measures.

Chapter 10 describes the overall conclusions drawn from the research: that it is possible to protect the vast majority of low-income households (though not all) and almost all recipients of means-tested benefits from the negative impact of a carbon tax through an appropriately designed compensation package.

2 POLICY MODELLING AND SCENARIO DESIGN

This chapter explains the methods underpinning our study, explaining carbon policy reduction opportunities and their impacts. The study uses CSE's Distributional Impacts Model for Policy Scenario Analysis (DIMPSA). This modelling tool has been developed by CSE, through close working with the Department of Energy and Climate Change (DECC), which uses the model for their own modelling analysis of policy impacts.[6]

DIMPSA

DIMPSA is based on the Living Costs and Food (LCF) survey, from which data on household energy consumption is derived. The LCF does not include detailed information on physical household characteristics, other than built form, which are important in modelling the impact of energy policies. Data from the 2007/8 English Housing Survey (EHS) was therefore used by CSE to generate a predictive model to identify wall type, loft insulation levels and heating system age/communal heating in the LCF dataset.

For the purpose of the model, data from four LCF surveys has been combined, (financial years 2004/5, 2005/6, and calendar years 2006, 2007) generating a sample size of over 20,000 cases. Time- and location-specific fuel price information was used to convert survey expenditure data on household fuels into consumption. The model then uses a look-up table containing a set of fuel prices from 2010 to 2030 by method of payment to estimate household energy bills in the baseline year.[7] These prices are based upon DECC figures for average gas and electricity prices (taken from the average price and bills model).

DIMPSA identifies types of households in the LCF that may be suitable for energy-efficiency measures and sustainable energy technologies.

A number of standard criteria are applied in the model to constrain the application of measures. Variables used include: tenure, built form, central heating type, number of rooms, occupants, age of household representative, rurality, and wall type (modelled). For example, solid wall insulation will be applied only to households with uninsulated solid walls, whereas biomass boilers may not be appropriate in urban areas.

Policies currently modelled within DIMPSA (as applied in this study) include:

- Carbon Emissions Reduction Target (CERT);
- Feed-in Tariff (FIT) and Renewable Heat Incentive (RHI);
- smart meters;
- Warm Home Discount;
- EU Emissions Trading Scheme (ETS);
- Renewables Obligation (RO);
- Carbon Capture and Storage (CCS);
- Product Policy;
- Energy Company Obligation (ECO) and Green Deal;
- Carbon Price Floor (CPF).

See the Glossary (page 68) for further explanation of these policies.

The total policy costs passed through to domestic customers are dependent upon which sectors the policy affects. For instance, FITs will apply to both domestic and non-domestic customers, so the costs have therefore been split between these two customer groups based on their total annual consumption. In addition, cost is distributed based on the fuel types covered by the policy, i.e. electricity, gas, oil, coal or liquid petroleum gas (LPG). The total policy costs to distribute domestically are then divided between the relevant fuels according to the weighted number of consumers using each type.

Policy measures are targeted at specific groups consistent with policy design and are randomly distributed between eligible households. For example, FIT measures are targeted at groups of early adopters of technology identified through specific household characteristics. ECO measures are targeted at groups that are identified as vulnerable households. The levels of savings associated with different measures are estimated based on the year and household characteristics, and are adjusted for comfort-taking. For any heat consumption reduction measure, renewable heat pump or insulation measure, the savings are adjusted in the model to allow for comfort-taking (for example, applying a rate of 15% to be consistent with the assumptions on comfort-taking used in the Green Deal impact assessment).

Product Policy improves the energy efficiency of appliances and other products that use energy by tightening the standards they must meet. Savings are applied in each year based on the number of large and small appliances the household has (with the savings associated with lighting distributed according to the number of rooms). Smart meter savings are based on a constant percentage reduction consistent with the roll-out profile in the government's smart meter Impact Assessment.

The installation of FIT measures will include some level of tariff payment. That is, the installation of a small-scale generator (for example, solar panels) reduces household consumption of electricity from the grid but also provides a payment on top. There is also an additional payment for any surplus electricity fed back into the grid. Depending on the type of measure, household and year, a corresponding tariff payment is estimated. Tariff payments from the grid to households taking up FIT measures are netted off the final bill.

The Warm Home Discount (WHD) provides a rebate on bills for certain vulnerable households (£130 per household in 2012/13). The discounts are targeted at three specific groups of vulnerable consumers: a 'legacy group' who will continue to receive support, including social tariffs, similar to that under the previous voluntary agreement between energy suppliers and the government; a 'core group' of low-income and vulnerable households; and a wider 'broader group'. Each group has specific characteristics consistent with criteria for vulnerable households.[8] The level of rebate is specified for each group and subtracted from the final bill.

Policy costs and measures are input into DIMPSA to produce an estimated final energy consumption and bill for each household in the model.

Modelling carbon taxation

This study is concerned specifically with the impact of carbon taxation, as applied to household energy use and personal travel. The LCF dataset underpinning CSE's DIMPSA model has been extended, through another JRF-funded project, to include estimates of household carbon emissions from surface transport (derived from the NTS, 2002–6) and aviation (from CAA APS data).[9] This research utilises this newly developed, comprehensive dataset to simulate the impacts of various designs for a carbon tax through DIMPSA covering the emissions from all modes of transport, including aviation.

As part of this project DIMPSA has been extended to allow the user to apply the CPF to all domestic fuels and also change the VAT rate of the final energy bill.

Carbon taxation scenarios

Modelling the impact of carbon taxation was done first with household energy only and was then extended to include both household energy and transport, thus enabling analysis of distributional differences between the two approaches. With respect to household energy, the project team considered several different approaches for modelling carbon taxation.

As the price of carbon in the EU ETS has not been certain enough or high enough to encourage sufficient low-carbon investment, the government has introduced the CPF to set a minimum price for carbon in the electricity generation sector. Our first decision on how to tax carbon emissions resulting from household energy use was to extend the CPF to include the household use of gas and non-metered fuels.[10] This would remove carbon-charging disparity across fuels used by domestic consumers. The team performed some initial analysis to vary the CPF by doubling the amount to be applied to all fuels; however, this approach seemed arbitrary without prior research to suggest a suitable higher price.

Our second decision was to remove the VAT subsidy on household fuels (i.e. to increase the VAT rate for household energy from 5% to the standard 20% VAT rate).[11] This resulted in the first two agreed scenarios for modelling: the first models the impact of applying the CPF to gas and non-metered fuels ('small carbon tax'); the second models the CPF on gas and non-metered fuels along with a change in the VAT rate ('large carbon

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tax'). These two scenarios are combined with the imposition, or not, of an additional carbon tax on all transport emissions, including aviation, applied at the same CPF rate.

As described above, DIMPSA has been extended to include the full range of UK Government carbon and fuel poverty policies, which utilise the latest thinking and assumptions from DECC. However, within these there remain several uncertainties around policy costs and impacts, for example around the Green Deal and ECO (final decisions about which had still to be taken at the time this research was being carried out), and assumptions around savings from Product Policy and the impact of comfort-taking. As such, for the purpose of this research study the team decided it prudent to run two policy scenarios in DIMPSA:

1. Limited: models only those policies where costs and outputs are less ambiguous (i.e. excluding the Green Deal, ECO, Product Policy and comfort-taking).
2. All: includes all policies, with assumptions built in as necessary.

Combining the carbon taxation scenarios (household fuels only/household fuels and transport; CPF only/CPF and VAT rate change) and policy modelling scenarios described above provides eight unique modelling scenarios to be simulated through DIMPSA, as shown in Table 1.

Table 1: Carbon pricing and policy scenarios modelled

Carbon taxation scenario	A: Policy Scenario – Limited	B: Policy Scenario – All
1 Small non-transport (CPF on gas & non-metered fuels only)	Scenario 1.A	Scenario 1.B
2 Large non-transport (CPF on gas & non-metered fuels & VAT rate change	Scenario 2.A	Scenario 2.B
3 Small inc. transport (CPF on gas & non-metered fuels, and transport)	Scenario 3.A	Scenario 3.B
4 Large inc. transport (CPF on gas & non-metered fuels and transport & VAT rate change)	Scenario 4.A	Scenario 4.B

Conclusion

In developing new mechanisms for carbon pricing and green taxation, the team could have explored a multitude of options. The final decision to extend the CPF to all domestic fuels and remove the lower VAT rate were partially based on the practical opportunity to implement and the predefined effects of their application, i.e. the CPF and the higher VAT rate are known.

3 OVERALL REVENUES RAISED FROM CARBON TAXATION

The results of running the carbon taxation and policy scenarios through DIMPSA showed there is only a marginal difference in the *overall* impact on emissions (and therefore in revenue raised) of the two different policy scenarios (i.e. 'limited policies' versus 'all policies' – see Table 2 and Figure 1).

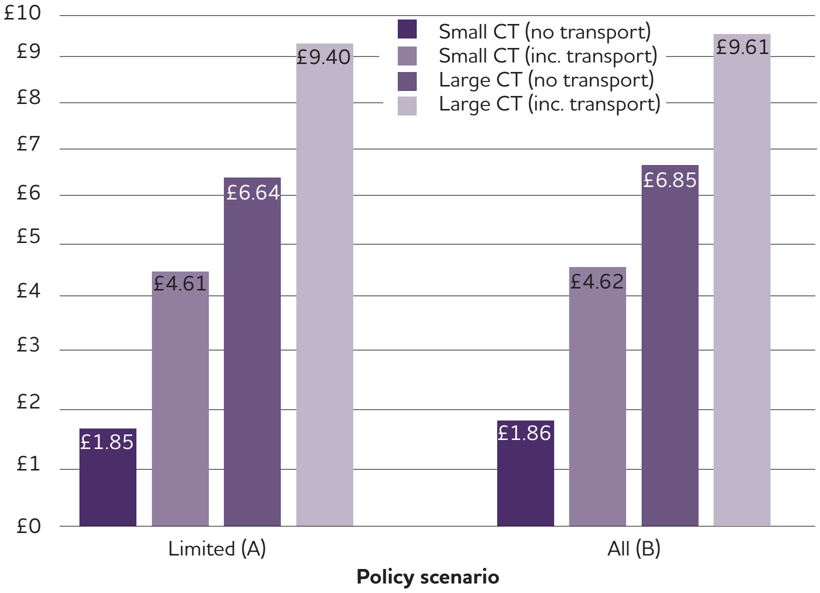
This is the result of interaction effects between Product Policy and the Green Deal and ECO: the benefits of the Green Deal and ECO – i.e. reductions in heat consumption resulting from measures – are outweighed by the impact of Product Policy, which indirectly increases gas demand when applied in the model because the energy savings for consumer electronics through improved efficiencies are such that heating use *increases* in some properties to counteract the loss of ambient heating from electronic products.[12]

The IFS TAXBEN model uses ONS population projections to create new weights in the dataset to mimic projected population change within the modelling timeframe (i.e. to 2017).[13] The weightings are designed to ensure that the population profile of the dataset used in this study corresponds with ONS figures for 2010 and 2017 (see Table 18, Chapter 9).

Table 2: Impact of policy modelling scenarios on household emissions

	Total household emissions	Average household emissions	Count of households
Baseline year (survey weight)	128 $MtCO_2$	5.3 tCO_2	24,206,750
Scenario A (Ltd) (2017 weight)	133 $MtCO_2$	4.5 tCO_2	28,097,519
Scenario B (All) (2017 weight)	127 $MtCO_2$	4.8 tCO_2	28,097,519

Figure 1: Total revenue raised under each Policy and Carbon Pricing Scenario (£billion)



TAXBEN uses these weightings to give an accurate reflection of the demand for welfare benefits in 2017. To ensure consistency, the Baseline Survey population in DIMPSA was weighted to arrive at a new 2017 population that took account of population growth (as shown in Table 18) in the analysis of the impacts of government policy on household emissions in 2017. This has implications for the level of emissions reductions resulting from policy impacts (as a direct result of the new weightings increasing the number of people and households represented in the dataset). This is explored in more detail in Chapter 9.

As Figure 1 shows, applying the CPF to gas and non-metered fuels only (small carbon tax without transport, shown as Small CT) raises revenue of around £1.86 billion (under the 'all policy' scenario). Extending the CPF to transport emissions as well (small carbon tax with transport) raises some additional £2.76 billion. Table 3 shows the revenues raised from each individual tax component in the scenarios, so that the total revenue raised under the small carbon tax with transport is around £4.6 billion. If the higher VAT rate is applied on top of the CPF (large carbon tax, shown as Large CT), an additional £4.99 billion is raised, bringing the total revenue to some £9.6 billion under the 'all policy' scenario with transport emissions tax. All the revenue is redistributed through the compensation mechanisms described in the next chapter.

Table 3: Revenue raised under each individual component of the taxation scenarios modelled

Carbon taxation	**Limited (A) (£bn)**	**All (B) (£bn)**
'Small CT' (CPF to gas & non-metered, no transport)	£1.85	£1.86
+ CPF on Transport Emissions	+£2.76	+£2.76
+ VAT @20%	+£4.79	+£4.99
Total Revenue Raised ('Large CT inc transport')	*£9.40*	*£9.61*

Conclusion

The eight scenarios have the potential to generate between £1.86 billion (under the 'small carbon tax with transport – all policy' scenario) and £9.6 billion (under the 'large carbon tax with VAT – all policy' scenario). Because the differences between the two policy scenarios ('limited policy' and 'all policy') are small, all of the further analysis was done only on the 'all policy' cases. Having run all the carbon pricing and policy scenarios through DIMPSA, the resulting values of revenue raised then formed the basis for modelling compensation packages in TAXBEN, as described in the next chapter.

Because the differences between the two policy scenarios ('limited policy' and 'all policy') are small, all of the further analysis was done only on the 'all policy' cases.

4 TAX AND BENEFIT COMPENSATION PACKAGES

This chapter uses the IFS tax and benefit microsimulation model TAXBEN to analyse compensation packages which recycle the revenue raised by the carbon taxes back to households. The distributional impact of each carbon tax and its associated compensation package is presented along with the number of winners and losers from the combined impact of each carbon tax and the compensation packages.

TAXBEN

TAXBEN calculates households' tax liabilities and benefit entitlements under different tax and benefit policies. It uses information on households' demographic characteristics, gross incomes, expenditures and entitlement to non means-tested benefits (from input data and tax/benefit parameters) to calculate households' direct and indirect tax liabilities and entitlements to means-tested benefits, tax credits and non means-tested benefits. A detailed, though dated, description of the model is given by Giles and McCrae (1995).[14] TAXBEN is set up to run on various UK household surveys, including the data from the Living Cost and Food (LCF) survey from 2004–7 that is used by the DIMPSA model. In our analysis, financial values from this data have been uprated to 2017/18 prices in line with actual earnings growth from 2007–12 and the Office for Budget Responsibility (OBR) forecast of earnings growth from 2012–17.

As described in the previous chapter, the DIMPSA model calculates the amount each household in the LCF data has to pay in each of the carbon tax scenarios. TAXBEN was then used to design appropriate compensation packages for these carbon taxes. As described above, TAXBEN uses information on each household's pre-tax income from the same LCF data to calculate how much they would gain from the compensation packages we consider for each of the variants of the carbon tax. The aim of the research team in constructing these compensation packages was to minimise the number of low-income losers from the introduction of the carbon tax. Combining this information with the simulated carbon tax liabilities for each household calculated by DIMPSA makes it possible to calculate whether each household in the LCF data gains or loses, and by how much, from the combined effect of the carbon tax and the compensation package.

The team modelled these changes as happening in 2017/18: this coincides with the full introduction of Universal Credit. The analysis does not take into account changes announced in Budget 2012 (in particular the increase in the personal allowance that will take place in 2013/14): this does not substantively affect the conclusions of our analysis, as the distributional impact of the higher tax allowances and benefit amounts will be much the same irrespective of the base system to which they are applied. In each case, the revenue is first used to increase the Income Tax Personal Allowance for those aged under 65 by £355 in nominal terms (under our pre-Budget 2012 base system, the personal allowance is £9,645, meaning that this increase takes the allowance to £10,000 in 2017/18; in reality the personal allowance will already be more than £10,000 in 2017/18 as a result of policy changes announced in Budget 2012 and the usual indexation of tax thresholds). To give a similar benefit to pensioners, the value of the basic State Pension is also increased. The remaining revenue is used to increase means-tested benefit rates, in order to minimise the number of low-income losers.

By 2017/18, the rollout of the government's new Universal Credit, which will replace most existing means-tested benefits and tax credits for those of working age, will be nearly complete.[15] Therefore, the compensation packages involve changes to Universal Credit, in particular increasing the basic amounts of Universal Credit and lowering the rate at which it is withdrawn as incomes rise.[16] The compensation packages in the two variants of the carbon tax are as outlined in Table 4. All figures are in nominal terms in 2017/18. Note that the increase in the personal allowance takes up almost all of the revenue in the case of the small carbon tax applied only to gas and non-metered fuels and that there is no increase in Universal Credit.

It is important to note that these compensation packages are intended to be illustrative: the aim of the research team was to minimise the number of low-income losers in a way that did not favour one particular household type over another (so we do not particularly favour pensioners or lone-parent households, for example). A government that wished to introduce a carbon tax would have its own distributional objectives: the analysis here is simply intended to show that the introduction of a carbon tax need not disproportionately impact on low-income households if combined with an appropriate compensation package.

Before showing the results of this analysis, it is important to bear two important caveats in mind. Firstly, TAXBEN assumes full take-up of means-tested benefits. As in practice there is some non-take-up of benefits, there will be more low-income losers than we estimate in our results. Clearly, the take-up rate of the new Universal Credit will be crucial in determining how important a factor this will be. Existing means-tested benefits and tax credits for those of working age already have high rates of take-up, often in excess of 90%, especially for those on lower incomes.[18] The government hopes that Universal Credit will have a higher take-up rate as it is a single benefit that families can continue claiming whether they are in or out of work. However, Pension Credit has a lower rate of take-up, particularly among pensioners

Table 4: Compensation packages

Annual increase in:	Small carbon tax package without transport	Large carbon tax package without transport	Small carbon tax package with transport	Large carbon tax package with transport
Personal allowance	£355	£355	£355	£455
Basic State Pension	£15	£70	£70	£100
Pension Credit for singles	£15	£300	£120	£450
Pension Credit for couples	£15	£500	£300	£850
Universal Credit for singles without children	£0	£300	£160	£325
Universal Credit for lone parents	£0	£200	£150	£350
Universal Credit for couples without children	£0	£700	£325	£925
Universal Credit for couples with children	£0	£300	£160	£400
Universal Credit taper rate[17]	65% (no change)	64% (1ppt reduction)	65% (no change)	63% (2ppt reduction)
Total cost of package	**£1.8 billion**	**£6.8 billion**	**£4.6 billion**	**£9.6 billion**

with small amounts of private income.[19] It is therefore likely that more lower-income pensioners will lose out from the introduction of a carbon tax than we estimate here.

