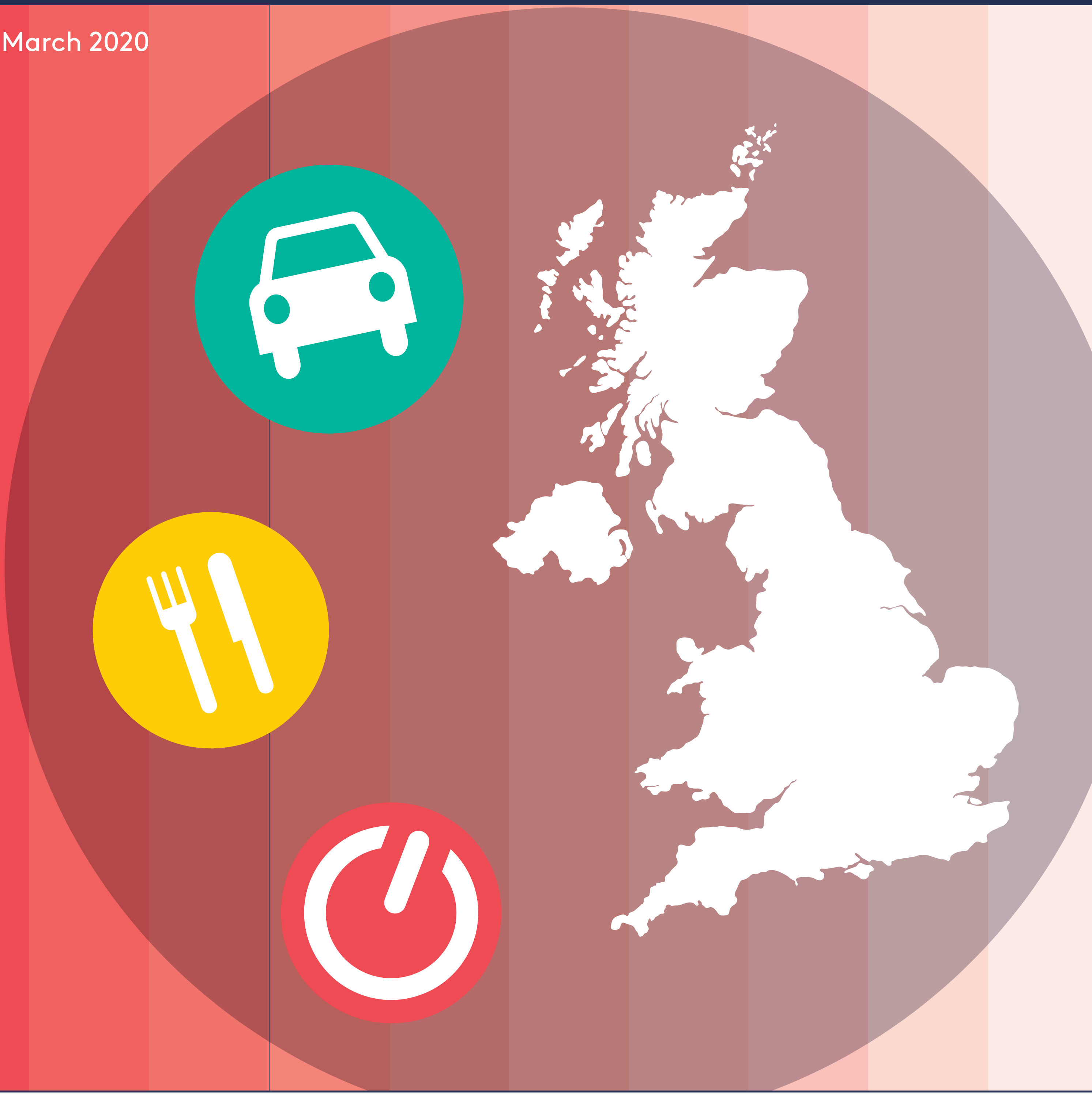
Distributional impacts of a carbon tax in the UK

Report 2: Analysis by income decile

March 2020



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About this report

This report has been written to inform the Zero Carbon Commission and the Zero Carbon campaign but is not influenced by the campaign or its commission. See www.zeroc.org.uk/

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Declaration of conflict of interest

All of the authors declare financial support from the Zero Carbon campaign for the submitted work and Sam Fankhauser is a member of the Zero Carbon Commission. Josh Burke and Sam Fankhauser declare financial support from the Grantham Foundation and the ESRC through the Centre for Climate Change Economics and Policy for the submitted work; Alex Kazaglis, Louise Kessler, Naina Khandelwal, Julia Bolk and Peter O'Boyle declare financial support from Vivid Economics for the submitted work. Anne Owen declares financial support from an EPSRC Fellowship award EP/R005052/1. The authors declare no other relationships or activities that could appear to have influenced the submitted work. All of the views expressed in this work are those of the authors and are independent of the funding institutions.

Acknowledgements

The authors are grateful to Adrian Gault and Aurélien Saussay for their helpful review comments. Thanks also to Daire McCoy, Alex Bowen, Ben Combes and Chris Beauman.

Editing and production by Georgina Kyriacou.

This report was first published in March 2020.

Suggested citation: Burke J, Fankhauser S, Kazaglis A, Kessler L, Khandelwal N, Bolk J, O'Boyle P and Owen A (2020) *Distributional impacts of a carbon tax in the UK: Report 2 – Analysis by income decile*. London: Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, London School of Economics and Political Science, and Vivid Economics.

This report is intended to inform decision-makers in the public, private and third sectors. It has been reviewed by internal and external referees before publication.

Contents

Executive summary

Main messages

- Carbon pricing is essential for effective climate action. It is a powerful fiscal and environmental tool that encourages emissions abatement where it is cheapest and sends a clear price signal that the polluter must pay.
- The UK's transition to net-zero greenhouse gas emissions must be distributionally fair, and policies must be designed to mitigate undesirable distributional impacts.
- Without mitigation measures, a carbon tax on energy fuels and agricultural goods is regressive, hitting low-income households disproportionately. In the transport sector a carbon tax is largely progressive as the share of income spent on transport increases with income.
- Understanding the geographic spread of carbon tax impacts is vitally important to prevent adverse impacts. For example, the impact of a carbon tax in Scotland will be particularly high in both absolute values (total tax impact in £/household/year) and relative values (impact as a proportion of income), because Scotland is colder and more rural than other parts of the UK, and therefore more heating and transport are used.
- Judicious use of carbon tax revenues – where economic 'losers' are compensated – can ensure distributional fairness and protection for low-income households.
- It is therefore possible to design a carbon tax scheme that leaves low-income households better off while driving the transition to net-zero emissions in the UK by 2050.
- Revenue recycling schemes that each use a similar amount of revenue can have vastly different impacts depending on how they are designed. We demonstrate that with a similar amount of revenue the redistribution policy can either be somewhat or extremely progressive.
- A pricing scheme that augments carbon prices with border carbon adjustment has a large impact on household bills across all income groups. However, of all the policy options it also generates the largest amount of revenue, which could be further used to mitigate the impact. A pricing scheme that uses carbon prices differentiated by sector has the least impact on bills across all income groups.

High-level recommendations

- The carbon tax level in the UK needs to be raised. A carbon tax consistent with net-zero emissions by 2050 would start at £50 per tonne of carbon dioxide.
- Conventional fiscal thinking that sees all revenue treated as general tax must change to ensure that the impacts of carbon pricing are distributed fairly and that the policy becomes more politically and socially acceptable. Carbon tax revenues should be explicitly used to correct undesirable distributional outcomes.
- Interventions focused on recycling revenue to households can make a substantial difference to the distributional impact of carbon pricing. Depending on the design of the revenue recycling, we show that distributing between 19 and 70 per cent of revenues to households via a uniform or targeted cash transfer can ensure that carbon tax policy is progressive.
- Using income and consumption differentials is a useful way to identify and understand the implications of carbon pricing policy. However, it is important to identify specific political entities within them, where opposition to carbon taxes may be particularly strong.
- When assessing the impact of carbon taxation, government must also assess both 'vertical' and 'horizontal' effects – that is, the differing effect of the tax on high- and low-income households, and the differing effects on households with similar incomes but different consumption patterns. Assessing these effects will ensure that carbon pricing can be designed to prevent regressive outcomes where there is within-income group variation in energy expenditures.

Now is an opportune time for the UK to reconsider how it prices carbon, in a way that ensures distributional fairness

The UK Government has committed to reducing greenhouse gas emissions to net-zero by 2050 and is also facing the implications of leaving the European Union. This confluence presents an opportunity to reconsider options for pricing carbon, a policy that is shown to reduce emissions.

Carbon pricing encourages emissions abatement where it is cheapest and sends a clear price signal that the polluter must pay. The latter is particularly important as it is poor people and communities that are most vulnerable to the societal and economic impacts of climate change and pricing carbon is a way of ensuring that the costs are not borne entirely by those who are affected rather than those who are causing the impacts through greenhouse gas emissions.

However, carbon pricing is often hard to implement as it is more transparent than other policies about its economic winners and losers. Therefore in its design of a carbon tax the UK must carefully consider how costs and benefits are distributed across society, to achieve both immediate political feasibility and the durability of carbon policy over time. With the new net-zero target there is an important opportunity to scrutinise conventional fiscal thinking – especially that all revenue is treated as general tax – to ensure distributional fairness.

Defining what is 'equitable' is a political judgment. Looking at the impacts on people at different levels of income is one way to conceptualise where and how these costs will fall and how spending on critical commodities as a proportion of income varies between different income groups. This report tests which revenue recycling methods ensure that the poorest households (in income deciles 1-3[1] who accounted for over 90 per cent of fuel poverty cases in 2019 according to the Government) are left either better off from a carbon tax or feel no net impact.

The UK has a number of carbon tax design features it can choose from

Conventional economic theory suggests that the price of carbon should be uniform, as this allows abatement costs to be equalised across sectors, ensuring cost-effectiveness. In reality the UK currently has a number of different carbon prices across the economy owing to overlapping policies and implicit and explicit price signals. Although unintended, this may not necessarily be a problem if the price levels are designed correctly, with the appropriate complementary policies.

Implementing an economy-wide carbon price in one single, large legislative reform is unlikely to be possible. Sectors for which carbon prices already exist can be grouped together in a first phase of tax policy reform. However, a carbon price may need to be phased in over time for those sectors where the institutional architecture to implement a tax does not exist, where the salience of pricing is low or where monitoring, reporting and verification (MRV) is likely to be complex.

There is a long-standing concern among policymakers that ambitious climate policies may lead to a loss of competitiveness in some industries. One solution to counter this leakage is the implementation of a border carbon adjustment (BCA) on the imports of energy-intensive goods from countries without appropriate environmental policies. The empirical evidence suggests that current carbon policies have had little impact on competitiveness. Nevertheless, BCAs have crept up the political agenda under Ursula von der Leyen's influence as new president of the European Commission.

'Vertical inequities' need to be addressed in carbon tax design

The vertical distributive effect of a carbon tax – the variation in impact along the income dimension – is found to be regressive. In other words, lower income households are hit harder than wealthier households, as the carbon tax represents a larger proportion of their income and they may have limited ability to offset higher energy costs through improving the insulation of their homes or by replacing low-high emitting vehicles with more efficient alternatives. This is also all the more unfair considering that in

1 Our analysis of 'income deciles' is based on dividing the 27 million households that were in the UK in 2016 into 10 equal sized groups by income, so each decile represents 2.7 million households.

2030, according to our findings, UK households in the highest income decile will on average emit 3.7 times more carbon dioxide-equivalent (CO_2e) than decile 1 and earn 9.4 times as much money.

Most literature on carbon taxation provides evidence for the regressivity of this tax. Government must assess these vertical effects, to ensure that carbon pricing can be designed to prevent a rise in fuel poverty and to increase public acceptability.

Revenue recycling

To increase the public and political acceptability of a carbon tax, revenues should be recycled in an equitable, cost-effective and visible manner. A revenue recycling scheme designed in this way may allow the implementation of carbon taxes with higher tax rates.

When designing a revenue recycling programme, government should weigh the importance of the efficiency and equity of the solution against its cost. Direct financial compensations are transparent and have direct financial benefit but their distributional impact heavily depends on the design of the policy. A differentiated cash transfer is more progressive in terms of benefitting lower income households more, but only when it is targeted correctly.

In our modelling for this report, households receive either a flat or a targeted transfer following carbon taxation: with a flat transfer each household receives the same amount, regardless of income, whereas with a targeted transfer, lower income deciles receive a higher rate, both in absolute and relative terms (as a percentage of income).

For low-income groups in the UK the effect of a carbon tax is minimal after financial compensation is received

Our model assesses issues raised in the literature, such as the effect on households' expenditure and temporal concerns, by modelling the effect of the carbon tax across 10 equally sized income deciles in the UK over the period 2020 to 2030. It also integrates a number of different revenue recycling schemes (flat versus targeted) and carbon price levels (uniform versus differentiated by sector), to examine how revenue recycling options affect these different income groups. This provides evidence for how revenue recycling may help alleviate the regressive impacts of carbon pricing among households at different income levels.

Modelled scenarios

This report models eight scenarios and compares the impact across income deciles at the household level in the UK by comparing household bills that have been subject to the policies and those that have not:

- Scenario 1 models the current situation (the baseline scenario).
- Scenario 2 models the impact of a carbon tax of £50/tCO_2 in 2020, rising to £75/tCO_2 in 2030 without any revenue recycling: that is, revenues accrue to the Exchequer as general tax.
- Scenarios 3–6 explore different tax rates.
- Scenarios 7–8 explore different recycling assumptions, using the central tax scenario.

Key findings on policy design

- There is a regressive impact overall of a carbon tax of £50/tCO_2 in 2020 and £75/tCO_2 in 2030 on UK households when there is no redistribution of tax revenues. A carbon tax at these rates on energy, food and transport sees households in the bottom three income deciles spending a higher proportion of their income, ranging from 2–4 per cent, on the tax than better-off households, with the top three income deciles spending 1–2 per cent of their income on the tax.
- The carbon tax on transport is, however, progressive, as the share of income spent on transport increases with income. The tax on energy is the most regressive.
- The redistribution of carbon tax revenues switches the tax from being regressive to progressive. The revenue recycling scenario with the redistribution of tax revenues and realisation of energy efficiency savings creates the smallest net impact in terms of household costs.

- While both flat and targeted redistribution scenarios are progressive, using the same amount of revenue, they show important differences in the net impact of the carbon tax between deciles. The difference between the highest and lowest income deciles is 2 percentage points for flat transfers, but 9 percentage points in the targeted case. This demonstrates that there can be a degree of flexibility in how revenues are redistributed.
- The difference between the region with the biggest impact (London) and the lowest impact (Northern Ireland) is £220 per household per year in 2030. The greatest impact of the tax in absolute terms, per household, is on households in London, followed by the South East and then Scotland. In relative terms the impact of the carbon tax is greatest in Scotland.