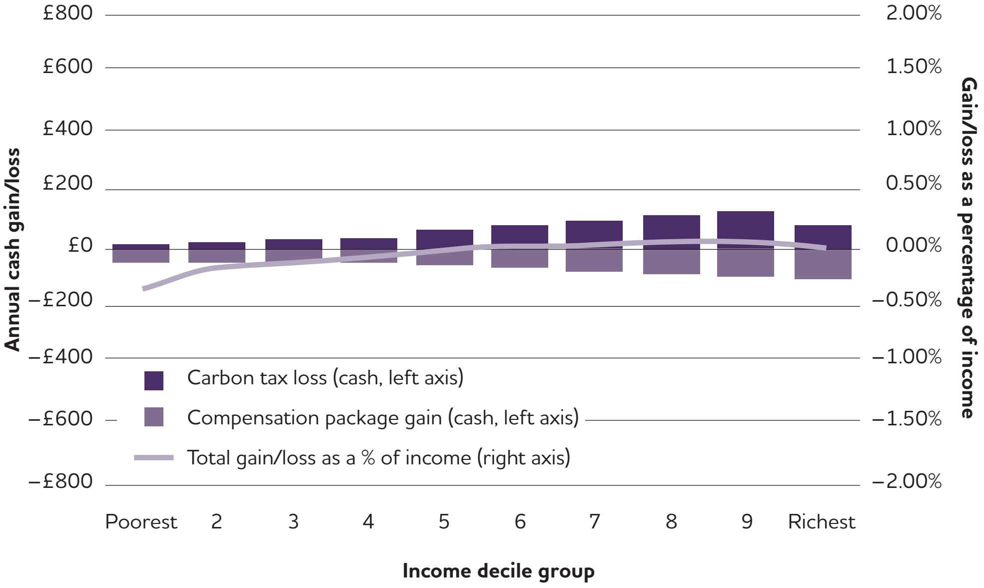
Secondly, the analysis does not take account of individuals changing their labour market or other behaviours in response to either the introduction of the carbon tax or increasing means-tested benefits. Both of these policies tend to weaken the incentives for individuals to do paid work, although this weakening is offset at least to some extent by the increase in the income tax allowance and the reduction in the rate at which Universal Credit is withdrawn as incomes rise, as included in the compensation packages. Any government wishing to introduce a compensation package for a carbon tax would in practice have to balance distributional goals against other objectives it may have.

Overview of distributional impacts from TAXBEN

Figures 2–5 below show the distributional impact of the overall packages by income decile. The figures show average carbon tax amounts and the average amount of compensation for each income decile.

The CPF on gas and unmetered fuels only, and its associated compensation package, has a very different overall distributional impact to the other variants and their compensation packages. As shown by Figure 2, it is higher-income households who benefit the most from a higher personal allowance in cash terms. Higher-income households tend to have two or more earners, and hence benefit more than once from the higher personal allowance. By contrast, around a third of adults in the UK do not have incomes high enough to pay income tax in the first place, so it is unsurprising that most low-income households do not benefit at all from this measure.[20] Because

Figure 2: Distributional impact of CPF on gas and unmetered fuels only (small carbon tax without transport) and associated compensation package



Notes: Income decile groups are derived by dividing all households into 10 equal-sized groups according to income adjusted for household size using the McClements equivalence scale. Decile group 1 contains the poorest tenth of the population, decile group 2 the second poorest, and so on up to decile group 10, which contains the richest tenth.
Source: Authors' calculations using DIMPSA and TAXBEN run on the 2004–7 Expenditure and Food Surveys

increasing the Income Tax Personal Allowance takes up most of the revenue in this scenario, there is little revenue left over to increase means-tested benefits that go to lower-income groups. The other scenarios raise more revenue and there is much more left over to increase benefits after the increase in the income tax allowance.

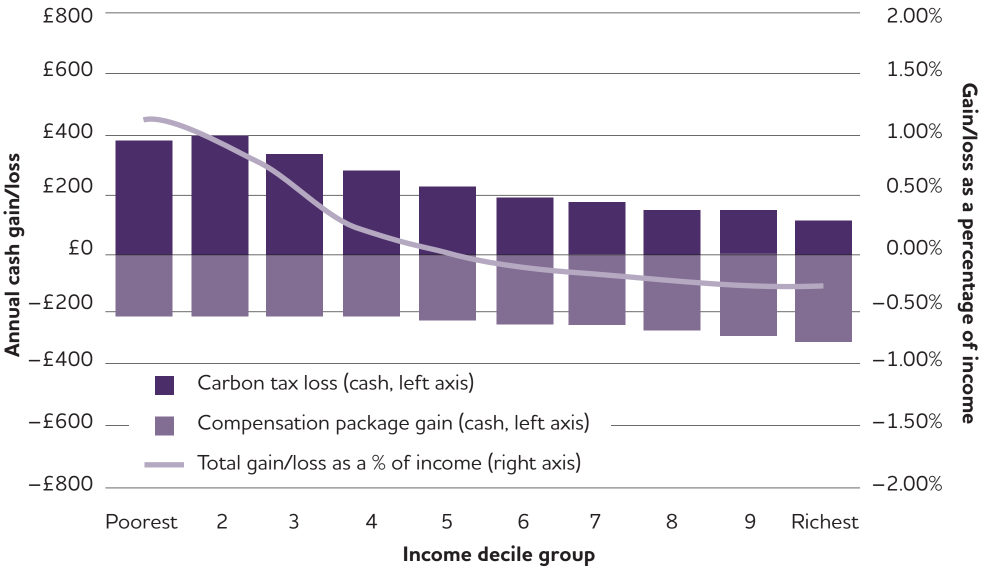
By contrast, as shown in Figure 3, the larger amount of revenue enables increases in Universal Credit and Pension Credit similar in size to the gains wealthier households receive from the increase in the Income Tax Personal Allowance, with the effect that on average households on lower incomes gain quite significantly. Revenue neutrality means that this gain is balanced by average losses in higher-income households, although because their incomes are much higher the losses are much smaller as a percentage of their incomes.

In Figure 4, lower-income households again gain on average. Because the revenues from the package shown in Figure 4 are smaller than in the previous package, the average gains and losses are smaller than those shown in Figure 3.

In Figure 5, lower-income households again gain on average. Because the package is bigger than in the preceding scenarios, the average gains and losses are greater.

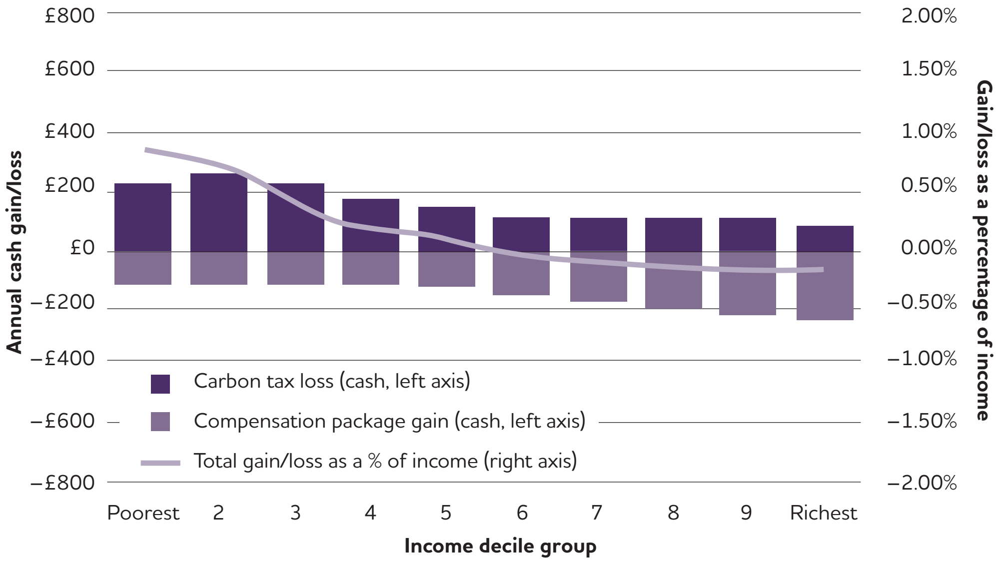
The small carbon tax without transport and its associated compensation package (shown in Figure 2) has a very different overall distributional impact to the other variants and their compensation packages because, as explained above, low-income households that do not pay tax gain no benefit from the increased personal income tax allowance, leaving little revenue to increase benefits. The reason for this is that the first package was designed to first achieve the stated government policy of increasing the Income Tax Personal Allowance to £10,000 a year, which left very little money over for benefit increases. However, it would of course be possible to design a compensation package for this measure that did not involve increasing the personal allowance and instead increased means-tested benefits: Figure 6 shows the impact of such a policy. However, in the remainder of the analysis in this and the following chapter, we retain the compensation package described in Table 4 and analysed in Figure 2.[21]

Figure 3: Distributional impact of CPF on gas and unmetered fuels and increased VAT on household energy (large carbon tax without transport) with associated compensation package



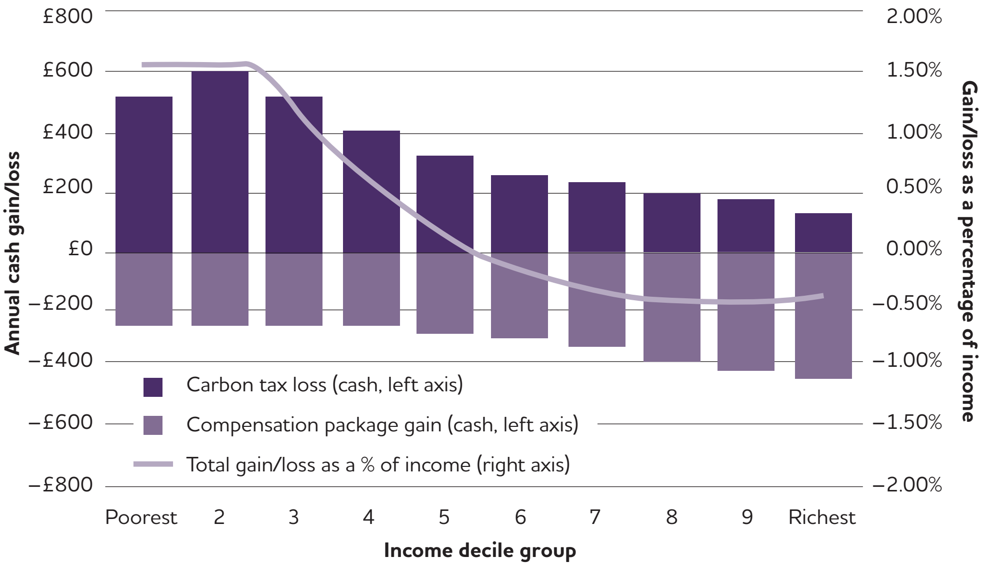
Notes and sources: as for Figure 2.

Figure 4: Distributional impact of CPF on gas, non-metered fuels and transport (small carbon tax with transport) and associated compensation package



Notes and sources: as for Figure 2

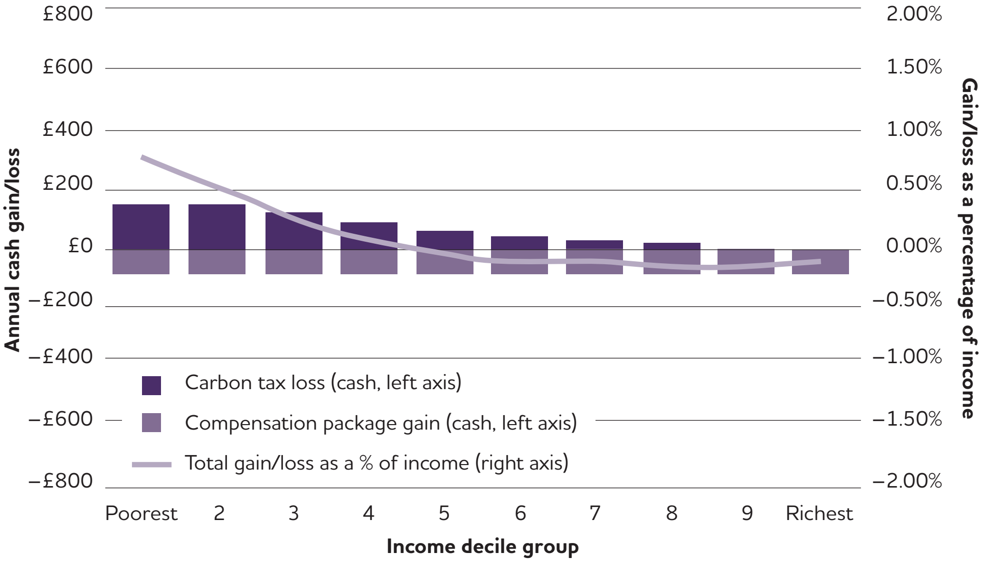
Figure 5: Distributional impact of CPF on gas, non-metered fuels and transport and increased VAT on household energy (large carbon tax with transport) and associated compensation package



Notes and sources: as for Figure 2

In Figure 6, the distributional outcome is similar to those shown in Figures 3–5, with low-income deciles gaining on average. Because the revenue is less than in the other scenarios, the average gains and losses are smaller too.

Figure 6: Distributional impact of small carbon tax without transport and more progressive compensation package



Notes and sources: as for Figure 2

Figures 2–5 show the average gain or loss by income decile from each of the carbon taxes and their associated compensation packages. However, as shown below, there are winners and losers from each overall package within each income decile group. In Figures 7–10, we show the proportion of each income decile group that gains or loses from the combined effects of each carbon tax and its associated compensation package. Following standard practice in IFS analysis, we include a 'broadly unaffected' category for those households who gain or lose less than one pound per week (£52 per year) as a combined result of the carbon tax and compensation package (see Box 1 for full details).

Box 1: Defining winners and losers

Overall gain or loss = compensation package gain minus carbon tax

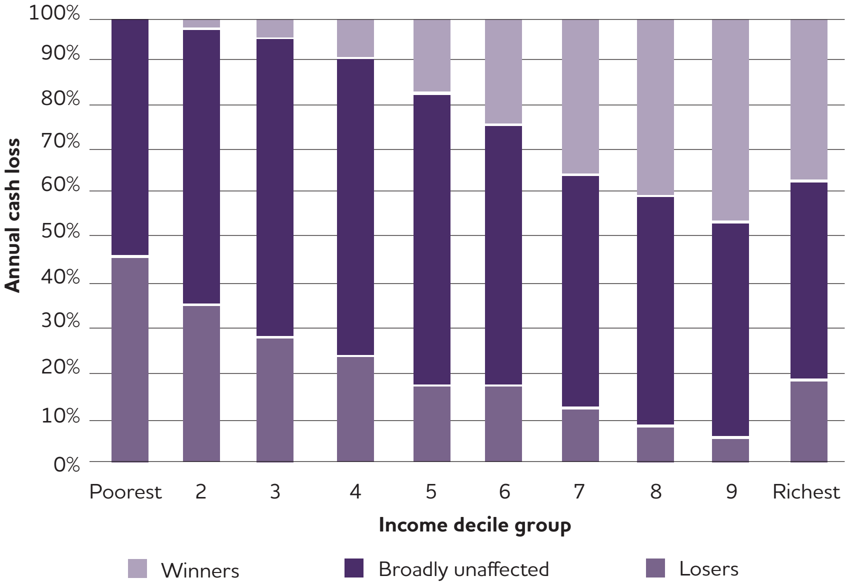
Winners = overall gain of at least £52 per year

Broadly unaffected = overall gain or loss less than £52 per year

Losers = overall loss of at least £52 per year

In Figure 7, the small carbon tax without transport (CPF on gas and non-metered fuels only) is relatively small in magnitude, so relatively few households are affected by more than one pound per week. Even those who lose by more than this in low-income deciles do not lose much more. Losers are predominantly found in lower-income groups – this is because, as explained previously, these groups gain little from the increase in the Income Tax Personal Allowance that forms the majority of the compensation package for the small carbon tax without transport.

Figure 7: Winners and losers by income decile from CPF on gas and unmetered fuels (small carbon tax without transport) and associated compensation package

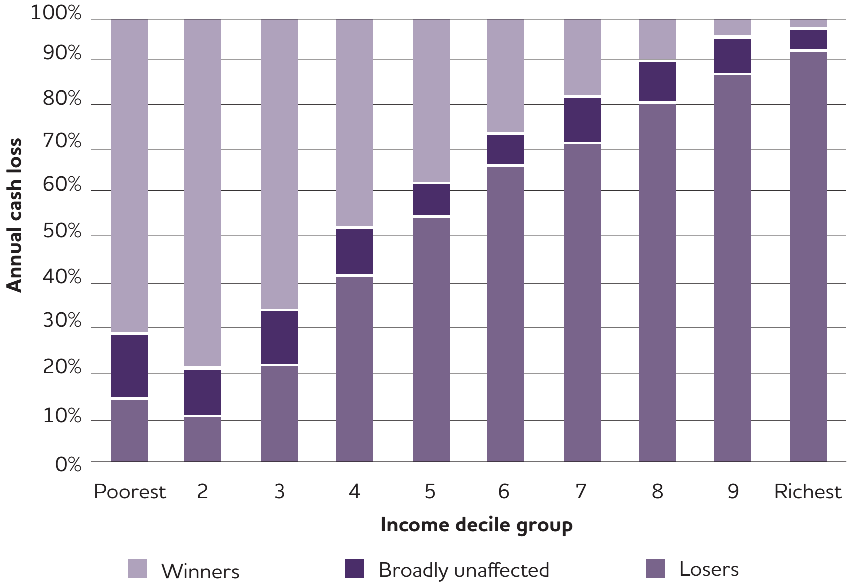


Notes and sources: as for Figure 2

The other tax scenarios and their associated compensation packages have relatively fewer households who are broadly unaffected. Most low-income households gain from these packages, and most high-income households lose. As the compensation packages are deliberately skewed towards lower-income households, this is unsurprising. Despite this, however, the compensation packages do not eliminate low-income losers completely, demonstrating how difficult it is to completely compensate all low-income households when a carbon tax is introduced.

In Figure 8, it can be seen that most low-income households gain and most high-income households lose, while fewer households are broadly unaffected.

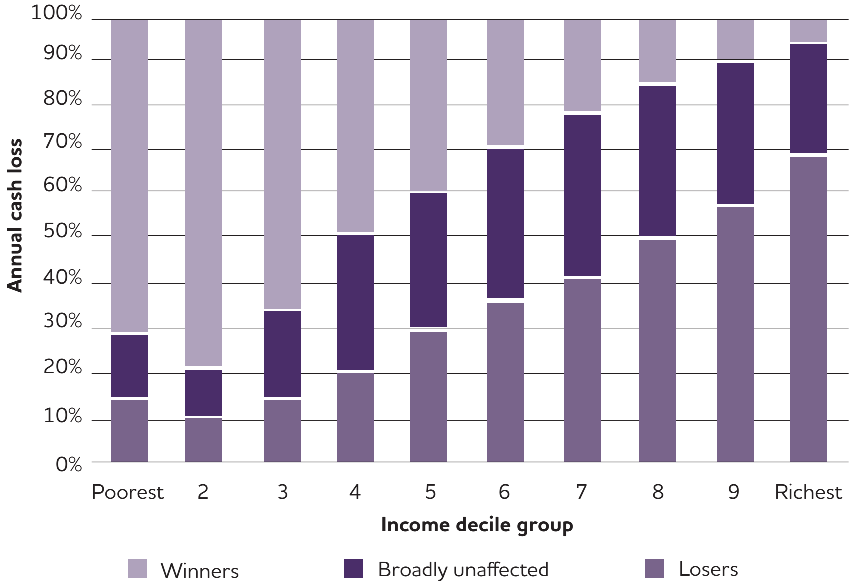
Figure 8: Winners and losers by income decile from large carbon tax without transport and associated compensation package



Notes and sources: as for Figure 2

In Figure 9, too, most low-income households gain and most high-income households lose.