Conclusions: An economy-wide carbon price will generate significant revenues to fund the net-zero transition and to ensure it is equitable

Our results reconfirm that without recycling revenues, the introduction of a carbon tax has regressive impacts on household bills. Lower income households, specifically those in deciles 1 and 2, spend a much higher proportion of their income on the tax than higher income households (deciles 7–10). This is the case in 2016, 2020 and 2030, but there is a larger impact in 2030 – both in absolute and relative (as a percentage of income) terms – as the carbon tax rate goes up.

The anticipated revenue raised by implementing these policy changes will depend on households' behavioral responses to higher prices. If households do not change the quantity of carbon intensive energy and food they consume and the type of transport they use, we estimate that this policy package will raise significant revenue. Before recycling, the study projects revenues ranging between £14 billion and £36 billion in 2030 depending on the level of the tax, which sectors it applies to, when it is introduced and whether or not the price is augmented with border carbon adjustments. When BCAs are included, this generates the most revenue, although this also has the biggest carbon tax impact for households across all deciles.

We have demonstrated that recycling the revenue via household dividends can mitigate any bill increases arising specifically from the carbon tax for income deciles 1–3 so that there is either no net impact of the tax or households are better off. Of the revenue generated and depending on the revenue recycling scheme, between 19 and 70 per cent is needed to prevent regressive impacts of carbon taxation. This demonstrates that there is a degree of flexibility in the way revenue recycling schemes can be designed and recycling revenues via household payments can be a powerful means of offsetting some of the regressive social impacts of carbon taxes in the UK, particular for low-income groups.

Once tax revenues have been used to compensate households, 30 per cent of the revenues, equal to about £5 billion, is left over. This leaves significant fiscal headroom to increase public acceptability of carbon pricing through appropriate redistribution of the revenues; this could be to industry where genuine competitiveness concerns exist, or to help fund research into, and the development of, new low-carbon technologies, or to pre-empt increases in energy bills arising from the carbon tax before energy efficiency improvements are implemented. The appropriate balance will depend on the political context.

Our study also recognises that the salience of carbon pricing varies from sector to sector and therefore must be supported by complementary policies. The appropriate balance between regulation, taxes and subsidies will need careful thought.

Contribution to the debate

It is important to recognise some limitations to our approach. We do not have data on price elasticities of energy, food and transport across the distribution of expenditure, which are important when trying to understand the distributional effect of the carbon price policy we outline. Part of the reason for the lack evidence is that it is very hard to calculate this robustly. That said, the Institute for Fiscal Studies believes that elasticities are lower for the bottom income deciles – the groups we are focusing on are deciles 1–3 – and therefore we are more likely to accurately capture costs for these households. However, this limitation may result in an overstatement of the costs of the policy for wealthier households.

This report aims to inform the debate about how to design carbon taxes to increase public acceptability. The numbers presented are helpful to provide a snapshot of the effect on consumers today and in 2030. The numbers are a static representation of cost and revenue and must be revised over time, to reflect the dynamic nature of economies and allowing for behaviour change and technological and process innovation. We use simple and transparent assumptions, which show that the impacts on bills and revenues raised are not trivial and therefore warrant further analysis to fully understand the substitution effects of different carbon prices imposed on households.

1. Introduction

The challenge of net-zero emissions

In June 2019 the UK government set itself an unprecedented challenge in legislating to reach net-zero greenhouse gas emissions by 2050. The UK was the first major economy to set a target of this magnitude and ambition, although several countries have since followed suit. The UK now faces the task of reaching that goal in reality. At the same time, the UK, having left the European Union on 31 January, must revisit EU-level climate policies such as the EU emissions trading system (EU ETS).

The confluence of the new net-zero target and Brexit presents an opportunity for the UK to reconsider its options for pricing carbon, with the possibility of widening the coverage, strengthening the price signal and incorporating lessons from successful pricing schemes around the world (Burke et al., 2019).

Under a net-zero target, a more emphatic use of carbon pricing is necessary to induce emissions reductions in an efficient way. Carbon pricing is a powerful fiscal and environmental policy tool (Vogt-Schilb et al., 2019) that encourages abatement where it is cheapest and sends a clear price signal that the polluter must pay. However, carbon pricing is often hard to implement as it is more transparent than other policies about its economic winners and losers. Consumers are extremely sensitive to changes in the prices of vital provisions such as energy, transport and food. Recent protests in Chile, France and Ecuador as well as unrest in North Africa in 2011 demonstrate this to be true (Hallegatte, 2019). Thus, carbon prices are often too low to be truly effective, many sectors are not covered, and in those that are, significant exemptions dilute policy efficacy.

Designing efficient and effective carbon tax policy for a net-zero world therefore requires careful consideration of how costs and benefits are distributed across society in ways that determine both the immediate political feasibility and the durability of carbon policy options over time (Jenkins 2019; Carratini et al., 2018). Looking at the impacts on people at different levels of income is one way to conceptualise where and how these costs will fall and how spending on critical commodities as a proportion of income varies between different income groups.

Underpinning carbon pricing with equity and fairness

The UK is beginning to experience the societal and economic impacts of climate change. Heavier rainfall is leading to the higher likelihood of surface water and river flooding, and heatwaves are becoming more frequent. Poor people and communities are the most vulnerable to these impacts; it is widely recognised that it is unfair for the costs of climate change to be borne entirely by those who are affected by the impacts rather than those who are causing the impacts through greenhouse gas emissions. Economists therefore advocate putting a price on emissions through a tax or emissions trading. This is consistent with the 'polluter pays' principle and ensures that low-emissions goods and services can compete on a level playing field without their high-carbon rivals enjoying the advantage of an implicit subsidy.

Equity and fairness also means giving those being taxed an opportunity to participate in the decision-making process. To do so, consumers need to fully understand the policy and have a chance to express their views. This report can contribute to this process by informing consumers about the impacts of carbon tax policy and the role of carbon taxes in achieving net-zero greenhouse gas emissions.

While many climate policies, including carbon pricing, have the potential to be regressive – that is, their costs are borne disproportionately by poorer people – it is possible to mitigate such impacts on households, to ensure fairness and political acceptability. Her Majesty's Treasury is currently undertaking a review of how the transition to net-zero will be funded and where the costs will fall. That review presents an opportunity to ensure that UK carbon policy is underpinned by principles of equity and fairness, contributing to a 'just transition' from a high to zero-carbon economy and society. In addition, doing so will help to avoid resistance and backlash from those who might otherwise lose out (Gambhir et al., 2018).

Defining what is 'equitable' is a political judgment. This report tests which revenue recycling methods ensure that the poorest households (income deciles 1–3) are either better off from a carbon tax or feel no net impact. These compensatory policies have to address both *vertical inequities* – between high- and low-income households – and *horizontal inequities* – where income levels are similar but other household characteristics, such as energy consumption, differ. Judicious use of the revenues is just as important as the price level. Higher carbon taxes will generate significant revenues and it is important to assess how best to use them.

Now that the Government has committed to a net-zero target, there is an important opportunity to scrutinise conventional fiscal thinking – especially that all revenue should be treated as general tax – to ensure distributional fairness, greater political acceptability and the durability of the measure. For example, tax revenues could be recycled to finance energy efficiency improvements, which reduce energy bills, or the social or economic impact of the tax could be cushioned by lowering other taxes or offering direct financial compensation to households. Recycling revenue in these ways would provide a progressive means to achieve an accelerated and just transition to a net-zero economy.

Project objectives

The main objectives of this study are:

- To explore the distributional impacts of a net-zero-consistent carbon price across different income deciles[2] in the UK.
- To examine which combination of interventions may reduce carbon consumption and still be progressive.

This work informs two related processes:

- The UK public debate on carbon pricing for net-zero, including HM Treasury's review of how the transition to net-zero will be funded and where the costs will fall.
- The design of the UK's post-Brexit carbon pricing regime.

The report directly informs – but is not influenced by – the Zero Carbon campaign[3] and the work of its commission.

Approach

This project covers two main workstreams, the findings of which are released in two separate reports.

- The first workstream is a case study analysis that models the impact of carbon taxation across different household types in the UK with compensatory policies, focussing mainly on energy efficiency measures (*Distributional impacts of a carbon tax in the UK, Report 1: Analysis by household type* [Burke et al., 2020]).
- The second workstream models the impact of a range of carbon tax scenarios (including different tax rates, border carbon adjustments and compensatory policies) on energy, food and transport bills across income deciles in the UK. In terms of compensatory policies we compare the effectiveness of carbon tax dividends and energy efficiency measures in ensuring equity. This is the focus of the current report.

Structure of the report

Section 2 outlines different features of carbon tax design, how impacts vary by income decile and how recycling revenue to households can mitigate regressive impacts. Section 3 describes the scenarios and our methodology. The results of our analysis are presented in Section 4, including a detailed assessment by income decile. Section 5 concludes. Full details of our methodology and additional graphs showing impacts of the different scenarios on different deciles are provided in the Appendices.

2 Our analysis of 'income deciles' is based on dividing the 27 million households that were in the UK in 2016 into 10 equal sized groups by income, so each decile represents 2.7 million households. See Appendix A for more information.

3 The Zero Carbon campaign was set up by Stephen Fitzpatrick, chief executive of Ovo Energy, to campaign for the UK to introduce a 'General Carbon Charge' that would account for carbon emissions within the price of goods and return the money raised to citizens through a 'carbon dividend'. See www.zeroc.org.uk/

2. Different features of carbon tax design

In this section we draw on existing literature to highlight important features of carbon pricing policy design.

Uniform versus differentiated carbon tax

Conventional economic theory suggests that the price of carbon should be uniform (Stiglitz, 2019), as this allows abatement costs to be equalised across sectors, ensuring cost-effectiveness. In reality the UK currently has a number of different carbon prices across the economy owing to overlapping policies and implicit and explicit price signals. Although unintended, this may not necessarily be a bad thing if the price levels are designed correctly with the appropriate complementary policies. For example, differentiated prices may be better utilised during transition periods to stimulate rapid implementation while allowing sectors that can decarbonise relatively cheaply to do so unburdened (Burke et al., 2019).

Moreover, differentiated sectoral pricing recognises that each sector has different emissions abatement opportunities and that investment needs to reach *net* zero. In sectors where it is cheap to decarbonise, the carbon price can be lower or rise more slowly. For energy-intensive sectors, such as steel and cement, reaching net zero will be more costly and requires rapid technological innovation. Here the carbon price should be higher, therefore, although greater reductions in emissions in difficult-to-decarbonise sectors may be achieved by also investing in low-carbon technologies (Vogt-Schilb et al., 2018), as a carbon price by itself is unlikely to stimulate the innovation required. For those sectors, sacrificing economic efficiency may be worthwhile to ensure political acceptability.

Phased-in carbon tax

Implementing an economy-wide carbon price in one single, large legislative reform is unlikely to be possible. Sectors for which carbon prices already exist can be grouped together in a first phase of tax policy reform. However, a carbon price may need to be phased in over time for those sectors where the institutional architecture to implement a tax does not exist, where the salience of pricing is low or where monitoring, reporting and verification (MRV) is likely to be complex. A phased approach also allows consumers to become familiar with the tax and understand its effectiveness (Carattini et al., 2018). Many countries struggle with design and implementation of MRV systems for agriculture and agroforestry due to technical and institutional challenges (Rosenstock et al., 2019) and therefore a phased approach may be especially helpful for those in the land use sector.

Border carbon adjustments

There is a long-standing concern among policymakers that ambitious climate policies may lead to a loss of competitiveness in some industries (Dissou and Eyland, 2011). Stringent environmental policies may increase the production cost and decrease the competitiveness of energy-intensive industries. Leakages of carbon can occur as production may shift offshore to countries without a carbon tax.

One solution to counter this leakage is the implementation of a border carbon adjustment (BCA) on the imports of energy-intensive goods from countries without appropriate environmental policies (Dissou and Eyland, 2011). BCAs reduce free-riding and put pressure on 'climate laggards' to reduce their own emissions, by facing them with higher exporting costs (Mehling et al., 2019).

The empirical evidence suggests that current carbon policies have had little impact on competitiveness (Dechezleprêtre and Sato, 2017), reducing the importance of adjustment measures. Moreover, there are potential barriers to BCAs. Since they act as hidden trade barriers, BCAs are not necessarily compatible with World Trade Organization rules (Trachtman, 2016) unless foreign and domestic goods are similar or like-products[4] so that no product discrimination arises (Majocchi, 2018). There are also high administrative costs. Choosing which goods and countries to cover is costly and complex, as it is difficult to measure foreign producers' emissions and to put a price on those (Kortum and Weisbach, 2016).

4 See www.wto.org/english/tratop_e/envir_e/envt_rules_gatt_e.htm for an explanation of like-products.

Nevertheless, BCAs have crept up the political agenda since Ursula von der Leyen became president of the European Commission. Von der Leyen pledged before her election to introduce a BCA to "ensure our companies can compete on a level playing field" and "avoid carbon leakage" (Von der Leyen, 2019) and thus it was no surprise that BCAs were a key inclusion in her vision for an EU Green New Deal. But given the UK's existing high carbon price, the EU is unlikely to impose a BCA on the UK in the post-Brexit negotiations. A more likely outcome is that the EU may insist that in the design of a post-Brexit ETS, the UK must reduce the number of permits freely allocated to trade-exposed industry.

BCAs function as an import tax on both final goods and imported intermediate inputs, and increase consumption prices, reducing the welfare of consumers in the home country. The welfare losses are potentially greatest for the very poor and very rich as these groups consume larger shares of imported goods that experience a price increase through the BCA (Sager, 2019). There is mixed evidence for the effect of BCAs on the consumption prices or welfare of those in the home country. Some research finds no welfare effects (Kortum and Weisbach, 2016) while other research finds that BCAs increase welfare costs to households through higher import costs (Dissou and Eyland, 2011).

Impacts of carbon taxes on households of different income level

The vertical distributive effect of a carbon tax – the variation in impact along the income dimension – is found to be regressive. In other words, lower income households are hit harder than wealthier households, as the carbon tax represents a larger proportion of their income and they may have limited ability to offset higher energy costs through improving the insulation of their homes or by replacing low-energy-efficient products with more efficient alternatives (Berry, 2019). Most literature on carbon taxation provides evidence for the regressivity of this tax.

Modelling by Feng et al. (2010) shows that with a carbon tax of £93 per tonne in the UK, the lowest income group would spend 6 per cent of their income on the tax and the highest income group only 2.4 per cent. Browne et al. (2013) model many different scenarios for the UK and also find that the carbon tax is regressive.[5] Higher income households spend a much smaller portion of their income on the carbon tax. For example, for the scenario of a small carbon tax that does not include transport, the absolute amount of carbon tax paid is fairly similar across income deciles. However, around 45 per cent of the lowest income decile are classed as 'losers' from the tax (defined as those who experience an overall loss of £52 per year), while the proportion of 'losers' in the highest income decile is only 20 per cent (ibid.).