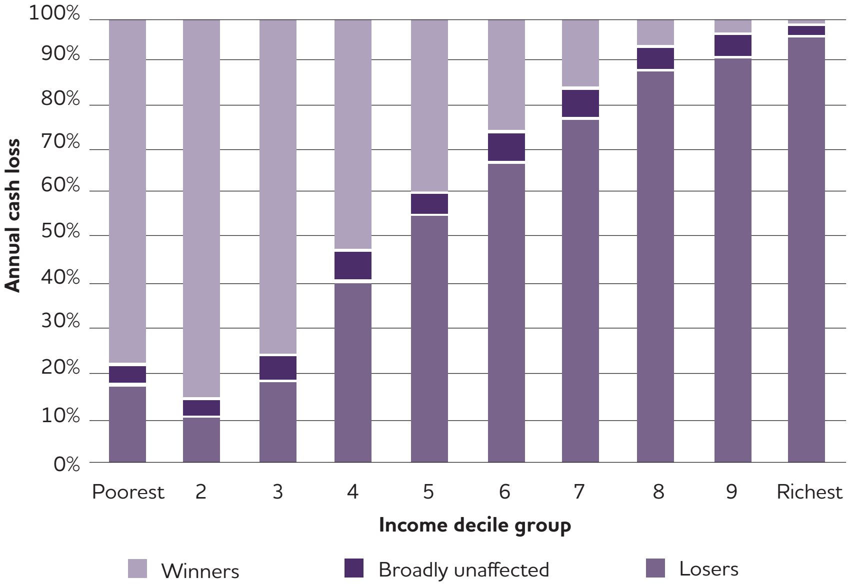
Figure 9: Winners and losers by income decile from small carbon tax with transport and associated compensation package



Notes and sources: as for Figure 2

In Figure 10, a very similar pattern is seen: most low-income households gain and most high-income households lose.

Figure 10: Winners and losers by income decile from large carbon tax with transport and associated compensation package



Notes and sources: as for Figure 2

Conclusion

This chapter has shown that it is possible to use the revenue from a carbon tax to compensate low-income households for the carbon tax payments they have to make in a way that leaves lower-income groups better off overall (and higher-income groups worse off overall) on average. However, it is not possible to eliminate low-income losers completely although, as the next chapter demonstrates, almost all of those entitled to Universal Credit do not lose out overall from the introduction of the large carbon tax. The relatively few low-income households that *do* lose out are usually not entitled to benefits. In some cases this is because they have considerable savings or other assets which mean that they are not entitled to Universal Credit, perhaps suggesting that they have only a temporarily low income. In others, it is because they are households of students, who are generally not entitled to benefits.

The next chapter discusses the characteristics of the winners and losers from the carbon taxes in more detail.

This chapter has shown that it is possible to use the revenue from a carbon tax to compensate low-income households for the carbon tax payments they have to make in a way that leaves lower-income groups better off overall (and higher-income groups worse off overall) on average.

5 WINNERS AND LOSERS

The outputs of TAXBEN were analysed to explore the distributional impacts of the different carbon pricing scenarios and compensation packages. Given the marginal difference between the two policy scenarios (i.e. the ‘limited policy’ scenario that only included those policies where the costs and outputs were already fairly certain, and the ‘all policy’ scenario that had to make assumptions about the effects of other policies – see Chapter 3) only the ‘all policy’ scenario results have been analysed.

Households are categorised as ‘winners’, ‘losers’ or ‘broadly unaffected’ according to the net impact (‘overall gain’) of the carbon tax and compensation packages (see Box 1 on page 26).

Overall winners and losers

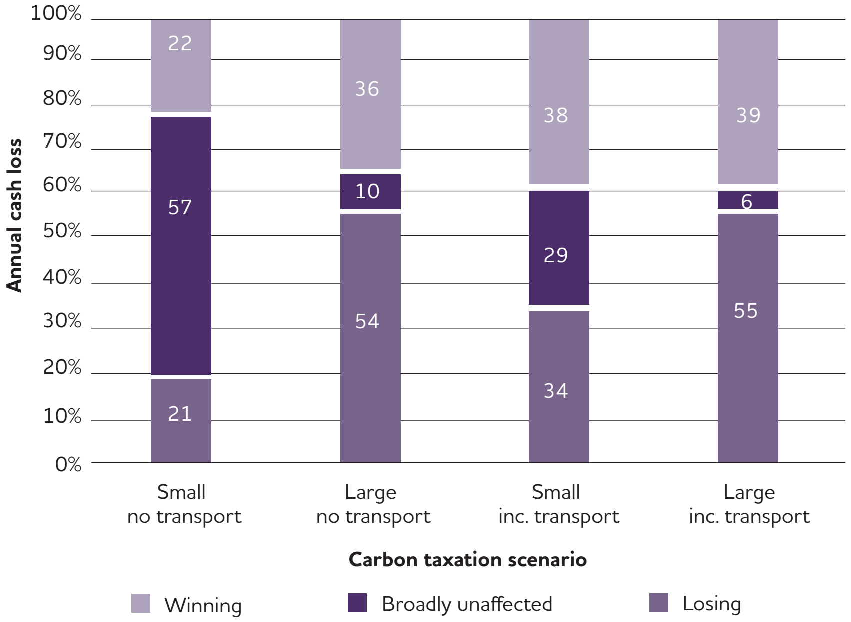
Applying the CPF to gas and non-metered fuels only (small carbon tax) and recycling the revenue through TAXBEN results in the majority of households (57%) being ’broadly unaffected’ (see Table 5). Furthermore, for those that are classed as winners or losers, the net change experienced is less than +/-£100 per year on average. The 2017 count is based on ONS projections for population and household numbers in that year.

However, combining this carbon taxation scenario with a change in the VAT rate (but still excluding transport) presents a very different result, with over half of all households now appearing worse off (see Table 5 and Figure 11); the average annual net loss is much greater, at just under £170. There is a simultaneous increase in the number of households considered to be winning, however, and the mean annual net gain they experience under this scenario is notably higher, at nearly £250 (see Table 5).

Table 5: Winners and losers under all carbon taxation scenarios (weighted for 2017 household count)

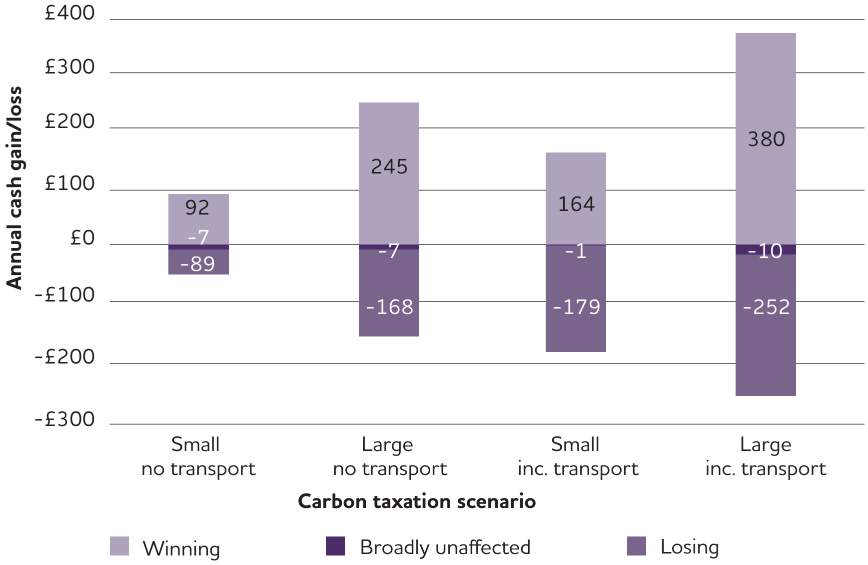
Carbon taxation scenario		Count	%	Mean 'net gain'
Small CT non-transport (CPF on gas & non-metered fuels only)	Loser	5,944,162	21%	-£79
	Broadly unaffected	15,962,165	57%	-£8
	Winner	6,191,192	22%	£92
Large CT non-transport (CPF on gas & non-metered fuels & VAT rate change)	Loser	15,178,303	54%	-£168
	Broadly unaffected	2,766,088	10%	-£7
	Winner	10,153,128	36%	£245
Small CT inc. transport (CPF on gas and transport)	Loser	9,473,495	34%	-£175
	Broadly unaffected	8,028,923	29%	-£1
	Winner	10,595,101	38%	£164
Large CT inc. transport (CPF on gas and transport & VAT rate change)	Loser	15,552,388	55%	-£262
	Broadly unaffected	1,607,874	6%	-£10
	Winner	10,937,257	39%	£380

Figure 11: Proportion of households winning and losing overall under each carbon tax scenario



This pattern of results under the small and large CT scenarios continues when transport emissions are included (see Figure 12). The maximum taxation scenario modelled here – CPF on gas, non-metered fuels and transport, and a change in the VAT rate to 20% – suggests that over half of households will experience a net loss overall, of over £260 a year on average, while just under two-fifths (39%) would stand to win, with an average net annual gain of £380.

Figure 12: Average net gain/loss of winning and losing households under each scenario



Distributional impacts

By income decile

The average annual amount of tax paid by the different income groups under each of the modelled scenarios is shown below in Figure 13. The pattern mirrors that of the distribution of household and transport emissions – i.e.

Figure 13: Mean annual carbon tax paid under each scenario by disposable equivalised income decile

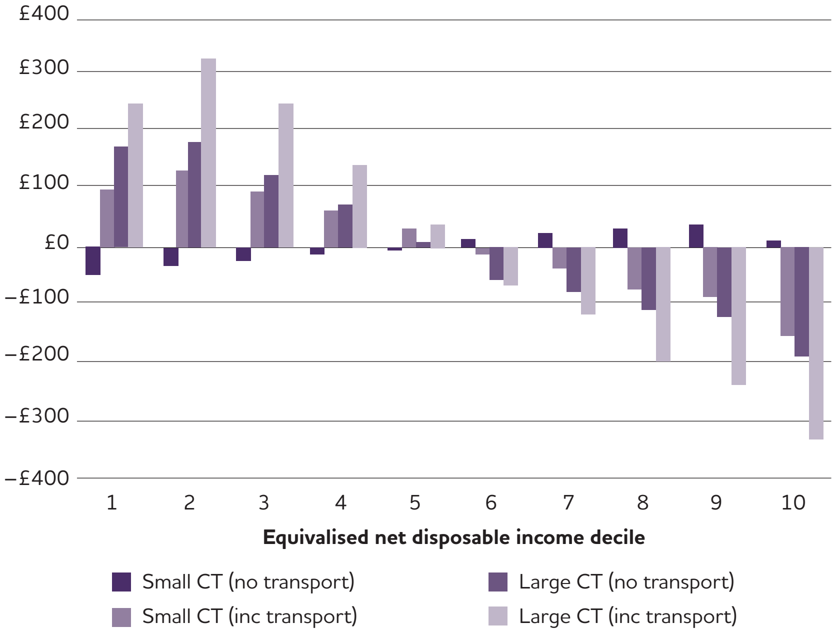
the lowest-income groups emit, and therefore pay, the least on average. Including transport in the carbon tax notably strengthens the trend of an increasing amount of tax paid from the poorest to the richest decile group (because the higher-income groups have notably higher transport emissions).

However, under the small carbon tax without transport scenario, while the lowest income groups pay the least in carbon tax on average, the impact of the compensation packages is limited (due to the limited revenue raised under this scenario) to the extent that the lowest four deciles experience an overall average net loss (see Figure 14), albeit this loss is less than £50 per year on average which is why the vast majority of households under this scenario are 'broadly unaffected' (see Table 5).

Including transport and both of the large carbon taxation scenarios reverses this trend: under these scenarios revenue raised through the taxation is higher, enabling the funding of compensation packages sufficient to 'protect' low-income households from the tax burden. As such, the lower-income deciles experience an overall net gain on average, while the higher-income deciles experience a net loss (see Figure 14).

Including transport and both of the large carbon taxation scenarios reverses this trend: under these scenarios revenue raised through the taxation is higher, enabling the funding of compensation packages sufficient to 'protect' low-income households from the tax burden.

Figure 14: Mean annual net gain/loss under each scenario with compensation by equivalised income decile



The overall proportion of winners/losers, the distribution of average annual carbon tax and net gain/loss by income decile shown above masks much within-decile variation (see Table 6 and Figures 15–18). For example, while overall the majority of households are 'broadly unaffected' under the small carbon tax (without transport) – and indeed this scenario has the lowest proportion of losing households of all the scenarios modelled – the distribution of winners and losers by income decile presents a regressive picture (see Figure 15): around 40% of the lowest decile is classed as losing, while a similar proportion of the upper-income deciles is classed as winning (albeit by little more than £100 per year on average).

Table 6: Proportion of winners and losers by income decile under each scenario

	Small CT no transport			Large CT no transport		
	Loser %	**Broadly unaffected %**	**Winner %**	**Loser %**	**Broadly unaffected %**	**Winner %**
1	45	54	1	15	13	**72**
2	33	65	2	11	11	**78**
3	29	66	5	22	12	**66**
4	25	66	9	43	9	**49**
5	17	66	17	54	8	38
6	16	59	25	66	9	25
7	13	52	36	71	10	18
8	9	49	42	80	11	9
9	6	47	46	86	10	4
10	19	44	37	92	7	1
Total	**21**	**57**	**22**	**54**	**10**	**36**

	Small CT with transport			Large CT with transport		
	Loser %	**Broadly unaffected %**	**Winner %**	**Loser**	**Broadly unaffected %**	**Winner %**
1	14	17	6	15	6	79
2	8	16	76	10	4	86
3	14	22	64	19	6	75
4	21	31	48	40	7	53
5	29	31	39	54	6	40
6	36	36	28	67	7	26
7	41	36	23	76	6	18
8	49	36	14	85	6	9
9	56	33	11	91	5	4
10	68	26	5	96	3	1
Total	**34**	**29**	**38**	**55**	**6**	**39**

Figure 15: Proportion of winners and losers (left axis) and mean net gain (for winners) and loss (for losers) (right axis): Small CT no transport

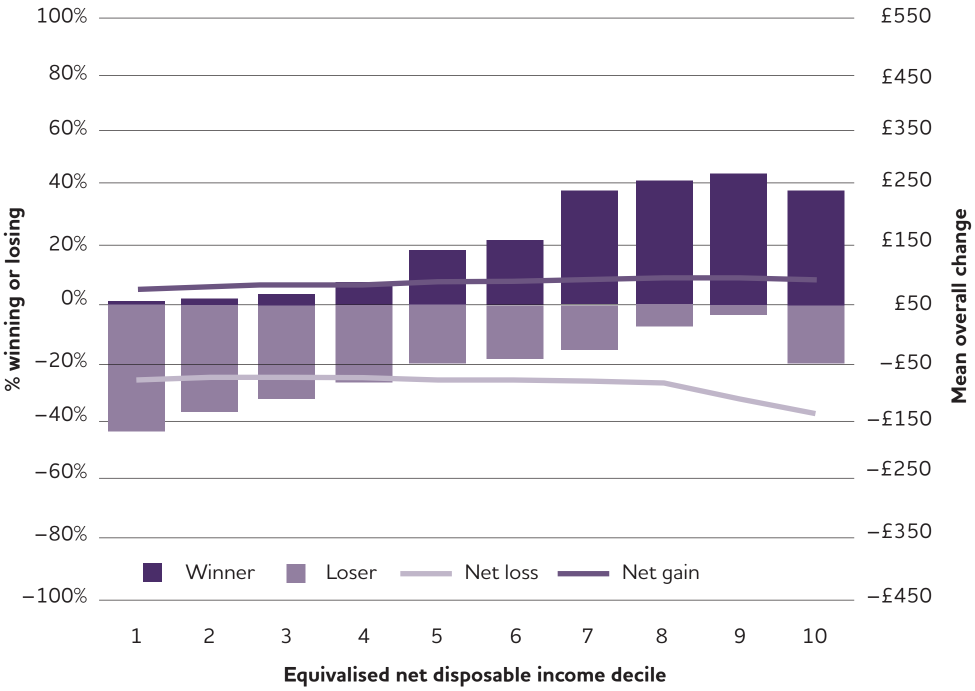


Figure 16: Proportion of winners and losers (left axis) and mean net gain (for winners) and loss (for losers) (right axis): Large CT no transport

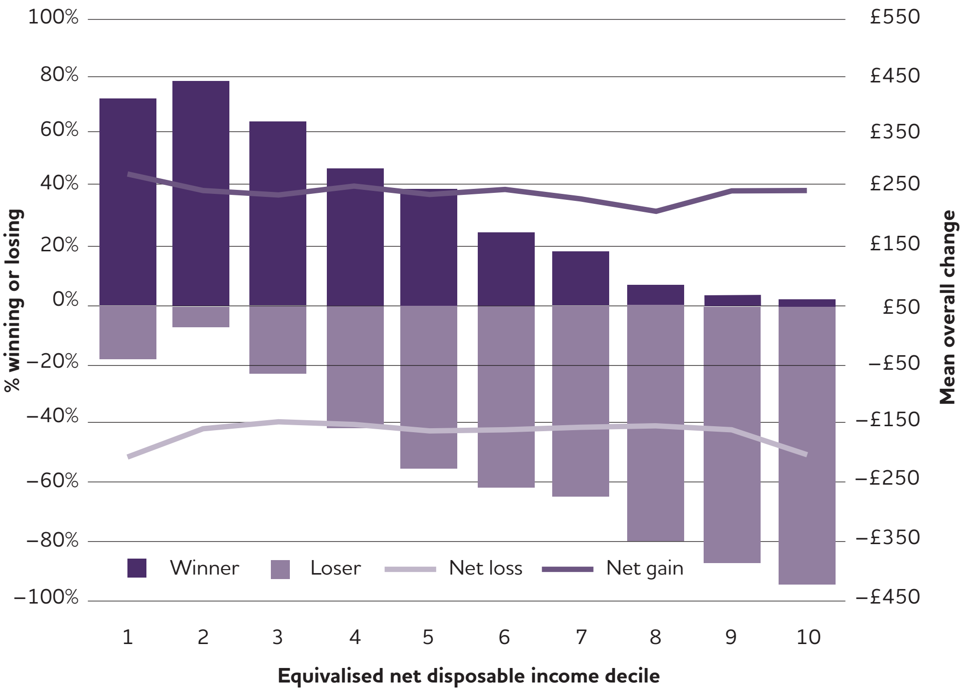
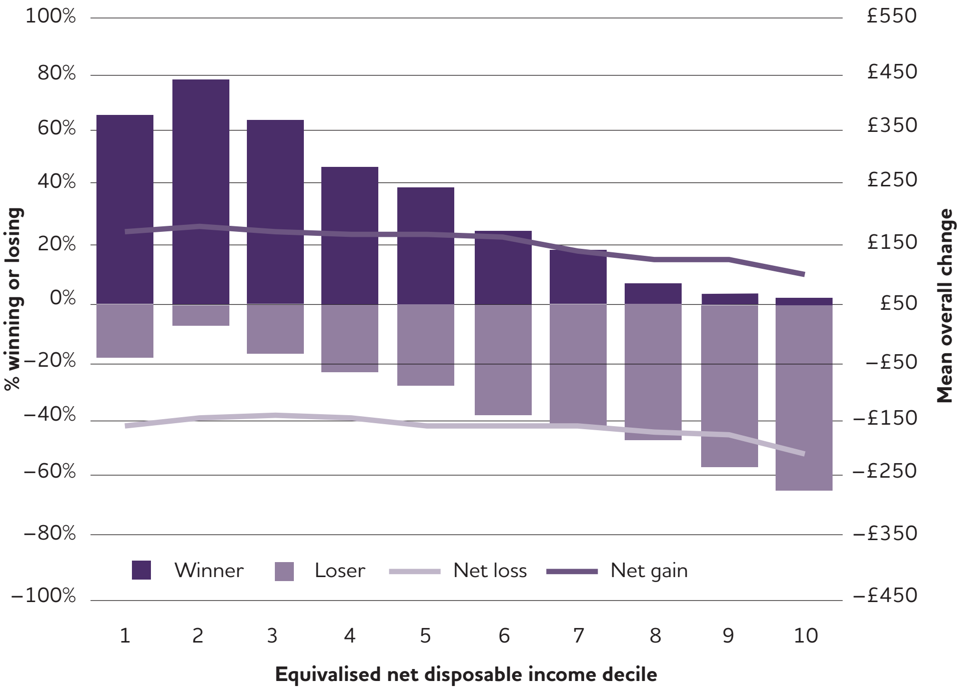
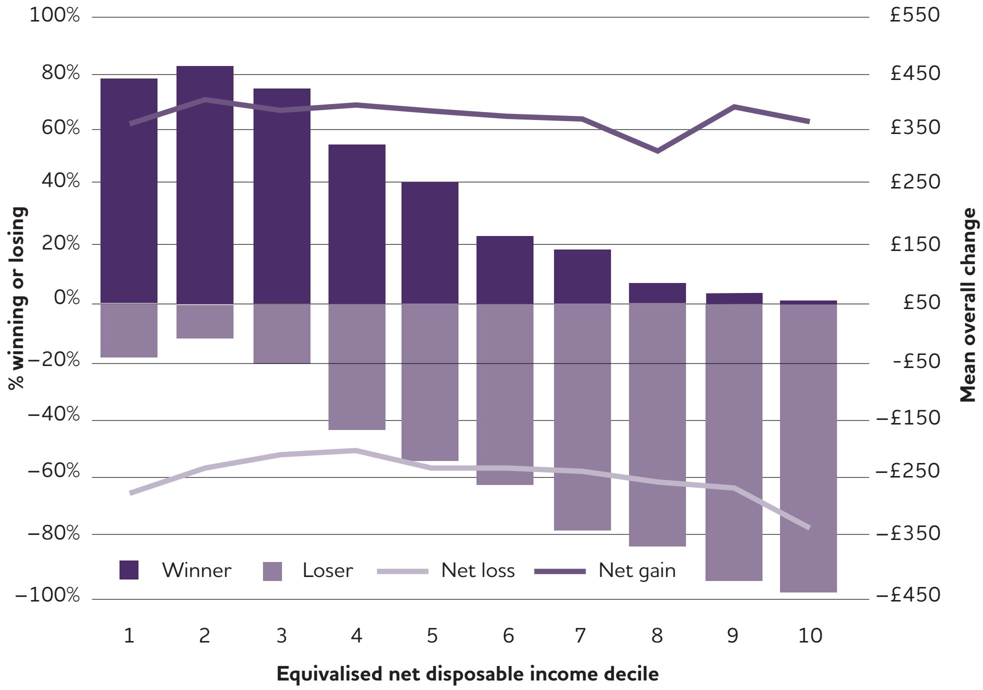