Regressive impacts observed in other regions of the world

The Canadian province of British Columbia implemented a carbon tax in 2008 with revenue recycling in place.[6] Without the revenue recycling the tax would be regressive (Murray and Rivers, 2015), as the lowest income decile spends 10 per cent of their total income on carbon-based energy goods, compared with 4 per cent of income for households in the upper half of income deciles. All else being equal, a carbon tax in British Columbia would reduce the disposable income of lower income households more compared with better-off households; however, the tax is designed to be revenue-neutral, with all revenues redistributed back to households in the form of tax reductions and direct transfers (see p11).

Research on a carbon tax in Ireland shows that a tax of €20/tCO_2 would have a skewed effect depending on income: the richest households emit 37 per cent more CO_2 than the poorest households, while their income is eight times higher (Callan et al., 2009). Similarly, in the UK Gough (2011) finds that household emissions for income decile 10 are on average six times greater than those of decile 1.

Micro simulation modelling in France finds that the carbon tax is expected to increase the share of households in fuel poverty by 6.4 per cent (Berry, 2019).

Level of regressivity by sector

The level of regressivity may also depend on the sector under consideration. A carbon tax is more regressive in the housing and food sectors than in others including transport. Lower income households

5 The scenarios modelled by Browne et al. (2013) are: Small carbon tax (CT), no transport: extend Carbon Price Floor (CPF) to household energy and other non-metered fuels; Large CT, no transport; Small CT including a VAT on household energy increase from 5 per cent to 20 per cent; Small CT including transport; Large CT including transport and extend the CPF also to transport.

6 This carbon tax was implemented at a level of C$30/t$CO_2$.

spend a larger share of their income on domestic energy use and often live in less energy-efficient housing than higher income households (Burke et al., 2019). Similarly, food is a 'necessary' expenditure with a low level of income elasticity and poorer households spend a greater percentage of their income than better-off households on food and cannot reduce this expenditure to reflect the addition of a carbon tax (Gough et al., 2011).

In the transport sector a carbon tax is less regressive as the share of expenditure on transport tends to increase as income increases. Higher income groups tend to use higher emitting transport options: for private road travel households in the highest income decile emit seven to eight times the amount that the lowest income decile emits (poorer households are less likely to own a car [Flues and Thomas, 2015; Landis et al., 2017]), and for aviation they emit 10 times as much (Preston et al., 2013).

Transport energy taxes can still have negative distributional implications *within* income groups (horizontally), even if they are progressive *between* income groups (vertically). For example, significant variation has been found within income octiles[7] in Sweden, particularly between those living in rural and urban areas or between central cities and suburbs in lower income octiles (Eliasson et al., 2016). Rural residents may simply drive more than urban residents do, and households within the same income group but located in different types of region face different welfare losses from a transport tax. Other disparities in impacts within income groups could arise from variations in car ownership in the poorest deciles or frequent flying in the richest deciles.

Revenue recycling

In our modelling for this report, households receive either a flat or a targeted transfer following carbon taxation: with a flat transfer each household receives the same amount, regardless of decile, whereas with a targeted transfer, lower income deciles receive a higher rate, both in absolute and relative terms (as a percentage of income).

This reflects approaches in the academic literature. For example, Berry (2019) compares the cost of different revenue options and finds that a targeted transfer – one targeted at low-income households in income deciles 1–3 – only requires 18 per cent of the revenue to be recycled to make the tax progressive. As a comparison, Berry finds that a flat transfer requires 59 per cent to be recycled and an income-based transfer where all households receive some sort of compensation requires recycling of 33 per cent of the carbon tax. As with our own study, these amounts reflect policy design choices and will therefore change depending on how the recycling policy is designed.

When designing a revenue recycling programme, government should weigh the importance of the efficiency and equity of the solution against its cost. Direct financial compensations are transparent and have direct financial benefit, but their distributional impact heavily depends on the design of the policy. While a flat transfer increases the equity and acceptability of the policy tool (Berry, 2019; Bourgeois et al., 2019) it is also a costly recycling policy as it pays all households. A differentiated cash transfer is more progressive in terms of benefitting lower income households more, but only when it is targeted correctly.

Other considerations that need to be taken into account pertain to possible rebound effects from revenue recycling. For example, financial transfers from the recycling of tax revenue may be used by households to purchase additional products and services: the exact mix of additional products and services purchased depends on the goods' income elasticities of demand. If these goods and services are highly emissions-intensive (e.g. flying for holidays) then this might limit the mitigation effect induced by the carbon tax. Policy strategies to mitigate the rebound effect can be found in the literature: these include economy-wide increases in environmental efficiency, shifts to greener consumption patterns and downsizing consumption (Font Vivanco et al., 2016).

Revenues from BCAs

Revenues from border carbon adjustments can be used to compensate both national and international jurisdictions where climate ambition is lower. Revenue collected through BCAs can be used to speed up the process of achieving net zero in the UK. As carbon taxes negatively affect export-oriented and

7 Where income is ordered into eight equal subsets.

energy-intensive industries, the proceeds of the BCA could be recycled back to those sectors to assist them. They could also be channelled back to countries that lose out from the BCA regime, such as developing countries, to support their climate change adaptation or mitigation. In such an instance the BCA results in financial flows to those countries that most need it while simultaneously contributing to international climate change policies (Mehling et al., 2019).

Revenue neutrality

Another policy option is to make the tax revenue-neutral, with all revenues recycled to households and businesses. While some households face zero net costs if their carbon tax expenditure is fully compensated by revenue from the tax, under this design they are still incentivised to reduce the consumption of polluting goods as these are the ones that are taxed and thus face higher prices.

As mentioned above, a revenue-neutral carbon tax has been implemented in British Columbia, mainly by reducing business and household taxes as a compensatory measure after a carbon tax is imposed. Such a design is seen as favourable as it has the potential to enhance economic growth by lowering pre-existing distortions from the existing tax system (Murray and Rivers, 2015). Increasing the carbon tax and using that revenue to reduce 'distortionary' income taxes will improve the overall efficiency of the tax system (Carbon Pricing Leadership Coalition, 2016): this is frequently called the 'double dividend'. It also increases acceptability as there are higher taxes on the 'bads' – i.e. pollution – than on the 'goods' – labour.

Recycling to avoid backlash and promote acceptability

Despite their fiscal and environmental benefits, carbon taxes often face political and societal backlash. Reasons are that the perceived distributional impacts are seen as unfair, taxpayers discount the benefits more than the costs, which are incurred immediately, and there is scepticism that there truly are environmental benefits (Dominioni and Heine, 2019). How acceptable a carbon tax is deemed depends on the fairness in the way the impacts are distributed, trust in politicians, policy stability (Klenert et al., 2018) and evidence that carbon taxes reduce emissions.

To increase the public and political acceptability of a carbon tax, revenues should be recycled in an equitable, cost-effective and visible manner. A revenue recycling scheme designed in this way may allow the implementation of carbon taxes with higher tax rates. Deciding on the 'best' bundle of policy options consists of a trade-off between efficiency, equity, acceptability and cost[8] and the distributional impacts are dependent on the macroeconomic context. A policy can enhance the progressiveness of the carbon tax and the acceptability to the public while being cost-ineffective and vice versa. No option is 'universally superior': cuts in labour taxes increase GDP, employment and consumption, but increase income inequality in some cases. Similarly, lump-sum transfers are strongly progressive, but are associated with less economic growth and smaller employment gains,[9] leading to reduced purchasing power (Combet and Méjean, 2017). A political judgement is needed to determine the right balance between considerations for efficiency, equity, cost and public acceptability.

Other revenue recycling options

There are many other revenue recycling options besides direct financial transfers and energy efficiency improvements to households; each has its own pros and cons. Several carbon tax proposals have been put forward in the United States, differing from one another only on the level of the tax and the use of revenue. All proposals set aside a proportion of revenues to protect vulnerable households but show varied options for the remainder of the revenue, which target different audiences: equal carbon dividends, infrastructure, reductions in labour taxes, investing in workers dependent on fossil fuel industry or social security payments (Kaufman et al., 2019). Revenue can also be used to provide transitional support to industry by supporting R&D and energy efficiency innovation (Carbon Pricing Leadership Coalition, 2016). A more detailed list of policy options and their pros and cons is provided in Table 2.1.

8 These four categories are direct effects of revenue recycling. Other categories can be included, such as environmental impact, economic impact and competitiveness (Canada's Ecofiscal Commission, 2016).

9 This is mainly caused by rising production costs that spread through the economy: higher energy costs are not counterbalanced by lower employment costs (a lower labour tax).

Table 2.1. Pros and cons of different revenue recycling options		
Approach	**Pros – opportunities**	**Cons – challenges**
Reduce other taxes	• Improve efficiency of tax system • Promote economic activity	• Preferential treatment of certain groups • Reducing other taxes can reduce efficacy of carbon tax
Household transfers	• Fairness and social impact • Public support	• Missed opportunities to improve productivity of whole economy • Administratively complex • Possible rebound affects
Transitional support for industry	• Economic growth • Reduces social and industry opposition • Boosts environmental benefits	• Can reduce efficacy of carbon price • Can unfairly benefit some firms or sections that have competitive advantage
Public debt and deficit reduction	• Long-term economic benefits • Intergenerational affordability: reduces cost of climate change that must be paid back by future generations	• Limited public acceptability, as it is less tangible than other options • No direct environmental benefit
General spending	• Increases government resource availability • Economic support	• Lack of clear returns
Climate investment funding	• Funding prioritisation of climate change investments • Corrective potential by targeting those adversely impacted by climate change • Thematic coherence and public support	• Negative perceptions of increased public spending • Inadequate levels of expenditure if revenues shrink

Source: Authors, based on Carbon Pricing Leadership Coalition (2016)

Testing these observations

In the next section we test the conclusions from the literature outlined above. The model assesses issues raised in the literature, such as the effect on households' expenditure and temporal concerns, by modelling the effect of the carbon tax across 10 equally sized income deciles in the UK over the period 2020 to 2030. It also integrates a number of different revenue recycling schemes and carbon price levels (uniform versus differentiated by sector), to examine how revenue recycling options affect these different income groups. This provides evidence for how revenue recycling may help alleviate the regressive impacts of carbon pricing among households at different income levels.

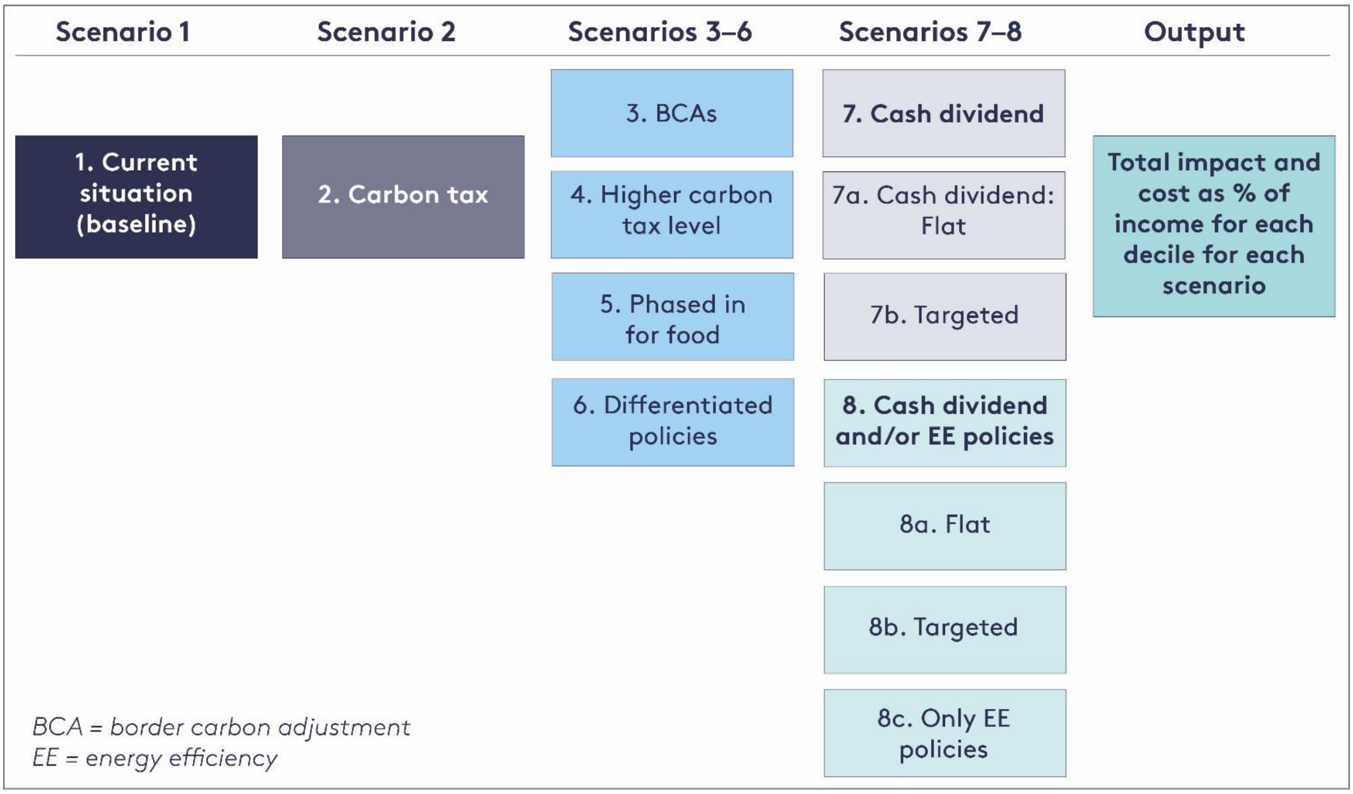
3. Methodology

Overview of scenarios

This report models eight scenarios and compares the impact across income deciles at the household level in the UK by comparing household bills that have been subject to the policies and those that have not:

- Scenario 1 models the current situation (the baseline scenario).
- Scenario 2 models the impact of a carbon tax of £50/tCO_2 in 2020, rising to £75/tCO_2 in 2030 without any revenue recycling: that is, revenues accrue to the Exchequer as general tax.
- Scenarios 3–6 explore different tax rates (see Figure 3.1/Table 3.1).
- Scenarios 7–8 explore different recycling assumptions, using the central tax scenario (see Figure 3.1/Table 3.1).

Figure 3.1. Overview of scenarios under consideration



Source: Authors

Assumptions behind the scenarios

Each scenario faces the following assumptions, with further details included in Table 3.1 below:

- The tax is levied on the energy, transport and food sectors, unless otherwise stated.
- Fuel duty for road transport is included in baseline scenario 1, then in subsequent scenarios is replaced by the carbon tax.
- Households face a rest of the world (RoW) tax of £2/tCO_2 in 2020 and £11/tCO_2 in 2030.
- Households pay the EU emissions trading system (ETS) tax on imported goods from the EU.
- The EU ETS is applied to UK domestic producers only in baseline scenario 1 and is replaced by the carbon tax in the other scenarios.
- Income deciles are not equivalised, which means that differences in households' size and composition are not taken into account (see Appendix A for further explanation).