Figure 17: Proportion of winners and losers (left axis) and mean net gain (for winners) and loss (for losers) (right axis): Small CT with transport



With compensation packages applied under the large carbon tax with transport scenario, the results appear highly progressive. The majority of low-income households appear to be winning under this scenario, and by some £350 a year on average, while the majority of households in the upper-income deciles lose by a similar amount (see Figure 18).

Figure 18: Proportion of winners and losers (left axis) and mean net gain (for winners) and loss (for losers) (right axis): Large CT with transport



Results by other socio-demographics

Figures 19–26 show (for four different socio-demographic descriptors:[22] tenure, dwelling type, age of Household Reference Person (HRP) and household composition):

- Mean annual carbon tax paid (left hand axis, bars) against mean annual household emissions (right-hand axis, lines) from household fuels and all sources respectively (left-hand graph); and
- Mean net gain/loss when the revenue from the carbon tax is used to distribute a compensation package (right-hand graph).

This shows that, on the whole, the higher carbon-tax payers (i.e. the higher-emitting households) experience a net financial loss on average, while low-emitting groups experience an average net gain. However, the overall 'average' picture masks much variation within these groups. This is illustrated by the pattern within tenures and dwelling types (see Figures 19–22). For example, properties owned outright appear as the second-highest-taxed group, but experience less than a £50 net loss on average, suggesting many of these high-emitting households are receiving compensation. The impact on social tenants is likely to be a factor of both their lower income levels and their eligibility for compensation, and to reflect the fact that social housing typically has higher levels of energy efficiency (due to regulatory requirements such as the Decent Homes standard), affording some protection from a carbon tax on household emissions.

Similarly, semi-detached houses have the second-highest average carbon tax, but their average net change is negligible. This suggests that there is much variation in the level of compensation received within this household type – i.e. that the high rate of tax paid by some semi-detached households is 'cancelled out' by the level of compensation received by others, reflecting the different incomes, socio-economic status, number of occupants etc. within this broad housing category.

Figure 19: Mean annual carbon tax by tenure

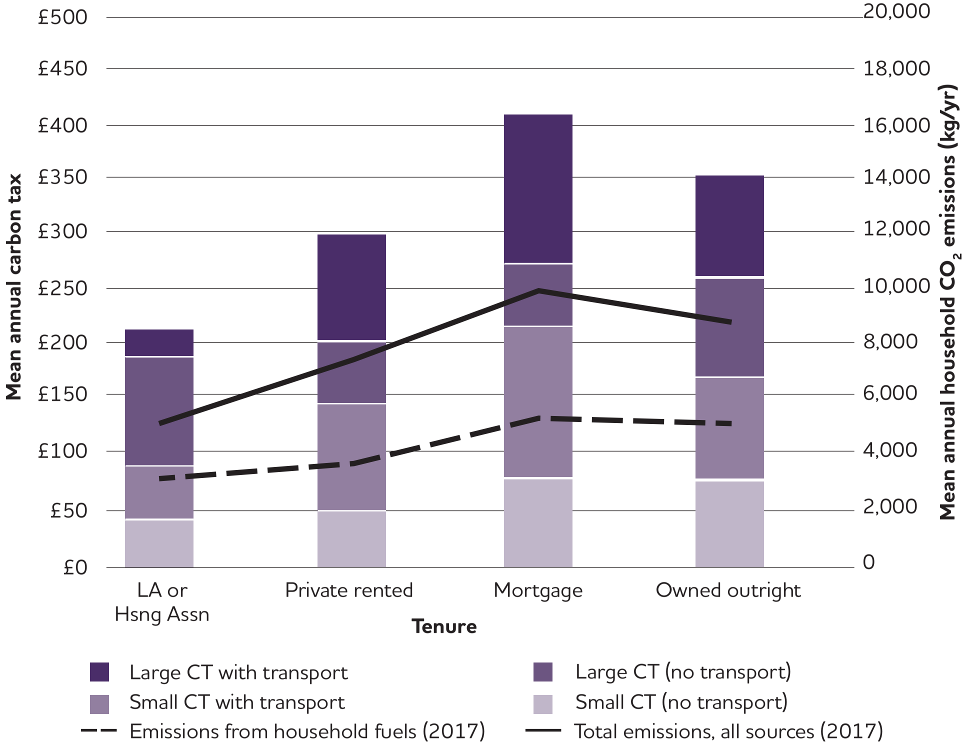


Figure 20: Mean net gain/loss by tenure

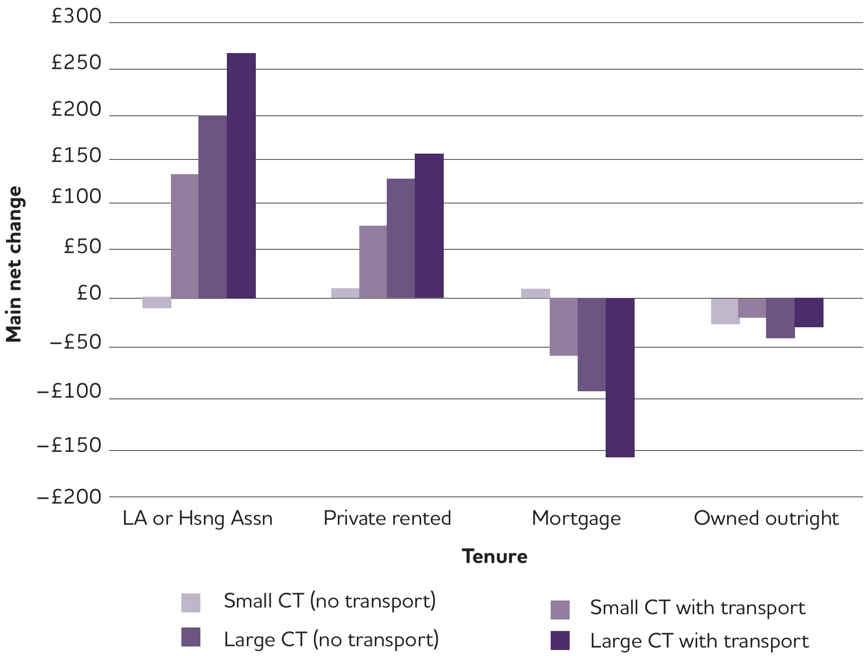


Figure 21: Mean annual carbon tax by dwelling type

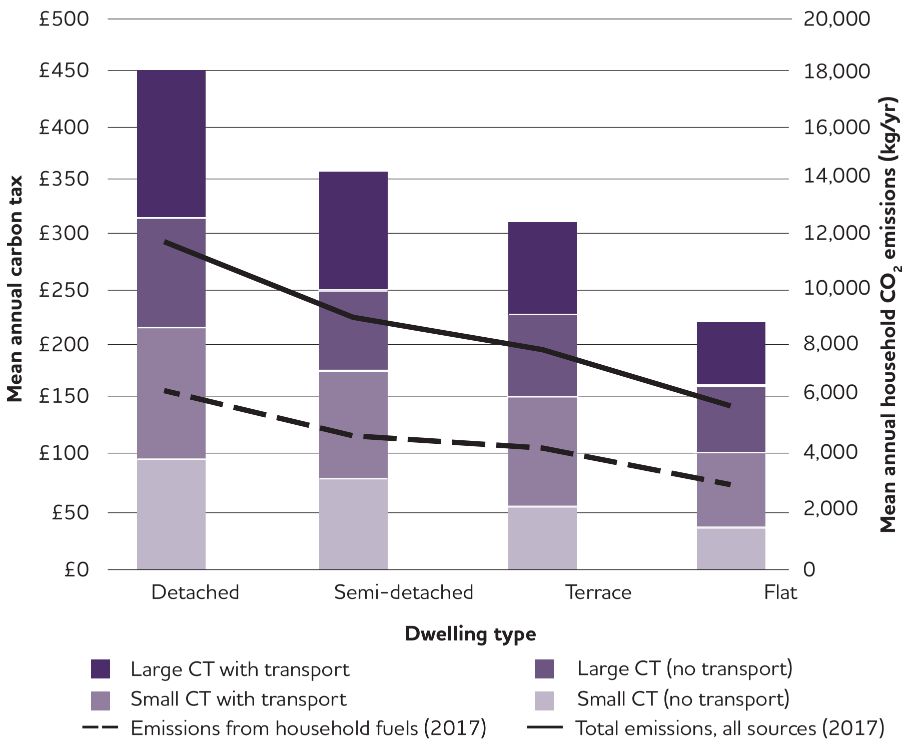


Figure 22: Mean net gain/loss by dwelling type

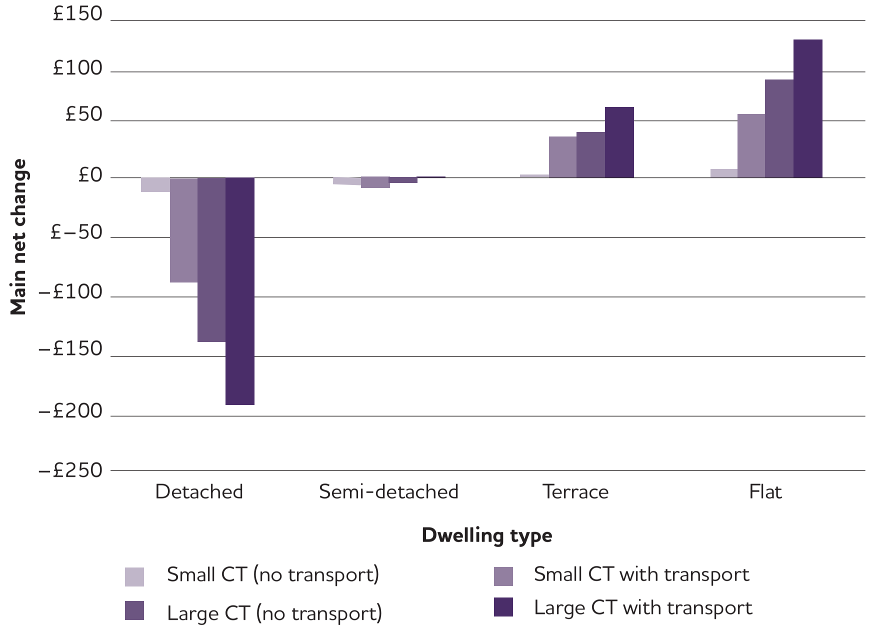


Figure 23: Mean annual carbon tax by age of HRP

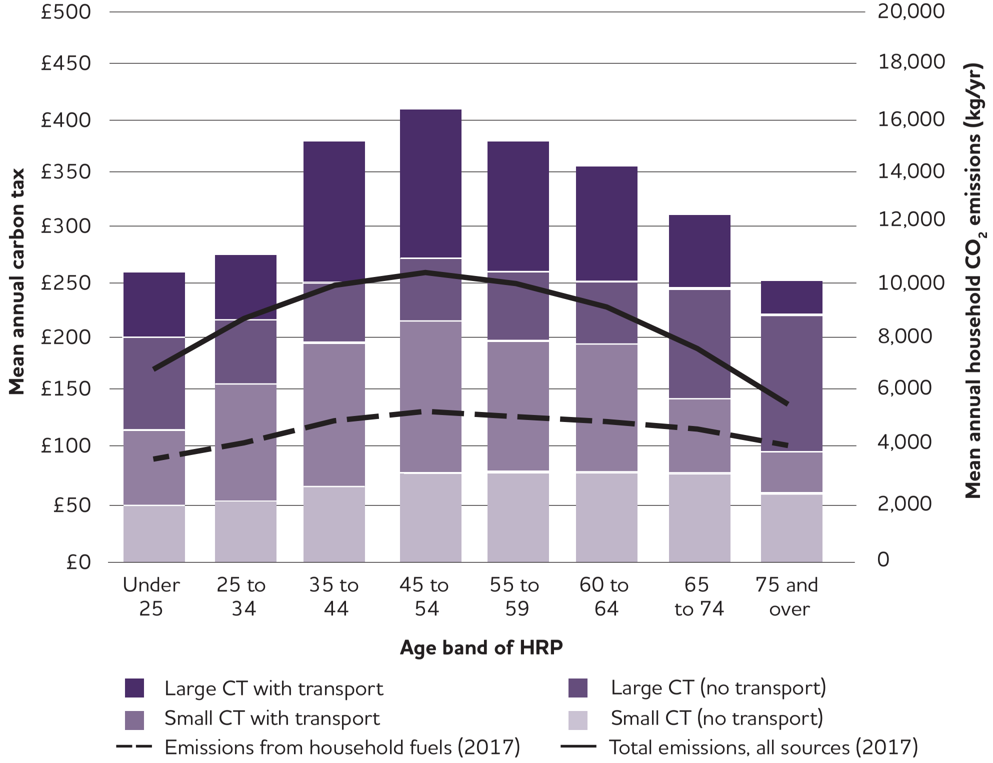


Figure 24: Mean net gain/loss by age of HRP

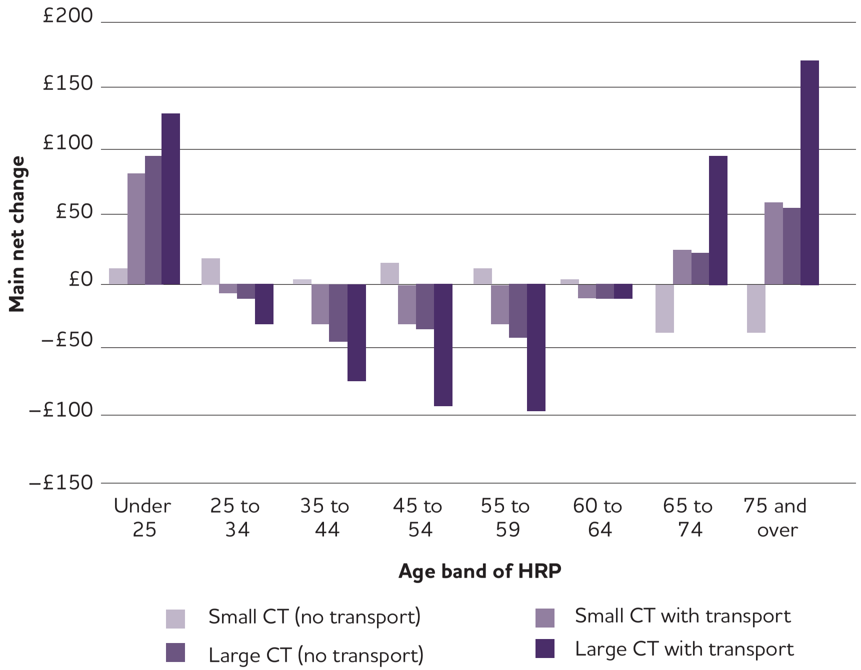


Figure 25: Mean annual carbon tax by household type

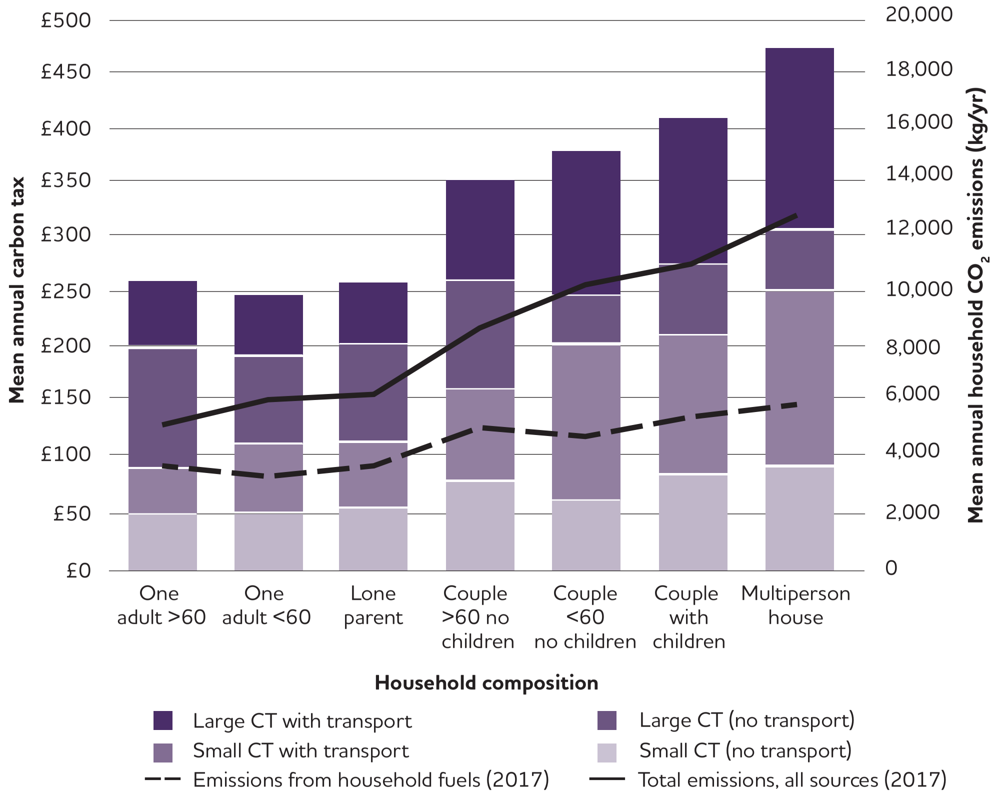
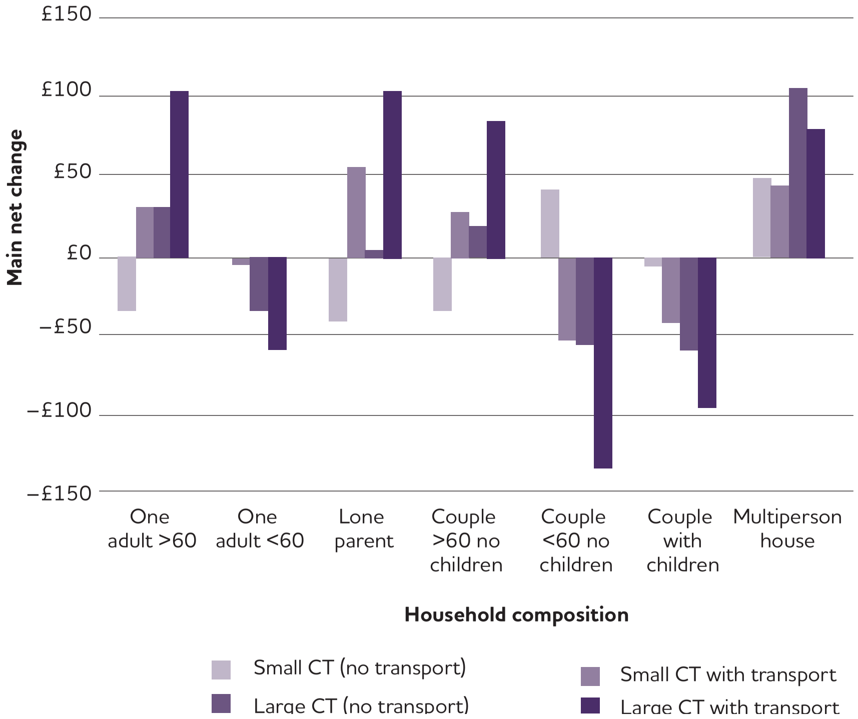