Table 3.1. Description of scenarios and their key underlying assumptions						
Scenario	Description	Assumptions	2020 tax	2030 tax	Sector specific	Recycling
Carbon price scenarios						
1	Current situation/ baseline	Use price levels of 2019 UK fuel duty and climate change levy	ETS in EU and UK: £26/tCO_2	ETS in EU and UK: £43/tCO_2	Only the power sector and Industry is covered	None
2	Carbon tax with no recycling	Fuel duty for road transport and climate change levy is replaced by the carbon tax	£50/tCO_2	£75/tCO_2	All sectors	None
3	Carbon tax with border carbon adjustments (BCAs)	Fuel duty for road transport and climate change levy is replaced by the carbon tax	£50/tCO_2	£75/tCO_2	All sectors; RoW tax is the difference between UK carbon tax and RoW tax level	None
4	Higher carbon tax level	Fuel duty for road transport and climate change levy is replaced by the carbon tax	£98/tCO_2	£142/tCO_2	All sectors	None
5	Phased in for food	Fuel duty for road transport and climate change levy is replaced by the carbon tax	£50/tCO_2	£75/tCO_2	The food sector faces a zero carbon tax in 2020, but is introduced in 2027 rising to £75/tCO_2 in 2030	None
6	Differentiated prices	Fuel duty for road transport and climate change levy is replaced by the carbon tax	£40/tCO_2	£60/tCO_2	Surface transport, buildings, agriculture and land use, waste, fuel	None
			£50/tCO_2	£75/tCO_2	Aviation, shipping, energy-intensive industry	None
Revenue recycling scenarios						
7a	Carbon tax with cash dividend – flat payment	Same as 2 but with cash dividend	£50/tCO_2	£75/tCO_2	All sectors	70% of total tax revenue raised is returned to households equally in 2020 and in 2030

Table 3.1. Description of scenarios and their key underlying assumptions						
7b	Carbon tax with cash dividend – targeted payment	Same as 2 but with cash dividend	£50/tCO_2	£75/tCO_2	All sectors	70% of total tax revenue raised is returned to households in 2020 and in 2030; D1* receives 25% of total revenue collected and D10 0%
8a	Carbon tax with flat cash dividend and energy efficiency policies	Same as 7a but with energy efficiency policies	£50/tCO_2	£75/tCO_2	All sectors	70% of total tax revenue raised is returned to all households equally in 2020 and in 2030
8b	Carbon tax with targeted cash dividend and energy efficiency policies	Same as 7b but with energy efficiency policies	£50/tCO_2	£75/tCO_2	All sectors	70% of total tax revenue raised is returned to households in 2020 and in 2030; D1* receives 25% of the total revenue collected and D10 0 %
8c	Carbon tax with energy efficiency		£50/tCO_2	£75/tCO_2	All sectors	None

*Notes: The carbon tax rates come from the Grantham Research Institute's high-level national carbon tax recommendations towards a net-zero target (Burke et al., 2019). *D1 and D10 = deciles 1 and 10. For % received by deciles 2–9, see Table 3.2 below. BCA = border carbon adjustment. RoW= rest of world. Source: Authors*

The origin of products is split between domestic, EU (excluding the UK), and the rest of the world (RoW). The RoW carbon price is £2/tCO_2 in 2020 and £11/tCO_2 in 2030.[10] The 2020 price is a weighted average of the current carbon prices of the UK's main trading partners, based on the gross value added (GVA) of imports to the UK. For 2030, the carbon price for countries with a current carbon price is either based on actual projections or on the growth rate of the EU ETS over the last 10 years. For countries without a carbon price we have assumed the carbon price will be US$5/t$CO_2$ in 2030.

10 The calculated RoW carbon prices were in US dollars, at $2.10/t$CO_2$ in 2020 and $13.90/t$CO_2$ in 2030. These numbers have been converted with the exchange rate from OFX, using the 2019 monthly average of $1 = £0.782354.

Table 3.2. Tax revenue returned to households under flat and targeted transfer policy										
Income deciles	D1 (lowest)	D2	D3	D4	D5	D6	D7	D8	D9	D10 (highest)
Flat transfer (7a)	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
	£492	£492	£492	£492	£492	£492	£492	£492	£492	£492
Targeted transfer (7b)	25%	20%	15%	12%	10%	10%	5%	3%	-	-
	£1,230	£984	£738	£591	£492	£492	£246	£148	-	-

Notes: In the flat transfer scenario all households receive the same amount: £492 in 2030; this level is calculated so that the net impact of the policy for decile 3 is zero. In the targeted transfer scenario, each decile receives a different amount of the total revenue pool so that lower deciles are even better off: the rebate to deciles 9 and 10 has been set to 0 as the low level of these rebates may not be worth the administrative burden. Source: Authors

Data sources

The UK's National Carbon Footprint Account

To investigate the effect of a carbon tax where households pay in proportion to the direct and embodied carbon associated with their expenditure on certain goods and services, we need to calculate the carbon footprint of households by income decile. The UK's carbon footprint is the total greenhouse gas emissions emitted to meet the final demand of UK households, government and capital investment. The carbon footprint of households includes both the direct and indirect carbon associated with the full supply chain of goods and services consumed by households in one year. This will include emissions from both foreign factories producing goods imported for UK households' consumption and UK households' consumption of domestic goods.

To calculate the carbon footprint of the UK – which is a National Statistic (DEFRA, 2019) – the Government uses a UK-focussed multiregional input-output (MRIO) database, developed by the University of Leeds. MRIO databases make the link between the environmental impacts associated with production techniques and the consumers of products (for more details see Appendix A). For our purposes, this national carbon footprint then needs to be disaggregated by household income decile. To do this we need data on the expenditure of households of different incomes.

The Living Costs and Food Survey

Since 1957, the Office for National Statistics (ONS) has annually surveyed UK households on their weekly expenditure (UK Data Service, 2019). In 2008 this survey became known as the Living Costs and Food Survey (LCFS). The LCFS achieves a sample of around 6,000 UK households and is used to provide information on retail price indices, National Account estimates of household expenditure, the effect of taxes and benefits, and trends in nutrition. As well as providing information on household spend on more than 300 different product types, additional information is collected such as the age, sex and occupation of household members, total household income, and the household's location, tenure and dwelling type.

We have used this survey to develop an expenditure profile for 10 household income groups and to calculate a carbon footprint by product expenditure category for each income group. The results are given in Section 4.

4. Analysis of distribution of carbon tax impacts across income deciles in the UK

Impacts of carbon taxation on household expenditure for different sectors, by income decile, for our core scenario

Across the sectors of transport, food, energy and 'other' (see below), we calculate that in 2030 UK households in the highest income decile will emit 3.7 times more carbon dioxide-equivalent (CO_2e) than decile 1 and earn 9.4 times as much money.[11] The last time a study quantified this for the UK, household emissions on average across the four sectors for the highest income decile were six times larger than for the lowest decile (Gough, 2011). Between 2011 and 2030 the gap therefore reduces by almost a half.