Figure 26: Mean net gain/loss by household type



Conclusion

Table 6 provides an overview of the impact of the four taxation scenarios by income deciles. The small carbon tax with transport has the highest proportion of households that are winners or broadly unaffected (67%), which may provide a rationale for its implementation over the others. However, compared to the large carbon tax without transport there are lower proportions of low-income households winning in the bottom four deciles. Transport is already heavily taxed, and adding a further level of taxation to petrol and diesel is almost certain to be politically unacceptable, despite the proven ability of the tax and benefits system to compensate low-income households.

The analysis by different socio-demographic variables presented gives an indication of the distributional impacts of the carbon taxation scenarios. In particular, the scenarios generally result in significant increases in energy costs for families living in larger properties that they themselves own. Lone parents and single elderly people tend to gain from the scenarios, which is likely to be politically acceptable as they are a key group of concern in terms of fuel poverty.

6 DETAILED CHARACTERISATION OF WINNERS AND LOSERS

The previous chapter highlighted how the average annual carbon tax may mask within-group variations. This chapter seeks to explore and identify defining characteristics of key winning and losing groups of households to help clarify the key factors in assessing where compensation is needed.

The Chi-squared Automatic Interaction Detector (CHAID) is a classification method which seeks to differentiate categorical 'predictor' variables with respect to their influence upon a single dependent variable – in this case the categorical variable representing 'overall gain' (see Box 1, page 26). This results in clusters, or 'nodes', of cases with similar defining characteristics to which a predicted value for the dependent variable is assigned. This method can enable grouping characteristics to be identified among winners and losers.

CHAID analysis has the advantage that it enables more detailed scrutiny of the socio-demographics of households in each category, while maintaining a sufficient number of cases (set at 200 in the normally weighted dataset) to give reliable estimates of values.

Four different CHAID models are run here, where the dependent variable being modelled is the proportion of 'winners', 'losers' and those 'broadly unaffected' under each of the carbon taxation and compensation package scenarios modelled.

Small carbon tax without transport scenario

This taxation scenario raises some £1.9 billion. The compensation package includes: an increase in personal allowance to £10,000; no increase in Universal Credit; an increase in pension credit by £15 for both singles and couples; and an increase in the State Pension by £15 per year (see Table 4).

Running CHAID analysis on the results of the small carbon taxation (without transport) scenario (CPF on gas and non-metered fuels only) correctly identifies 66% of cases (see Table 7), to give a total count of 4.3 million losing households (compared to the actual count of 5.9 million). Predictor variables used in the model (i.e. variables that the model identified as having a statistically significant difference with respect to the dependent variable) are shown in Box 2.

Table 7: Results of CHAID on small carbon tax without transport scenario outputs

		Predicted			
		Loser	**No overall change**	**Winner**	***Percent Correct***
Observed	**Loser**	2,425,298	3,153,895	364,121	*41%*
	No overall change	1,919,390	11,792,569	2,251,054	*74%*
	Winner	66,272	1,801,640	4,323,280	*70%*
	Overall Percentage	*16%*	*60%*	*25%*	***66%***

Box 2: Variables selected as predictors in the CHAID model on small carbon tax without transport scenario outputs

- Household composition
- Universal Credit recipient
- Tenure
- Category of dwelling
- Number of children
- Heating fuel,
- Age of HRP (banded)
- Sex of HRP
- Govt. Office Region
- Number of adults

Cross-tabulating the nodes created in the CHAID analysis with socio-demographic variables in the LCF dataset helps to identify the underlying drivers for winning and losing under the small carbon taxation (without transport) scenario. Table 8 summarises the key characteristics of the most significant winners and losers (i.e. the nodes with the highest or lowest mean overall gain respectively). More detailed descriptions of each group are included in Appendix 1 (see http://www.psi.org.uk/index.php/site/project_detail/419).

Summary of losing nodes

The most significant losing nodes are: working couples with children, on Universal Credit; lone parents in medium-sized gas-heated houses, eligible for Universal Credit; low-income single elderly people in smaller detached houses in more rural areas, not eligible for Universal Credit; elderly couples without children who own their home outright, not on Universal

Table 8: Summary of key characteristics of most significant winning and losing nodes under the small carbon tax without transport scenario

Node	UK average	Highest Losing Nodes						Highest Winning Nodes				
		27	53	32	78	17, 70	31	45, 56	49	72	73, 75	47
Count of HHs	***28,097,519***	837,304	519,310	358,962	672,564	1,443,639	427,779	1,266,688	497,389	519,820	1,397,147	877,074
Mean net gain/loss	***-£0.68***	-£56	-£54	-£51	-£49	-£44	-£46	£92	£77	£62	£53	£55
Annual equivalised disposable income	***£35,319***	£19,083	£33,816	£26,190	£39,593	£31,982	£19,912	£37,993	£49,169	£43,899	£51,609	£45,791
Change % of income	***0.01%***	-0.29%	-0.16%	-0.20%	-0.12%	-0.14%	-0.23%	0.24%	0.16%	0.14%	0.10%	0.12%
Total trans. transport (tCO_2)	***3.9***	4.23	2.86	3.29	4.47	1.83	1.62	7.21	5.24	5.05	6.01	8.43
Total HH (tCO_2)	***5.2***	5.99	6.17	5.17	6.78	5.07	4.04	6.33	4.03	4.60	5.39	8.07
Total tCO_2	***9.1***	10.21	9.04	8.46	11.25	6.91	5.65	13.55	9.27	9.64	11.40	16.50
Transport CO_2% total	***43%***	41%	32%	39%	40%	27%	29%	53%	57%	52%	53%	51%
Adults	***Single 37%*** ***Couples 52%***	Couples	Couples	Single	Couples	Single	Single	HMOs	Couples	Couples	Couples	HMOs
Children	***No 73%***	Yes	No	Yes	No	No	Yes	–	No	No	No	–
Tenure	***Mort. 37%*** ***OO 32%*** ***Soc. 19%*** ***PRS 11%***	Mort.	OO	Mort.	OO	OO	Soc.	Mort. OO	Mort. PRS	Mort. OO	Mort. OO	
Dwelling	***Semi. 31%*** ***Terr. 27%*** ***Det. 21%*** ***PB 15%***	Terr. Semi	Det.	Terr. Semi	Det.	Det. Semi	Terr.	Terr. Semi	PB	Terr. Conv.	Terr. Semi	Det.
Sex HRP	***M 62%***	M	M	F	M	F	F	M	–	M	M	M
Age HRP	***<34 20%*** ***35–59 43%*** ***60–74 22%*** ***>74 15%***	25–44	>74	25–44	65–74	>64	25–34	45–59	<35	<60 (42% <34)	25–54	45–59
Heating fuel	***Gas 81%*** ***Elec. 13%***	Gas	Gas Oil	Gas	Gas Oil	Gas Oil	Gas	Gas	Gas Elec.	–	Gas	Gas
Income quintile		1	2	2	5	2	1	4	5	4	5	5
Bedrooms	***<3 38%*** ***3 46%*** ***>3 15%***	3	3–4	3	3–4	2–3	3	3	2–3	2–3	2–3	4–5
Rurality	***Urban 79%***	Urban	Less urban	Urban	Rural	Less urban	Urban	Urban	Ldn	–	–	Less urban
Employment	***FT 42%*** ***Ret. 29%*** ***NW 12%***	FT Self emp.	Ret.	NW PT	Ret.	Ret.	NW	FT	FT	FT	FT	FT Self emp.
UC	***24% No***	Yes	No	Yes	No	No	Yes	No	No	No	No	No
Transport CO_2 quintile		4	2	3-4	4	1	1	5	1	2	3–4	5
HH CO_2 quintile		3	3	3	4	2	1	5	5	5	5	5

Notes: HHs = households; Total trans. = total transport emissions; tCO_2 = tonnes of CO_2; Mort. = mortgaged; OO = owned outright; Soc. = social landlord (local authority or housing association); PRS = private rented sector; Semi = semi-detached; Det. = detached; Terr. = terraced; PB = purpose-built flat; Elec. = electric heating; FT = full time employment; Ret. = retired; NW = not working; PT = part time employment; UC = Universal Credit.

Credit; retired couples in larger detached houses in more rural areas who own their home outright, not eligible for Universal Credit; very low-income lone parents, not working, in medium-sized terraced local authority (LA)/ Housing Authority (HA) houses, eligible for Universal Credit; very low-income single middle-aged adults (under pension age), not working, in small urban terraced houses, private or LA rented, eligible for Universal Credit; and lower-income pensioner singles or couples in medium-sized houses with gas heating, mainly in urban areas. As already noted, these groups tend to lose because, as largely non-taxpayers, they do not benefit from the increased personal income tax allowances which are the main form of recycling the carbon tax revenues in this scenario, there being only a small increase in the pension and no increase in Universal Credit. Although none of these groups loses on average more than £55 per year, many of them are in the groups categorised as 'vulnerable to fuel poverty' and as such even small increases would therefore be a cause of concern to be addressed through other measures if possible. This is considered in Chapter 7.

Summary of winning nodes

CHAID designated 11 different nodes entirely as winning (some 6.9 million households). Of these, seven have a mean annual net gain greater than £52 for the small carbon tax without transport scenario (and therefore are considered to be winning according to our definition). These groups are dominated by higher-income households, all of whom are likely to benefit from the changes to the personal income tax allowance. None of them are on Universal Credit, so they are broadly unaffected by the fact that this is unchanged in this scenario.

Large carbon tax without transport scenario

This taxation scenario raises some £6.9 billion. The compensation package includes: an increase in personal allowance to £10,000; an increase in Universal Credit amounts by £300 for singles, £200 for lone parents, £700 for couples without children and £300 for couples with children; an increase in pension credit by £300 for singles and £500 for couples; and an increase in the state pension by £70 per year.

Running CHAID analysis on the results of the large carbon taxation (without transport) scenario (CPF on gas and non-metered fuels and VAT rate change) correctly identifies 81% of cases (see Table 9), to give a total count of 17 million losing households (compared to the actual count of 15 million). Predictor variables used in the model (i.e. variables that the model identified as having a statistically significant difference with respect to the dependent variable) are shown in Box 3.

Table 9: Results of CHAID on large carbon tax (without transport) outputs

		Predicted			
		Loser	**Broadly unaffected**	**Winner**	***Percent Correct***
Observed	**Loser**	13,886,090	83,382	1,204,275	*92%*
	No overall change	1,489,153	382,340	897,000	*14%*
	Winner	1,536,017	243,140	8,376,122	*82%*
	Overall percentage	*60%*	*3%*	*37%*	***81%***

Box 3: Variables selected as predictors in the CHAID model on large carbon tax (without transport) outputs

- Universal Credit recipient
- Household composition
- Tenure
- Sex of HRP
- Number of children
- Category of dwelling
- Age of HRP (banded)
- Gas supply
- Number of adults

As in the analysis of the small carbon tax scenario above, cross-tabulating the nodes created by CHAID with socio-demographic variables in the LCF dataset helps to identify the underlying drivers for winning and losing under the second carbon taxation scenario. Table 10 summarises the key characteristics of the most significant winners and losers (i.e. the nodes with the highest or lowest mean overall gain respectively). More detailed descriptions of each group are included in Appendix 1 (see http://www.psi.org.uk/index.php/site/project_detail/419).

Summary of losing nodes

The most significant losing nodes for the large carbon tax without transport scenario (with an average annual net loss of around £150 to £250 across the node) are dominated by higher-income couples with or without children, in larger properties and not eligible for Universal Credit, but with high fuel bills and emissions – at least 70% of all these nodes are in emissions decile 6 and above. Being higher-income households, the fact that they are losing out is less of a concern from a social justice point of view, but would be a politically sensitive issue.

Summary of winning nodes

CHAID designated 19 different nodes entirely as winning households. Of these, 15 have a mean annual net gain greater than £100. Unlike under the small carbon tax without transport scenario, these winning groups are mainly lower-income households, all being eligible for Universal Credit. They are in urban areas and the majority have gas central heating.

Seven nodes appear as low emitters, four very notably. However, there are still some high-emitting households among the winners. Having gas central heating, they would be particularly impacted by the carbon taxation, but gain significantly from the increases to Universal Credit. The characteristics of these groups are described in more detail in Appendix 1 (see http://www.psi.org.uk/index.php/site/project_detail/419). As these pen portraits show, small, low-income and multi-person rented properties are common among the biggest winning nodes.

The multi-person characteristic may be apparent among winning households under the carbon tax scenario modelled here due to ‘economies of scale’ of household fuel consumption versus having several income/benefit units in the household. The additional tax paid due to slightly higher fuel consumption as a result of having one or more additional adults in the household is outweighed by the additional income/benefits which that individual brings. When transport is included in the carbon tax, this winning phenomenon associated with multi-person households may well disappear.

Table 10: Summary of key characteristics of most significant winning and losing nodes under the large carbon tax without transport scenario

Node	UK average	Highest Losing Nodes						Highest Winning Nodes					
		68, 30	37, 70	54, 52	61	67	71	8	7	47	24, 48	45	46
Count of HHs	***28,097,519***	1,157,400	1,333,904	834,323	396,045	447,386	767,468	371,164	693,407	386,733	1,043,871	576,179	386,721
Mean net gain/loss	***-£2.70***	-£246	-£201	-£179	-£181	-£181	-£160	£446	£417	£371	£328	£218	£185
Annual equivalised disposable income	***£35,319***	£44,798	£51,326	£35,900	£46,747	£44,008	£40,514	£21,271	£19,554	£28,705	£25,387	£21,008	£19,023
Change % of income	***0.01%***	-0.55%	-0.39%	-0.50%	-0.39%	-0.41%	-0.39%	2.10%	2.13%	1.29%	1.29%	1.04%	0.97%
Total trans. transport (tCO_2)	***3.9***	7.12	6.28	6.29	5.45	5.54	6.10	3.01	2.55	5.02	5.70	3.34	2.64
Total HH (tCO_2)	***5.2***	7.66	6.85	6.40	6.95	6.65	5.96	5.09	4.39	6.48	6.39	4.85	4.61
Total tCO_2	***9.1***	14.78	13.13	12.69	12.39	12.19	12.06	8.09	6.95	11.49	12.09	8.20	7.26
Transport CO_2% total	***43%***	48%	48%	50%	44%	45%	51%	37%	37%	44%	47%	41%	36%
Adults	***Single 37%*** ***Couples 52%***	Couples	Couples	Couples	Couples	Couples	Couples	Couples	Couples	HMOs	HMOs	Couples	Couples
Children	***No 73%***	Yes	No	Yes	No	Yes	Yes	No	No	No	Yes	Yes	Yes
Tenure	***Mort. 37%*** ***OO 32%*** ***Soc. 19%*** ***PRS 11%***	Mort.	Mort. OO	Mort.	OO	Mort.	Mort.	OO	Soc/PRS	PRS	Mixed – Mort. & Soc	Soc PRS	Soc
Dwelling	***Semi. 31%*** ***Terr. 27%*** ***Det. 21%*** ***PB 15%***	Det.	Det. Semi	Semi Terr.	Det.	Det. Semi	Semi Terr.	Semi Terr.	Flats	Terr.	Semi Terr.	Terr.	Terr.
Sex HRP	***M 62%***	M	M	M	M	M	M	–	M/F	M	M	M	F
Age HRP	***<34 20%*** ***35–59 43%*** ***60–74 22%*** ***>74 15%***	35–54	45–59	35–44	60–64	45–54	25–34	>60	<60	<25 or 55–50	35–44	25–44	<45
Heating fuel	***Gas 81%*** ***Elec. 13%***	Gas	Gas Oil	Gas	Gas Oil	Gas Oil	Gas	Gas	–	Gas	Gas	–	Gas
Income quintile		4–5	5	3	5	5	4	1	1	1	1	1	1
Bedrooms	***<3 38%*** ***3 46%*** ***>3 15%***	4–5	4	3	4	3–4	3–4	2–3	2	3–4	3	3	3
Rurality	***Urban 79%***	Less urban	Rural	–	Rural	–	Urban	Urban	Urban	Urban	Urban	Urban	Urban
Employment	***FT 42%*** ***Ret. 29%*** ***NW 12%***	FT	FT Self emp.	FT	NW PT	FT	FT	Ret. NW	NW Self emp.	NW Ret.	NW Self emp.	FT Self emp.	NW PT
UC	***24% No***	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Transport CO_2 quintile		5	5	5	5	5	5	1	2	4	5	2	1
HH CO_2 quintile		5	5	5	5	5	5	2	2	5	5	2	2

Notes: HHs = households; Total trans. = total transport emissions; tCO_2 = tonnes of CO_2; Mort. = mortgaged; OO = owned outright; Soc. = social landlord (local authority or housing association); PRS = private rented sector; Semi. = semi-detached; Det. = detached; Terr. = terraced; PB = purpose-built flat; Elec. = electric heating; FT = full time employment; Ret. = retired; NW = not working; PT = part time employment; Self-emp. = self-employed; UC = Universal Credit.

The characteristics of the biggest winning nodes under the large carbon tax (without transport) scenario are described in more detail in Appendix 1 (see http://www.psi.org.uk/index.php/site/project_detail/419).

Small carbon tax with transport scenario

This taxation scenario raises some £4.6 billion. The compensation package includes: an increase in personal allowance to £10,000; an increase in Universal Credit amounts by £160 for singles, £150 for lone parents, £325 for couples without children and £160 for couples with children; an increase in pension credit by £120 for singles and £300 for couples; and an increase in the state pension by £70 per year.

Predictor variables used in the CHAID model of the outputs for this taxation and compensation scenario (i.e. variables which the model identified as having a statistically significant difference with respect to the dependent variable) are shown in Box 4. Running CHAID analysis on these results correctly identifies 62% of cases (see Table 11), to give a total count of 7 million losing households (compared to the actual count of 9.5 million). Table 12 summarises the key characteristics of the most significant winners and losers (i.e. the nodes with the highest or lowest mean overall gain respectively). More detailed descriptions of each group are included in Appendix 1 (see http://www.psi.org.uk/index.php/site/project_detail/419).

Box 4: Variables selected as predictors in the CHAID model on small carbon tax with transport scenario outputs

- Universal Credit recipient
- Tenure
- Number of children
- Number of adults
- Household composition
- Government Office Region
- Category of dwelling
- Sex of HRP
- Age of HRP (banded)
- Heating fuel
- Gas supply

Table 11: Results of CHAID small carbon tax with transport scenario outputs

		Predicted			
		Loser	**Broadly unaffected**	**Winner**	***Percent Correct***
Observed	**Loser**	7,107,803	1,489,980	875,712	*75%*
	No overall change	4,065,651	1,810,904	2,152,368	*23%*
	Winner	1,061,044	1,099,740	8,434,317	*80%*
	Overall percentage	*44%*	*16%*	*41%*	***62%***

Table 12: Summary of key characteristics of most significant winning and losing nodes under the small carbon tax with transport scenario

Node	**UK average**	**Highest Losing Nodes**						**Highest Winning Nodes**					
		31	74	41	57	75	77	49	50	22	20	53	17 & 16
Count of HHs	***28,097,519***	703,036	457,449	597,531	440,187	701,599	761,842	495,504	441,822	539,417	386,448	381,269	1,176,756
Mean net gain/loss	***£2.41***	**-£180**	**-£174**	**-£140**	**-£139**	**-£124**	**-£118**	**£260**	**£219**	**£205**	**£155**	**£143**	**£141**
Annual equivalised disposable income	***£35,319***	£50,296	£40,807	£49,010	£36,089	£52,414	£39,885	£19,543	£19,128	£28,333	£19,462	£19,260	£22,210
Change % of income	***0.01%***	0.36%	0.43%	0.29%	0.38%	0.24%	0.30%	1.33%	1.15%	0.72%	0.79%	0.74%	0.63%
Total trans. transport (tCO_2)	***3.9***	7.3	6.8	6.3	6.4	6.0	6.1	4.1	2.3	6.3	1.9	2.0	4.6
Total HH (tCO_2)	***5.2***	7.5	7.7	7.2	6.7	6.1	5.9	5.9	4.6	6.8	3.9	4.2	6.2
Total tCO_2	***9.1***	14.8	14.5	13.5	13.2	12.1	12.0	9.9	7.0	13.1	5.8	6.2	10.8
Transport CO_2% total	***43%***	49%	47%	47%	49%	50%	51%	41%	33%	48%	34%	32%	42%
Adults	***Single 37%*** ***Couples 52%***	Couples	Couples	Couples/ HMOs	Couples	Couples	Couples	Couples/HMOs	Couples	Single	HMOs	Couples	Single
Children	***No 73%***	Y	Y	N	Y	N	Y	N	Y	N	N	Y	Y
Tenure	***Mort. 37%*** ***OO 32%*** ***Soc. 19%*** ***PRS 11%***	Mort.	Mort	OO/Mort.	Mort.	Mort.	Mort.	Soc.	PRS	PRS	OO	Mort.	Soc.
Dwelling	***Semi.31%*** ***Terr. 27%*** ***Det. 21%*** ***PB 15%***	Det.	Det./Semi	Det.	Semi	mixed houses	Terr./ Semi	Terr./PB Flats	Terr.	Flats	mixed houses	Semi	Terr./PB Flats
Sex HRP	***M 62%***	M	M	M	M	M	M	M|F	M	-	M	M	F
Age HRP	***<34 20%*** ***35–59 43%*** ***60–74 22%*** ***>74 15%***	35–44	45–54	55–59	35–44	45–54	25–34	45–59	<34	<34	45–59	25–44	25–44
Heating fuel	***Gas 81%*** ***Elec. 13%***	Gas/Oil	Gas	Gas/Oil	Gas	Gas	Gas	Gas	Gas	Elec.	Gas	Gas	Gas
Income quintile		5	4	5	3	5	4	1	2	3	1	1	1
Bedrooms	***<3 38%*** ***3 46%*** ***>3 15%***	4–5	4–5	4	3	3	3	2	2	1–2	3–4	3	2–3
Rurality	***Urban 79%***	Less urban	Less urban	Less urban	Less urban	Urban	Urban/ Fringe	Urban	Urban	Ldn	Urban	Urban	Urban
Employment	***FT 42%*** ***Ret. 29%*** ***NW 12%***	FT/Self emp.	FT/	FT	NW PT	FT	FT	Ret. NW	NW Self emp.	NW Ret.	NW Self emp.	FT Self emp.	NW PT
UC	***24% No***	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Transport CO_2 quintile		5	5	5	5	5	5	1	2	1	5	4	1
HH CO_2 quintile		5	5	5	5	5	5	1	2	1	5	3	1

Notes: HHs = households; Total trans. = total transport emissions; tCO_2 = tonnes of CO_2; Mort. = mortgaged; OO = owned outright; Soc. = social landlord (local authority or housing association); PRS = private rented sector; Semi = semi-detached; Det. = detached; Terr. = terraced; PB. = purpose-built flat; Elec. = electric heating; FT = full time employment; Ret. = retired; NW = not working; PT = part time employment; Self-emp. = self-employed; UC = Universal Credit.

Summary of losing nodes

The most significant losing nodes for this scenario are dominated by higher-income working-age couples in larger dwellings with gas central heating but in less urban areas. These characteristics in combination result in high average emissions from both household fuels and personal travel, hence they are hit hardest by the carbon tax. Being higher-income and working-age, these households do not benefit from the adjustments to Universal Credit or pension; furthermore, the benefit from the shift in the income tax threshold appears insufficient to counteract the impact of the carbon tax.

Summary of winning nodes

CHAID designated 22 different nodes entirely as winning households (i.e. that have a mean annual net gain greater than £52) under the small carbon tax with transport scenario. These groups are dominated by lower-income households, in smaller properties with mains gas central heating in urban areas. In the main they have relatively low household and transport emissions and hence are less affected by a carbon tax, despite having gas central heating. The most significant winners are also eligible for Universal Credit and therefore would benefit from the adjustments to the tax and benefit system.

Large carbon tax with transport scenario

This taxation scenario raises some £9.6 billion. The compensation package includes: an increase in the personal income tax allowance to £10,000; an increase in Universal Credit amounts by £325 for singles without children, £350 for lone parents, £925 for couples without children and £400 for couples with children; a reduced Universal Credit taper to 63% rather than 65%; an increase in pension credit by £450 for singles and £850 for couples; an increase in the state pension by £100 per year.

Predictor variables used in the CHAID model of the outputs for this taxation and compensation scenario (i.e. variables which the model identified as having a statistically significant difference with respect to the dependent variable) are shown in Box 5. Running CHAID analysis on these results correctly identifies 84% of cases (see Table 13), to give a total count of 16.7 million losing households (compared to the actual count of 15.6 million) and 11.4 million winning households (compared to the actual count of 10.9 million).[23] Table 14 summarises the key characteristics of the most significant winners and losers (i.e. the nodes with the highest or lowest mean overall gain respectively). More detailed descriptions of each group are included in Appendix 1 (see http://www.psi.org.uk/index.php/site/project_detail/419).

Box 5: Variables selected as predictors in the CHAID model on large carbon tax with transport outputs

- Universal Credit recipient
- Tenure
- Number of children
- Number of adults
- Household composition
- Category of dwelling
- Sex of HRP
- Age of HRP (banded)
- Government Office Region

Table 13: Results of CHAID on large carbon tax with transport outputs

		Predicted			
		Loser	Broadly unaffected	Winner	*Percent Correct*
Observed	**Loser**	14,182,283	0	1,370,105	*91%*
	No overall change	903,870	0	704,004	*0%*
	Winner	1,596,072	0	9,341,185	*85%*
	Overall percentage	*59%*	*0%*	*41%*	***84%***

Table 14 summarises the characteristics of the most significant winning and losing nodes for the large carbon tax with transport scenario.

Summary of losing nodes

The most significant losing nodes (with an average annual net loss of £266–£396 across the node) are dominated by working higher-income couples, with or without children, in large properties and not eligible for Universal Credit, but with high household fuel and transport emissions. Being higher-income households, the fact that they are losing out is less of a concern from a social justice point of view, but would be a politically sensitive issue, particularly given the nature of these groups ('hard-working' adults and families) and the higher average net loss compared to the other carbon taxation scenarios modelled (over £250 to almost £400 a year for the most significant losing groups).

Under the large carbon tax with transport scenario, lower-income and/or vulnerable households (e.g. lone parents or the elderly) appear protected from the impacts of the carbon tax (because of a more substantial pot of revenue to be redistributed through the benefits system).

There are, however, two groups of potentially vulnerable older households that do appear to be worse off under this scenario. These are mainly couples – though some 25% are single households – aged 65–74, who own their 3–4 bed detached houses outright. These dwellings are in rural areas, with gas or oil heating and have higher household emissions than transport. There is a spread of incomes, but a tendency towards the upper deciles (~25% top quintile) – see Appendix 1 at http://www.psi.org.uk/index.php/site/project_detail/419 for full descriptions.

Summary of winning nodes

The key winning groups under the large carbon tax with transport scenario are dominated by: low-income families and lone parents in LA housing; private renters (families and single adults out of work); elderly people in LA electrically heated purpose-built flats (see Appendix 1 at http://www.psi.org.uk/index.php/site/project_detail/419 for full descriptions).

Conclusion

There is considerable homogeneity in the findings from the detailed analysis of winners and losers under each carbon taxation scenario. In general, wealthier households with higher emissions stand to lose, with a growing rural dimension if transport is included. Conversely, lower-income households living in smaller, socially rented properties stand out as consistent winners. The lower emissions of these household types are likely

In general, wealthier households with higher emissions stand to lose, with a growing rural dimension if transport is included. Conversely, lower-income households living in smaller, socially rented properties stand out as consistent winners.

Table 14: Summary of key characteristics of most significant winning and losing nodes under the small carbon tax with transport scenario

Node	UK average	Highest Losing Nodes						Highest Winning Nodes					
		28	67	54	36	69	70	42	71	47	18	6	55
Count of HHs	***28,097,519***	698,765	630,715	417,632	711,943	524,734	706,696	497,081	366,327	431,002	623,386	352,831	489,948
Mean net gain/loss	***£2.51***	**-£396**	**-£347**	**-£321**	**-£299**	**-£296**	**-£292**	**£434**	**£432**	**£372**	**£359**	**£357**	**£357**
Annual equivalised disposable income	***£35,319***	£50,158	£43,187	£36,242	£46,031	£43,355	£52,021	£20,581	£21,190	£22,566	£24,735	£23,608	£26,172
Change % of income	***0.01%***	0.79%	0.80%	0.88%	0.65%	0.68%	0.56%	2.11%	2.04%	1.65%	1.45%	1.51%	1.36%
Total trans. transport (tCO_2)	***3.9***	7.28	6.45	6.39	5.59	8.75	6.04	2.13	3.26	3.43	2.91	2.30	1.01
Total HH (tCO_2)	***5.2***	7.47	7.39	6.68	6.32	7.25	6.11	4.32	5.07	4.86	4.37	3.34	3.59
Total tCO_2	***9.1***	14.76	13.83	13.06	11.91	15.99	12.15	6.45	8.32	8.29	7.28	5.64	4.61
Transport CO_2% total	***43%***	49%	47%	49%	47%	55%	50%	33%	39%	41%	40%	41%	22%
Adults	***Single 37%*** ***Couples 52%***	Couples	Couples	Couples	Couples	HMOs	Couples	Couples / HMOs	Couples / HMOs	Couples / HMOs	Single	Single	Single
Children	***No 73%***	Yes	Yes	Yes	No	-	No	No	Yes	Yes	Yes	No	No
Tenure	***Mort. 37%*** ***OO 32%*** ***Soc. 19%*** ***PRS 11%***	Mort.	Mort.	Mort.	OO/Mort.	Mort.	Mort.	Soc.	Soc.	Soc.	PRS	PRS	Soc.
Dwelling	***Semi.31%*** ***Terr. 27%*** ***Det. 21%*** ***PB 15%***	Det.	Det./Semi		Det./Semi	Det./ Semi	Det./ Semi	Terr.	Semi.	Semi.	Terr.	Conv.	PB/Terr.
Sex HRP	***M 62%***	M	M	M	M	M	M	F	M	F	F	M	M
Age HRP	***<34 20%*** ***35–59 43%*** ***60–74 22%*** ***>74 15%***	35–44	45–54	35–44	55–59	45–54	45–54	45–59	35–54	25–44	<34	<34	>75
Heating fuel	***Gas 81%*** ***Elec. 13%***	Gas 80% Oil 8%	Gas	Gas	Gas 80% Oil 8%	Gas	Gas	Gas	Gas	Gas	Gas	Gas/Elec (22%)	Gas/Elec (20%)
Income quintile	**Income**	5	5	3	5	4	5	1	1	1	2	1	2
Bedrooms	***<3 38%*** ***3 46%*** ***>3 15%***	4–5	4–5	4	4	4	4–5	2–3	3	3	2–3	1–2	1–2
Rurality	***Urban 79%***	Less urban	Less urban	Less urban	Less urban	–	Less urban	Urban	Urban	Urban	Urban	Urban	–
Employment	***FT 42%*** ***Ret. 29%*** ***NW 12%***	FT	FT	FT/Self emp.	FT	FT	NW	NW 33% FT 34%	NW 38% FT 25% PT 15%	NW 33% FT 30% PT 18%	NW 38% FT 23% PT 15%	Ret. 99%	NW PT
UC	***24% No***	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No
Transport CO_2 quintile		5	5	5	5	5	5	1	2	2	2	1	1
HH CO_2 quintile		5	5	5	5	5	5	1	2	1	5	3	1

Notes: HHs = households; Total trans. = total transport emissions; tCO_2 = tonnes of CO_2; HMOs = Houses in multiple occupation; Mort. = mortgaged; OO = owned outright; Soc. = social landlord (local authority or housing association); PRS = private rented sector; Semi. = semi-detached; Det. = detached; Terr. = terraced; PB = purpose-built flat; Elec. = electric heating; FT = full time employment; Ret. = retired; NW = not working; PT = part time employment; Self-emp. = self-employed; UC = Universal Credit to reflect both their (lack of) affluence and more energy efficient properties, testament to the legacy of previous programmes to improve social housing, i.e. the Decent Homes standard.

Chapter 5 reviewed the distributional impacts of carbon taxation scenarios by household income and demographics. The analysis concluded that the large carbon tax without transport provides the best fit between progressivity and political acceptability. The CHAID results support this conclusion, with this scenario generating sufficient revenue to support a net gain for 10.5 million households, the majority of which are lower-income households eligible for Universal Credit; they are in urban areas and must have gas central heating.

The low-income winners nodes identified generally contain households that have low energy bills and emissions (and therefore pay less in carbon tax). However, there are still some high-emitting households among the winners. Having gas central heating, these higher emitters would be particularly impacted by the carbon taxation, but gain significantly from the increases to Universal Credit. As the pen portraits show, small low-income multi-person rented properties are common among the biggest winning nodes.

The most significant 'losing' nodes under the large carbon tax without transport scenario (with an average annual net loss of around £150–£250 across the node) are dominated by higher-income couples, with or without children, in larger properties and not eligible for Universal Credit, but with high fuel bills and emissions. As mentioned above, penalising this group of 'hard-working families' could be politically sensitive for the government, especially if the taxation package includes a levy on transport, which already carries a significant level of fuel duty and also adds a rural impact (i.e. where there are fewer alternatives to car use, a higher cost of fuel may be more difficult to adapt to and therefore disproportionately burden households in these areas).

7 POSSIBILITIES FOR FURTHER COMPENSATING LOW-INCOME LOSERS

Chapter 6 showed that most, but not all, low-income losers could be compensated for the imposition of a carbon tax. The next stage in the project explored a number of ways in which further policy measures could reduce the number of low-income losers.

Low-income losers

Table 15 shows the numbers of winners and losers by income band, i.e. deciles 1–3 represent low incomes, 4–7 middle incomes, and 8–10 high incomes. The results show that approximately 1.9 million (6.9%) of the 28.1 million households in 2017 are low-income losers under the small carbon tax without transport scenario, with a lower count of 1.4 million (4.8%) under the large carbon tax without transport scenario. Under the small carbon tax without transport scenario there is a higher number of low-income losers but the overall scale of the impact is relatively low, i.e. an average annual net loss of £53 (which is only marginally higher than our ‘broadly unaffected’ threshold). While the large taxation without transport scenario contains a lower number of low-income losers there is a stronger reason for compensation to reduce losses among low-income households as the average net loss is higher, i.e. £171.

Administrative feasibility of compensation measures

The government could therefore design an additional compensation package to ensure low-income households are protected from the adverse impacts of a carbon tax. Because of concern in advance that using the tax and benefits system may not be sufficient to adequately compensate low-income

Table 15: Winners and losers by income band under the two carbon taxation scenarios applied to household fuels

		Small tax no transport			Large tax without transport		
Income band	**Winning or losing**	**Count**	**%**	**Mean Overall Gain**	**Count**	**%**	**Mean Overall Gain**
Low income	Loser	1,927,654	23%	-£53.10	1,357,414	16%	-£171.26
	Broadly unaffected	5,777,365	69%	-£33.84	1,003,870	12%	£5.09
	Winner	724,778	9%	-£7.44	6,068,513	72%	£249.63
Middle income	Loser	1,696,161	15%	-£53.59	6,573,394	58%	-£157.82
	Broadly unaffected	6,836,381	61%	-£5.03	1,004,078	9%	-£10.66
	Winner	2,706,370	24%	£57.88	3,661,440	33%	£240.49
Higher income	Loser	787,145	9%	-£30.36	7,242,939	86%	-£175.66
	Broadly unaffected	4,134,358	49%	£6.27	760,545	9%	-£19.25
	Winner	3,507,307	42%	£71.55	425,326	5%	£216.31

households for higher energy and transport taxes, other ways to tackle the issue were also investigated, including the idea of exemptions for certain types of households from the energy taxes. Key issues relating to such exemptions are administrative cost, complexity and feasibility.

A range of issues relating to the administrative feasibility of different ways of arranging the tax and compensation mechanisms were explored. Firstly, we looked at the compensatory measures relevant for household energy, considering the mechanics of applying a carbon tax to bills – the idea of a rising block tax or VAT at a higher rate for consumption above a threshold. The main alternative we examined was the idea of exempting certain households from the tax – instead of compensation through benefit payments, eligibility for certain benefits would be used to exempt those households from the tax, rather like the way certain households are eligible for free school meals and other concessions.

Secondly, we looked at transport duty and, in particular, concessions for motorists in rural areas, either by extending the Rural Fuel Duty Rebate scheme to areas beyond the islands that it already covers, or by reducing Vehicle Excise Duty (VED) for cars registered in rural areas.

A detailed discussion of the project's research in these areas is in Appendix 2 (see http://www.psi.org.uk/index.php/site/project_detail/419). The analysis shows that the administrative problems with these additional measures could not be easily resolved for either household energy or transport, and that there would need to be compelling reasons, in terms of improving the distributional outcomes from carbon taxation, for them to be introduced. However, the analysis, particularly that documented in Chapter 6, showed that the great majority of low-income households could be compensated for the carbon tax by redistributing the revenues raised. It has therefore been concluded that compensation through the tax and benefits system would be sufficiently effective, and that the additional complexity involved in other approaches would not be justified. Similarly, applying a lower rate of VED in rural areas would also be administratively complex, open to abuse and would decrease the incentive to buy the most fuel-efficient cars, which already have zero VED.

The one exception to this conclusion of the practical infeasibility of supplementing compensation through the tax-benefit system with additional

The analysis, particularly that documented in Chapter 6, showed that the great majority of low-income households could be compensated for the carbon tax by redistributing the revenues raised.

measures is that it *would* appear practical to extend the Rural Fuel Duty Rebate scheme from the islands to parts of the mainland in the Scottish Highlands. This would compensate households in those areas for the lack of public transport and the greater need, therefore, for car use. These areas also have fuel prices well above the national average, and the distance between petrol stations is so great that fuel tourism is unlikely. (The practical problem with extending the scheme to rural areas more generally is that it would make fuel tourism more likely.) In any case, fuel prices in the islands and in remote parts of the Scottish Highlands are much higher than the national average, but this is not generally the case in rural areas.

There are a number of other policy options that could be considered to try to reduce further the number of low-income losers shown in Table 15, especially in the large carbon tax without transport scenario. Two of the most promising appear to be: adjustments to the Winter Fuel Payment (currently paid to everyone over 65, and some below 65, irrespective of their income) such that older, lower-income pensioners get paid more; and targeting of this type of pensioner to receive rebates to their fuel bills through the Warm Home Discount. However, as already noted, the costs and administrative processes related to such compensation schemes would also require further careful analysis, as with the measures examined in Appendix 2 (see http://www.psi.org.uk/index.php/site/project_detail/419): this was outside the scope of this project.

It is worth making one final point concerning the administrative feasibility of compensating low-income households for disproportionate effects from otherwise socially desirable measures such as carbon taxes. The simple structure of Universal Credit makes it straightforward to increase benefit payments for particular kinds of family, making it easier to compensate all households of a particular type from measures such as carbon taxation than it would be with the more complicated structure of the existing benefits system.

Conclusion

Compensation through the mechanisms modelled in this report would be effective at ensuring that there would be relatively few low-income losers compared to the number of low-income winners, but these mechanisms do not eliminate the problem of low-income losers. Since nearly every household eligible for Universal Credit will gain anyway, the administrative complexity of a system of exemption from a tax increase on household energy could not be justified. Adjustments to Winter Fuel Payments so that they were targeted at older lower-income pensioners may be a feasible option, but this was not examined in detail. Broadening the Rural Fuel Duty Rebate scheme from the islands to include remote parts of the mainland in the Scottish Highlands would be feasible, but there would be practical problems with wider concessions to rural motorists.

8 REAL AND MODELLED DATA

Actual changes in energy demand due to energy-efficiency measures such as cavity-wall filling, loft insulation, double glazing and boiler replacement have been shown to vary from predictions. This is because of the limitations of models to accurately describe actual house features and household behaviours that would influence real-life energy demand.

This ‘gap’ between actual and predicted energy demand will be a combination of technical, socio-behavioural, physical and environmental factors. In terms of savings due to a refurbishment designed to reduce energy demand through efficiency improvements to a dwelling’s physical features (i.e. fabric or heat system improvements), these are based on assumptions about installation quality, that occupant behaviour is consistent before and after, and that environmental features have not changed. These assumptions are a primary cause of the discrepancy between actual and modelled changes in energy demand, and are the result of a lack of real empirical evidence.

Recent studies, however, have assessed the impact of energy-efficiency interventions using a combination of survey data and house-level energy usage.[24] The results have shown ‘real’ changes in demand associated with an energy-efficiency intervention. In a sample of houses, broadly representative of the UK housing stock, the changes between 2005 and 2007 were shown for dwellings with and without energy-efficiency interventions. Table 16 shows these changes in absolute and percentage terms.

Table 16 shows the ‘actual’ changes for all houses with a selected measure. The base energy-efficiency group was the control group, without any measures. They had an average change of -6% in gas demand (i.e. a reduction of 6%) from 2005–7. This baseline change in demand will be due to factors such as changes in energy prices (an increase of approximately 50% during the period) and the perceived downturn in the economic climate. This ‘baseline’ trend is used to establish what change would be expected for dwellings with no additional efficiency measures. The table then shows the change in energy demand for dwellings with an installed measure: the effective, or 'actual', change, is the percentage change minus the base change. For example, loft insulation shows, on average across all house types, a 3% reduction in energy use. These actual changes also tend to vary by building characteristics, i.e. type, age, size etc. However, the values themselves tend to be lower than the modelled prediction implemented in DIMPSA , e.g. 15% (actual) compared to 22% (DIMPSA) for cavity-wall insulation and 3% (actual) compared to 10% (DIMPSA) for loft insulation (depending on the type of property and the level of insulation).

Table 16: Changes in energy consumption in dwellings with and without various energy efficiency interventions

Group	2005 – mean kWh	2007 – mean kWh	Change 2005–2007	Change 2005–2007 (adjusted for base)	% Change 2005–2007
Base Energy Efficiency Group Individual Measures 2006	19,389	18,136	-1,253	-	-6%
Loft insulation	21,258	19,246	-2,013	-760	-9%
Cavity wall insulation	20,243	17,184	-3,059	-1,806	-15%
Glazing Replacement	20,215	18,610	-1,605	-352	-8%
Condensing Boiler	19,305	16,573	-2,732	-1,479	-14%
Multiple Measures					
Cavity + Loft	20,649	17,884	-2,765	-1,511	-13%
Cavity + Glazing	19,586	16,784	-2,802	-1,549	-14%
Cavity + Boiler	18,197	14,692	-3,505	-2,252	-19%
Loft + Glazing	20,194	18,425	-1,770	-517	-9%
Loft + Boiler	20,538	17,659	-2,879	-1,626	-14%
Glazing + Boiler	19,139	16,771	-2,368	-1,115	-12%

It should be noted that the 'actual' change in demand includes a host of factors, such as how people may change their energy use in practice following an intervention, affecting the levels of change associated with a measure. These 'in use' factors result in the predicted savings not being met. However, it should be noted that predicted savings are idealised and do not include these 'in use' factors that, to date, are poorly understood. However, as this is an average, there are still households that will achieve the expected savings; a better understanding of those households could offer insights into how to address the savings gap. The implication is that models, such as DIMPSA or the DECC Green Deal model, may need to apply these 'in use' factors to alter the savings for efficiency measures to reflect the average behaviour associated with past measures.

Using the above analysis from DECC's NEED report and a selection of house features drawn from the Home Energy Efficiency Database (HEED),[25] a set of factors is established for a selection of house types – defined by dwelling age, type, size and tenure – which can be applied to the DIMPSA model outputs for sensitivity testing. The effect is to reduce the impact that a modelled measure has on a household's energy demand. In some cases this will have the effect of households maintaining a higher than expected fuel demand and therefore paying more tax on their fuel consumption.

Conclusion

The savings associated with energy-efficiency measures are, in reality, subject to a host of factors that influence the level of change achieved compared to modelled approaches. This effect, commonly referred to as 'rebound' or 'take-back', means that models used to predict energy savings following an efficiency measure may overestimate the savings. In the cases examined in this report, the implication is that fuel bills will not be reduced as much as expected, thus the level of taxation may be higher than otherwise modelled. As part of the analysis, the 'in use' factors associated with the above measures were included as part of the sensitivity testing in order to understand the implications of the savings gap.

This effect, commonly referred to as 'rebound' or 'take-back', means that models used to predict energy savings following an efficiency measure may overestimate the savings.

9 SENSITIVITY ANALYSIS: IMPACT OF ENERGY TRENDS, COMFORT-TAKING AND POPULATION GROWTH

There are a number of assumptions and a standardised set of inputs that are applied in DIMPSA for assessing the impacts of government policies on household energy consumption. These assumptions have important implications for the results obtained.

At the beginning of this study, we explored the impact of running the model with different policy assumptions – the 'all policy' and 'limited policy' scenarios. This showed that there was little difference in the overall impacts on total household emissions, hence the remainder of the modelling and analysis applied the 'all policy' model results only.

To assess the implications of other model assumptions/omissions, sensitivity analysis was undertaken to explore the impact on results of the following three key model parameters: trends in energy demand and product policy, comfort-taking and population change. This chapter summarises the report on the sensitivity analysis. For the full discussion, see Appendix 3 (http://www.psi.org.uk/index.php/site/project_detail/419).

Trends in energy demand and product policy

Unlike the long-term trend for energy use in the home – which shows an increase in total and *per capita* gas and electricity consumption (from

1981 to 2009) – the short-term weather-corrected trend shows a decline for both fuels, i.e. as weather has been controlled, so the trend is non-weather-dependant.[26] The trend is more pronounced for electricity, which may demonstrate some success of, for example, recent changes to lighting regulations. The trend occurred despite, during the ten-year period from 2001–10 inclusive, an increase in the number of households in the UK of 7.2%. During this time the population (number of persons) increased by 5.3%, while the number of persons per household fell slightly from 2.41 to 2.36 on average. The short-term trend therefore indicates that household energy demand is on the decline, despite growth in the number of people and households. Energy use is falling both per person and per household, and overall.

In their recent modelling of the impacts of product policy (PP, i.e. regulated standards for improvements in the energy efficiency of consumer products) on consumer energy bills, the government and Climate Change Committee (CCC) applied the same assumptions, which include the most recent savings that stem from developments in EU Product Policy.[27] The product policy savings allow for *growth in demand* resulting from population change and a *reduction in demand* resulting from improved product efficiency and changing usage patterns. It also assumes some increase in gas demand due to the 'heat replacement effect'.[28] The resulting figures are shown in Table 17.

The analysis undertaken in this study pre-dates these latest assumptions from DECC and uses more conservative estimates of product policy savings (see Table 17). Although more conservative, these assumed values – which are spread across all households in the dataset – still result in a significant change in household gas and electricity demand. An alternative, even more conservative, method for modelling the underlying trend in consumer energy demand was therefore explored, to assess the implications of these product policy assumptions for the results obtained in this study.

The alternative approach removes product policy from the model and instead takes estimates for changes in demand derived from trends in domestic electricity and gas consumption over the previous five years (2005–10) from Digest of United Kingdom Energy Statistics (DUKES).[29] This gives a change in 2020 of -10.45 TWhs for electricity and +0.97 TWhs for gas, as shown in Table 17. The average annual change implied by these figures was then applied to the energy consumption values in the modelling baseline year (2010), and energy consumption projected forward to 2017.

Table 17: Assumed changes in total household energy demand in 2020 due to product efficiency improvements and heat replacement effect

	Change in total electricity demand in 2020	Change in total gas demand in 2020
DECC and CCC latest PP assumptions	-18.47 TWhs	+8.96 TWhs
Assumptions used in this study	-12.74 TWhs	+7.15 TWhs
Adjusted using energy trends	-10.45 TWhs	+0.97 TWhs

The consumption of gas increases significantly for the product policy scenarios above due to the heat replacement effect. The short-term trend for gas use does not reflect this; in other words, as electricity use falls we do not necessarily see an increase in gas use. This may be due to the fall in electricity being associated with behavioural changes or households choosing to accept the slight decrease in ambient temperature due to improved lighting standards and product efficiency. And if all of the electricity savings are due to more efficient products, this could suggest an additional trend for cooler houses. The standard modelling of product policy may therefore be over-exaggerating an increase in householders' heating fuel consumption as a result of the heat replacement effect.

However, there are a multitude of additional factors that could be responsible for this trend that cannot be identified from this analysis. If we are to truly understand trends for energy consumption in the home then data on actual consumption and demand temperatures must become more freely available.

Comfort-taking

To explore the impact of government policies on household energy consumption, DIMPSA models the deployment of sustainable energy measures across the housing stock. In doing so, DIMPSA has a set of standard inputs that are applied for modelling the savings resulting from measures. These are in line with DECC's own modelling assumptions. However, research has suggested that, in practice, households may take more benefit from household energy-efficiency measures in the form of comfort (i.e. higher room temperatures) than is generally assumed. If this is the case, the model will be overestimating the impact of measures on household energy consumption (i.e. the savings and emissions reductions will be lower than expected).

Research described in Chapter 8 of this report explores the 'real' impact of energy-efficiency measures on household energy consumption. The results from this analysis, described in more detail in Appendix 3 (see http://www.psi.org.uk/index.php/site/project_detail/419), found an increased level of comfort-taking (and therefore lower energy and emissions savings) than assumed in the model. The assumed level of comfort-taking for key household insulation measures (lofts and walls) and boilers was adjusted in DIMPSA (see Table 18).

Table 18: Energy savings, standard and adjusted for increased comfort-taking

Insulation	Standard	Adjusted
Cavity wall insulation	19%	5%
Solid wall insulation (internal)	25%	16%
Solid wall insulation (external)	51%	33%
Loft insulation (full)	10%	1%
Loft insulation (top up)	4%	1%

The model was re-run with these adjusted values, and without the assumed product policy savings as described above, to produce a new set of impacts of government energy and climate policies on consumer energy bills to

2020. These outputs were then compared with the results derived from the standard modelling assumptions. The results suggest that the government's standard modelling of energy policies has an over-optimistic view of the derived carbon savings and potential reductions to energy bills as a result of the installation of energy-efficiency measures.

Allowing for population change

The IFS TAXBEN model uses ONS population projections to create new weights in the dataset to mimic projected population change within the modelling timeframe (i.e. to 2017).[30] The weightings are designed to ensure that the population profile of the dataset used in this study corresponds with ONS figures for 2010 and 2017 (see Table 19).

Table 19: Weighting the survey data to allow for population growth (counts represent households in thousands)

Household type	Baseline Survey population	2010 population	2017 population
Couple, no children, under 60	4,050	4,264	4,578
Couple, no children, over 60	4,091	4,482	5,029
Couples with children	4,722	4,828	4,919
Lone parent	1,394	1,601	1,640
Multi-person house	3,139	3,123	3,196
One adult, under 60	3,105	3,734	3,827
One adult, over 60	3,706	4,607	4,906
Total households	**24,207**	**26,641**	**28,098**
Total persons	*57,012*	*60,463*	*63,323*

TAXBEN uses these weightings to give an accurate reflection of the demand for welfare benefits in 2017. To ensure consistency, the Baseline Survey population in DIMPSA was weighted to arrive at a new 2017 population that took account of population growth (as shown in Table 19) in the analysis of the impacts of government policy on household emissions in 2017. This has implications for the level of emissions reductions resulting from policy impacts (as a direct result of the new weightings increasing the number of people and households represented in the dataset).

Results of sensitivity analysis

The results of the sensitivity analysis on overall household emissions in 2017 are shown in Table 20. Figures in brackets show the difference in total household emissions in 2017 compared to the standard modelling scenario (taking account of projected population growth).

The results, which are presented in more detail in Appendix 3 (see http://www.psi.org.uk/index.php/site/project_detail/419), show that:

- Emissions reductions resulting from policy impacts appear greater when no population growth is assumed (i.e. using the Baseline Survey population). Re-weighting the dataset to mimic ONS projections for population change to 2017 results in higher estimates of carbon emissions and energy demand in the modelling year.

Table 20: Impact of survey weighting and policy/model assumptions on emissions results

Modelling scenario	Count of HHS	Residential emissions ($MtCO_2$)	% Change in emissions on 1990
UK 1990 Baseline emissions		155.5	–
Modelling baseline year (as shown in Table 2) (survey weight)	24,206,750	128.3	17.50%
Row A: standard outputs (as shown in Table 2) 2017 – All policies, standard assumptions + population growth (*2017* population in Appendix 3, Table 37 – see http://www.psi.org.uk/index.php/site/project_detail/419)	28,097,519	127.4	18.00%
Row B: sensitivity analysis 1 2017 – All policies, standard assumptions + survey population, Table 37 (i.e. no population growth)	24,206,750	112.1 (↓15.3)	27.90%
Row C: sensitivity analysis 2 2017 – Row A (standard outputs assumptions, as shown in Table 2) + without PP + comfort-taking adjusted + population growth (2017 population in Table 37)	28,097,519	134.3 (↑22.2)	13.60%
Row D: sensitivity analysis 3 2017 – Row C: (standard outputs assumptions, as shown in Table 2, without PP, plus adjusted comfort-taking) + short-term energy demand trends built in + population growth (2017 population in Table 37)	28,097,519	130.6 (↑18.5)	16.00%

Note: figures in brackets show change from standard outputs, Row A

- However, the projected weighting to 2017 is likely to overestimate emissions in that year (and therefore *underestimate* emissions savings) as emissions do not necessarily grow at the same rate as the population (i.e. there may be more people who are using less). Thus, we might expect the 'real' result to lie somewhere between the two (i.e. between the totals of Row A and Row B).
- Increasing comfort-taking rates of some key energy-efficiency measures deployed in the modelling, and removing the assumed impacts of product policy, reduces the level of emissions reduction achieved in 2017 by some 4% compared to standard model assumptions for comfort-taking (the difference between Row A and Row C).
- Increasing comfort-taking rates of some key energy-efficiency measures and incorporating short-term energy demand trends reduces the level of emissions reduction achieved in 2017 by some 2%, compared to standard

model assumptions for comfort-taking and without energy trends included (the difference between Row A and Row D).

- The level of reduction in emissions achieved under all of these different modelling scenarios is still significantly lower than that required by the CCC in its latest calculations, which suggest a need for emissions reductions of 32% by the end of 2017 (see Appendix 3 at http://www.psi.org.uk/index.php/site/project_detail/419 for the detail of these calculations).

Conclusions and implications for carbon tax analysis

The sensitivity analysis presented above shows that model inputs and assumptions about energy demand trends, the performance of energy-efficiency measures, product policy, comfort-taking and population growth have significant implications for the estimated impact of government policies on household emissions. The data on the actual performance of measures *in situ* suggests that expectations that policy will deliver the claimed savings are unrealistic.

DECC's Annual Energy Statement (referred to as the AES[31]) analyses the distributional impacts of UK climate-change policies. The research applies the same comfort-taking factor as this study, i.e. 15% for any heat consumption reduction measure, renewable heat pump or insulation measure. However, the recent DECC Green Deal and ECO consultation included additional in-use factors for measures' performance and installation quality. The additional factors increase comfort-taking to approximately 50%. These factors are based on an analysis of measures' performance data by Sanders and Phillipson.[32] The more recent analysis of measures and policy performance is therefore adapting to the actual performance of energy-efficiency measures.

In the context of this study specifically, the level of emissions in 2017 will affect the amount of revenue raised in carbon tax and how much individual households have to pay. Under the sensitivity analysis modelling scenario that adjusts for the performance of sustainable energy measures and recent trends in domestic energy demand (rather than incorporating assumptions about product policy, i.e. Row D in Table 20), household emissions are 18.5 $MTCO_2$ higher in 2017 than under the standard modelling scenario. In the context of carbon taxation, these higher emissions translate into a higher carbon tax paid (calculated for the 'small carbon tax without transport' scenario in Appendix 3, see http://www.psi.org.uk/index.php/site/project_detail/419). This has further implications for the level of revenue generated from the tax, which could be recycled to further assist in compensating low-income or vulnerable households. It also potentially strengthens the rationale for an additional increase in energy costs through taxation, as this may in turn stimulate additional behavioural change resulting in the improved performance of measures.

Under the sensitivity analysis modelling scenario that adjusts for the performance of sustainable energy measures and recent trends in domestic energy demand [...], household emissions are 18.5 $MTCO_2$ higher in 2017 than under the standard modelling scenario.

10 CONCLUSIONS

Basic principles of public finance posit the undesirability of environmentally perverse subsidies and different rates of environmental taxes, such as carbon taxes, across different sectors of the economy. In the UK, both of these economic distortions are in evidence in the absence of carbon taxation from the use of gas for household heating, and in the low rate of VAT on the home use of energy more broadly.

Using the recently developed household energy model, DIMPSA, this project set out to examine how to design an environmental tax reform that would remove these distortions and give further incentives to reduce the carbon emissions from transport, while also protecting low-income households from negative impacts.

Four different designs of environmental tax reform were modelled. On the tax side, these scenarios extended the Carbon Price Floor (CPF) to the use of household energy and other non-metered fuels ('small carbon tax'), and raised the rate of VAT on household energy from 5% to 20% ('large carbon tax'). Transport taxes were then levied on two scenarios, giving four overall (small/large carbon tax with/without transport).

On the compensation side, Income Tax Personal Allowances were first raised to £10,000 per year, then remaining revenues were used to increase the basic State Pension, Pension Credit and Universal Credit. The modelling year, 2017, was chosen as that is the year in which Universal Credit will be fully implemented. It is worth noting that the introduction of Universal Credit makes compensating low-income households for policies such as carbon taxation much easier than under the present patchwork system of multiple overlapping benefits.

The project found that only the design that directed most of the revenues from the tax measures to increasing the Income Tax Personal Allowance (and increased benefits very little) made low-income households worse off on average (this was the 'small carbon tax without transport' scenario). The other three designs made most low-income households better off on average.

The modelling found that using Universal Credit and Pension Credit (as well as increasing the Income Tax Personal Allowance and the basic State Pension) would redistribute the tax revenue so that most (69% to 86%) households in the bottom two deciles would gain from higher taxation of household energy, and few (8% to 15%) of these households would lose. Such a tax reform is therefore very progressive overall.

Very few households claiming Universal Credit or Pension Credit would lose, either. Existing means-tested benefits and tax credits for those of working age already have relatively high rates of take-up, often in excess of 90%, at least for those on lower incomes. The government hopes that the introduction of Universal Credit will increase take-up further because people will no longer have to apply for separate benefits, only for Universal Credit. However, Pension Credit has a lower rate of take-up, particularly among pensioners with small amounts of private income. Because the modelling assumed take-up by all eligible households – although in fact not everyone eligible for the benefits claims them – more low-income households, and particularly more lower-income pensioners, will perhaps lose out from the introduction of a carbon tax than we estimate here.

Almost all of those entitled to Universal Credit do not lose out overall from the introduction of the large carbon tax. However, there are some low-income households that will not be eligible for Universal Credit or Pension Credit. This is usually because they either have too much in savings or other assets (meaning they are not entitled to Universal Credit) perhaps suggesting that they have only a temporarily low income, or that they are households of students, who are generally not entitled to benefits.

The project also examined in detail which kinds of household 'win' or 'lose'. The most significant losing groups identified through CHAID analysis are dominated by working higher-income couples with or without children, in larger properties and not eligible for Universal Credit, but with high household fuel and transport emissions. Being higher-income households, the fact that they are losing out is less of a concern from a social justice point of view, but could be a politically sensitive issue given the nature of these groups ('hard-working' adults and families). In the modelling, we have tried to protect low-income households, meaning that most of them gain from the packages we have simulated. That inevitably means that there have to be higher-income losers to keep each package revenue-neutral.

Because of concern at the start of the project that using the tax and benefits system may not be sufficient to adequately compensate low-income households for higher energy and transport taxes, other ways to tackle the issue were also investigated, including the idea of exemptions for certain types of household from the energy taxes. However, the results of the project have shown that compensation through tax and benefits would be sufficiently effective to compensate low-income households, and that the extra distributional benefits derived from other approaches would not justify the additional administrative complexity involved.

The research has therefore shown that higher taxation of household energy and transport in the UK can be implemented in such a way that, through appropriate recycling of the tax revenues, most lower-income households could be made better off rather than worse off.

The government could therefore choose to introduce a carbon tax on the household use of gas and non-metered fuels in the knowledge that the tax and benefits system can protect low-income households. Furthermore, the lower rate of VAT on fuel could be ended, removing the environmentally perverse subsidy that this represents, with the tax and benefits system again protecting low-income householders. The impact on consumption of these tax measures on energy costs has not been modelled. In recent years, rapidly increasing prices have not reduced consumption significantly; however, the carbon tax measures detailed in this report would be expected to receive high-profile media coverage and as such might stimulate action.

GLOSSARY

Carbon Capture and Storage (CCS) – technology attempting to prevent the release of large quantities of CO_2 from fossil-fuel use in power generation and other industries into the atmosphere by capturing CO_2, transporting it and, ultimately, pumping it into underground geologic formations to securely store it away.

Carbon Emissions Reduction Target (CERT) – a UK government obligation that requires all domestic energy suppliers with a customer base in excess of 250,000 to make savings in the amount of CO_2 emitted by households. Suppliers meet this target by promoting the uptake of low-carbon energy solutions to household energy consumers. The programme was originally to run from April 2008 to March 2011, but it was extended to the end of 2012.

Carbon price – the cost of emitting a ton of carbon dioxide or its equivalent under a carbon tax or an emissions trading system.

Carbon Price Floor (CPF) – the carbon price set by the European Union (EU) Emissions Trading Scheme (ETS) has not been certain enough or high enough to encourage sufficient investment in low-carbon electricity generation in the UK. The CPF is a pricing mechanism that has been created to set a minimum price for carbon emissions in the traded EU ETS market for carbon from the electricity generation sector, starting at £16 per tonne of CO_2 in 2013 and rising linearly to £30 per tonne in 2020.

Chicago Convention – known formally as the International Convention on Civil Aviation, this is a treaty dating from 1944 that established the International Civil Aviation Organisation. Among the terms of the convention is a provision that duty cannot be charged on fuel used in international aviation.

Energy Company Obligation (ECO) – the Energy Act 2011 amends existing powers in the Gas Act 1986, Electricity Act 1989 and the Utilities Act 2000 to enable the Secretary of State to create a new Energy Company Obligation to take over from the existing obligations to reduce carbon emissions – the Carbon Emissions Reduction Target (CERT) and Community Energy Saving Programme (CESP) – which expired at the end of 2012 and to work alongside the Green Deal finance offer by targeting appropriate measures at those households that are likely to need additional support, in particular those containing vulnerable people on low incomes and those in hard-to-treat housing.

EU Emissions Trading Scheme (ETS) – the European Union greenhouse gas emissions trading scheme began in 2005 and covers carbon dioxide emissions from six sectors of heavy industry, including electricity generation, steel-making, cement-making, pulp and paper, and glass. Companies covered by the scheme may emit only a certain quota of carbon dioxide each year, and are issued with carbon permits for every tonne of the quota. They can trade these permits with each other. In successive phases of the scheme, the quota is reduced so that the overall emissions fall.

Feed-in tariff (FIT) – a feed-in tariff scheme offers guaranteed cash payments to home-owners, businesses and organisations such as schools and community groups that generate their own electricity through small-scale green energy installations such as solar photovoltaic (PV) panels or wind turbines. It guarantees a minimum payment for all electricity generated by the system as well as an additional payment for the unused electricity produced that can be exported to the grid, known as the generation tariff and export tariff respectively. The level of payment depends on the technology and whether it is being fitted to an existing home or installed as part of a new build. In the UK, future payments are guaranteed for the next 20 years for solar and wind turbine-generated power and are linked to inflation. Solar installations registered before 1 August 2012 will receive the payment for 25 years.

Green Deal – a new UK government scheme to tie low-interest loans, issued by Green Deal Providers, for energy-efficiency improvements to the energy bills of the properties the upgrades are performed on. These debts would then be passed on to new occupiers when they take over the payment of the bills. It is proposed that the costs of the loan repayments would be less than the savings on the bills from the upgrades, although this will not be a legally enforceable guarantee. The Green Deal will work in conjunction with the Energy Company Obligation (ECO).

Heat replacement effect – in the context of Products Policy (see page 70), this relates to the impact of improvements in appliance efficiency resulting in reductions (savings) in electricity consumption. However, at the same time, improved efficiency levels mean that less waste heat is generated from electrical products. To maintain the same levels of warmth in the home, it is therefore assumed that additional heating is required to replace this lost heat. The assumptions applied in modelling here the impact of product policy on both electricity consumption and heating fuel consumption in the home is consistent with the government's own assumptions.

Living Costs and Food Survey (LCF) – the Living Costs and Food Survey (LCF) is a survey by the Office of National Statistics which collects information on household expenditure, food consumption and income, reflecting household budgets across the country. In April 2001, the Family Expenditure Survey (1961–2001) and the National Food Survey (1974–2000) were combined to form the Expenditure and Food Survey (EFS). From January 2008, the EFS became known as the Living Costs and Food Survey (LCF), a module of the Integrated Household Survey (IHS). The survey includes 12,000 households per year.

Pension Credit – a means-tested benefit aimed at the poorest retired people. It has two elements. Guarantee Credit is an income-based benefit which is paid if the income of the applicant and partner (plus a notional income from savings) is below a certain level. The minimum age for claiming is rising in line with the increase in women's retirement age; it is currently just over 60, but by April 2020 the minimum age for claiming will be 65. When the applicant or partner reaches 65, the second element, Savings Credit, is also payable. Savings Credit is designed to 'reward' people who saved for their pension during their working life. It therefore provides an additional benefit to retired people who are not well off and may not qualify for the full Guarantee Credit, but do have savings or a personal pension.

Product Policy – a policy measure aimed at influencing the design of a product so as to reduce its impact on the environment. In this context, it usually refers to tightening regulatory standards for the energy or water consumption of household appliances and electronic devices.

Renewable Heat Incentive (RHI) – a payment system for the generation of heat from renewable energy sources. The RHI operates in a similar manner to the feed-in tariff scheme. In the first phase, which started in November 2011, payments are paid to owners who install renewable heat-generation equipment in non-domestic buildings. The extension of the RHI to domestic buildings has been delayed, but it is expected in 2013. Through the RHI, generators are paid for hot water and heat which they use themselves. The RHI tariff depends on which renewable heat systems are used and the scale of generation, and the annual subsidy will last for 20 years.

Renewables Obligation (RO) – a policy designed to encourage generation of electricity from eligible renewable sources in the United Kingdom. The RO places an obligation on licensed electricity suppliers in the United Kingdom to source an increasing proportion of electricity from renewable sources.

Smart meter – a smart meter is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Smart meters enable two-way communication between the meter and the central system. Unlike home energy monitors, smart meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter.

Universal Credit – a new welfare benefit in the United Kingdom that will replace all the main means-tested benefits and tax credits for working-age people except for Council Tax Benefit. The government plans to introduce Universal Credit over the period 2013–17.

Warm Home Discount Scheme – a scheme which helps some older people with energy costs. Energy companies give those eligible a discount on their bill (£130 in 2012/13). People are eligible if they are less than 80 years old and receiving only the Guarantee Credit element of Pension Credit (no Savings Credit) or if they are over 80 and receiving the Guarantee Credit element of Pension Credit (even if they receive Savings Credit as well). Some other older people are eligible, but the rules vary depending on which energy supplier they are with.

Weather Correction – energy consumption from different time frames needs to be corrected for the weather to allow useful comparison. For example, energy used for heating in a cold winter will be higher than in a warm winter; the consumption is therefore corrected by degree days which account for the time that the ambient temperature is below 16.5°C.

NOTES

1 The non-metered fuels are all household fuels except electricity and mains gas. The main ones are oil, coal, smokeless fuel, bulk liquid petroleum gas (LPG), bottled gas, anthracite nuts and grain, wood and peat.

2 The tax on transport fuels would be passed on to those buying fuel directly (and then through the price of tickets for buses, coaches and diesel trains, in the same way that the cost of fuel duty is already passed on). Because a treaty prohibits imposing taxes directly on fuel for international aviation, the tax would instead be on aviation emissions, passed on to people buying airline tickets.

3 See http://www.hmrc.gov.uk/stats/personal-tax-credits/cwtc-take-up-09-10.pdf and http://statistics.dwp.gov.uk/asd/income_analysis/jun_2010/0809_Publication.pdf

4 A household is currently defined as being in fuel poverty if it would need to spend more than 10% of its income to achieve a certain level of household warmth and other necessary energy services.

5 When households save money through energy-efficiency measures, they may spend some or all of that money on using energy to make their homes warmer or for other purposes, so that the energy savings from the energy-efficiency measures are less than anticipated. This is called the rebound effect.

6 DECC (November 2011) 'Estimated impacts of energy and climate change policies on energy prices and bills'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/68820/3593-estimated-impacts-of-our-policies-on-energy-prices.pdf

7 Using DECC's Central Scenario, see: www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/2933-fossil-fuel-price-projections-summary.pdf

8 These were developed through CSE's work with DECC, in conjunction with DECC's Fuel Poverty team.

9 The dataset was developed through the project: 'Understanding the social impacts of UK climate change policies', being undertaken by CSE, working with the Universities of Bristol and Oxford, and with funding from the Joseph Rowntree Foundation.

10 The non-metered fuels are all fuels except electricity and mains gas. The main ones are oil, coal, smokeless fuel, bulk liquid petroleum gas (LPG), bottled gas, anthracite nuts and grain, wood and peat.

11 While this is strictly an energy, rather than a carbon, tax its imposition is justified because it removes an environmentally perverse subsidy on energy use.

12 The assumptions underlying Product Policy are equivalent to those used by DECC, as supplied by Defra's Market Transformation Programme (MTP) team.

13 Table A2-2: Population projections by the Office for National Statistics (Great Britain) available at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-229866

14 C. Giles and J. McCrae (1995), 'TAXBEN: The IFS microsimulation tax and benefit model', IFS Working Paper, available at: http://www.ifs.org.uk/wps/wp1995.pdf. Although this paper is dated, most of the main features of the model have not changed since then.

15 More precisely, the transition from the current system of means-tested benefits and tax credits to Universal Credit will be finished by the end of 2017: see DWP (2011) 'Managing the build up of claims to Universal Credit', Universal Credit Policy Briefing Note 15, available at: http://www.dwp.gov.uk/docs/ucpbn-15-managing-claims.pdf. Thus there will still be a small number of families claiming the current set of means-tested benefits and tax credits at the start of the 2017–18 fiscal year. We ignore this for the purposes of our analysis, assuming that Universal Credit is fully in place.

16 Note that not all aspects of the operation of Universal Credit have yet been decided upon. We therefore consider the variant outlined in the government's Welfare Reform White Paper published in November 2010 and ignore some aspects of the tax and benefit system (for more details see M. Brewer, J. Browne and W. Jin (2011) 'Universal Credit: a preliminary analysis of its impact on incomes and work incentives', Fiscal Studies Vol. 33 (1) pp. 39–71, available at: http://www.ifs.org.uk/publications/5415). This has been superseded by later announcements concerning the localisation of Council Tax Benefit (meaning that this will not now be incorporated within Universal Credit), but as not all details of how this will operate have been announced, we continue with the proposals in the White Paper. Changes to Universal Credit announced since the White Paper would in any case make little difference to the gain and loss for each family from the reforms we consider here.

17 The taper rate is the rate at which Universal Credit will be withdrawn for each additional pound of income. For example, a taper rate of 65% means that for an additional pound of income, UC will be reduced by 65p, so the claimant will keep 35% of any additional income.

18 See http://www.hmrc.gov.uk/stats/personal-tax-credits/cwtc-take-up-09-10.pdf and http://statistics.dwp.gov.uk/asd/income_analysis/feb2012/tkup_full_report_0910.pdf

19 According to DWP analysis, between 62% and 68% of pensioners entitled to Pension Credit claimed their entitlements in 2009–10, with between 20% and 27% of the total cash entitlement not being claimed. See http://statistics.dwp.gov.uk/asd/income_analysis/feb2012/tkup_full_report_0910.pdf

20 See Browne, J. (2012), 'A £10,000 personal allowance: who would benefit, and would it boost the economy?' IFS Observation, available at: http://www.ifs.org.uk/publications/6045.

21 This policy involves increasing the Pension Credit Guarantee by £150/year for singles and £270/year for couples and increasing Universal Credit by £150/year for singles without children, £120/year for lone parents, £375/year for couples without children and £150/year for couples with children.

22 HRP refers to the 'Household Reference Person', defined as the householder with the highest income (or the oldest of two or more householders with the same income)

23 Note that while the CHAID model does not use the 'no overall change' category, in fact there are four nodes, totalling some 1.9 million households, that have a mean net/gain within the +/-£52 bracket and hence would be classed as 'no change' according to our definition. This is not far off the actual count of households in this category (some 1.6 million).

24 DECC (June 2011) 'National Energy Efficiency Data-Framework: Report on the development of the data-framework and initial analysis'. Available at: http://webarchive.nationalarchives.gov.uk/20130109092117/http://decc.gov.uk/assets/decc/11/stats/energy/energy-efficiency/2078-need-data-framework-report.pdf

25 The Home Energy Efficiency Database is managed by the Energy Saving Trust and can be briefly described as a national database which tracks house-by-house the energy efficiency characteristics of the UK's housing stock.

26 Data source: Department of Energy and Climate Change (DECC), Table 3.1: Domestic energy consumption by fuel 1970 to 2010 and Table 1.3c: Seasonally adjusted and temperature corrected final energy consumption data.

27 DECC (November 2011). 'Estimated impacts of energy and climate change policies on energy prices and bills'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/68820/3593-estimated-impacts-of-our-policies-on-energy-prices.pdf

28 The heat replacement effect takes account of the fact that, as a result of efficiency improvements, consumer products in the home produce less heat. To maintain the same level of thermal comfort, the householder therefore needs to increase heating fuel consumption.

29 Digest of United Kingdom Energy Statistics: Table 4.1.1: Natural gas and colliery methane production and consumption, 1970 to 2010; Table 5.1.2: Electricity supply, availability and

consumption, 1970 to 2010. Available at: www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/source.aspx

30 Table A2-2: Population projections by the Office for National Statistics (Great Britain) available at: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-229866

31 DECC (November 2011) 'Estimated impacts of energy and climate change policies on energy prices and bills'. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/68820/3593-estimated-impacts-of-our-policies-on-energy-prices.pdf

32 Sanders and Phillipson, 'Review of Differences between Measured and Theoretical Energy Savings for Insulation Measures, Centre for Research on Indoor Climate and Health', Glasgow Caledonian University: December 2006

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