Table 4.1. Household emissions by income decile in 2030 (tonnes of carbon dioxide equivalent/CO_2e)

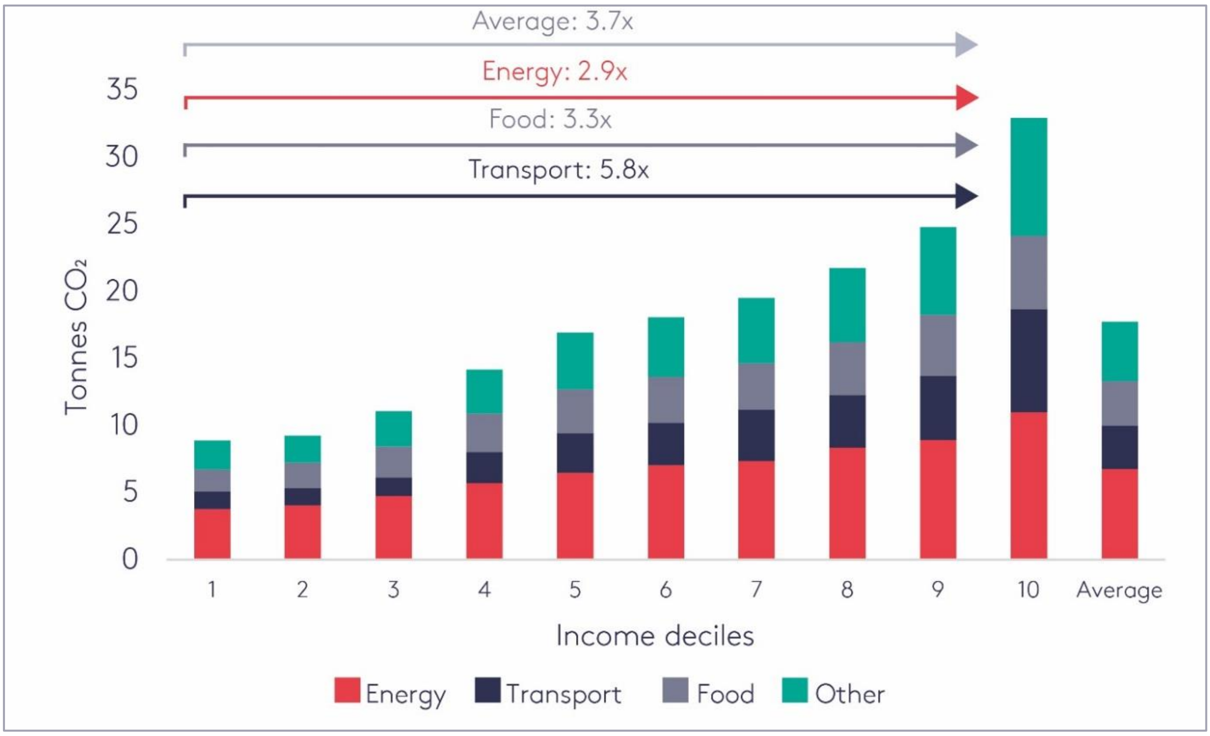
	Income deciles (1 is the lowest)										
Sector	1	2	3	4	5	6	7	8	9	10	Av.	10:1 ratio
Transport	1.32	1.29	1.39	2.30	2.95	3.15	3.78	3.95	4.79	7.67	3.26	5.83
Food	1.65	1.90	2.32	2.91	3.27	3.43	3.51	3.95	4.55	5.48	3.30	3.32
Energy[1]	3.79	4.05	4.72	5.70	6.47	7.04	7.36	8.32	8.91	10.98	6.73	2.92
Other[2]	2.14	2.00	2.65	3.27	4.23	4.46	4.84	5.52	6.55	8.79	4.44	4.12
Total	8.86	9.24	11.08	14.17	16.92	18.07	19.49	21.73	24.80	32.93	17.73	3.71
Average household income (£)[3]	10,958	15,563	20,236	25,546	31,151	37,721	45,494	56,169	73,043	102,770	41,865	9.37

Notes: 1. Energy covers heating and electricity. 2. 'Other' includes consumables such as furniture, glassware and education. 3. Income does include benefits. Source: Authors

The main difference in emissions by decile is in the transport sector: high-income households tend to use more emissions-intensive transport – such as aviation – more than lower income households. This is evidenced by the highest income households emitting 5.8 times as much CO_2e from transport use as the lowest income households. A tax imposed on transport is therefore not necessarily regressive. A tax on energy (heat and electricity) is the most regressive, as decile 10's emissions from energy are just 2.9 times the amount of decile 1's (see also Figure 4.1 below).

11 These calculations are based on 2016 emissions which have we have modelled for 2020 and 2030.

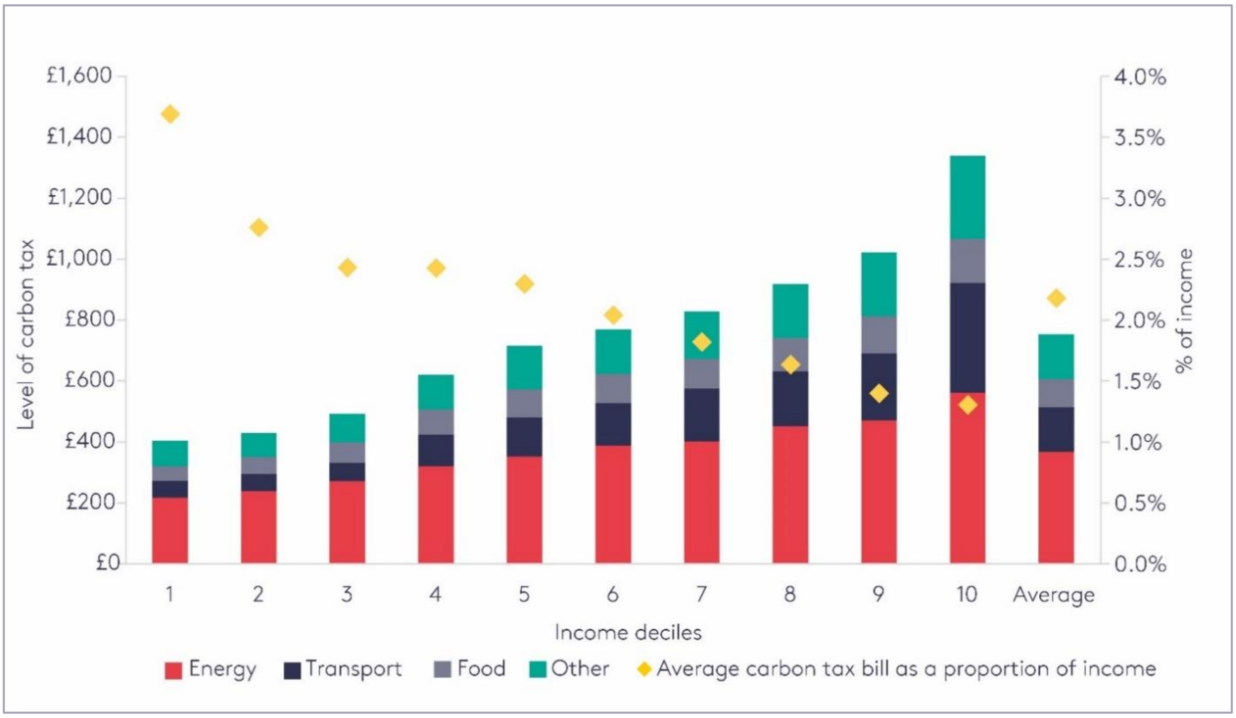
Figure 4.1. Household emissions by income deciles in 2030 (tonnes CO_2e)



Note: Arrows indicate the greater magnitude of decile 10's emissions compared with decile 1's. 'Other' includes consumables such as furniture, glassware and education. Source: Authors

Figure 4.2 shows the impact of carbon taxation introduced as described in scenario 2 – our core scenario – on income deciles in the UK.

Figure 4.2. Total carbon tax for each decile, split between food, transport, energy and other, for scenario 2* in 2030



*Note: *Scenario 2 is a carbon tax at £50/tCO_2 in 2020, £75/tCO_2 in 2030 for all sectors with no revenue recycling. 'Other' includes consumables such as furniture, glassware and education. Source: Authors*

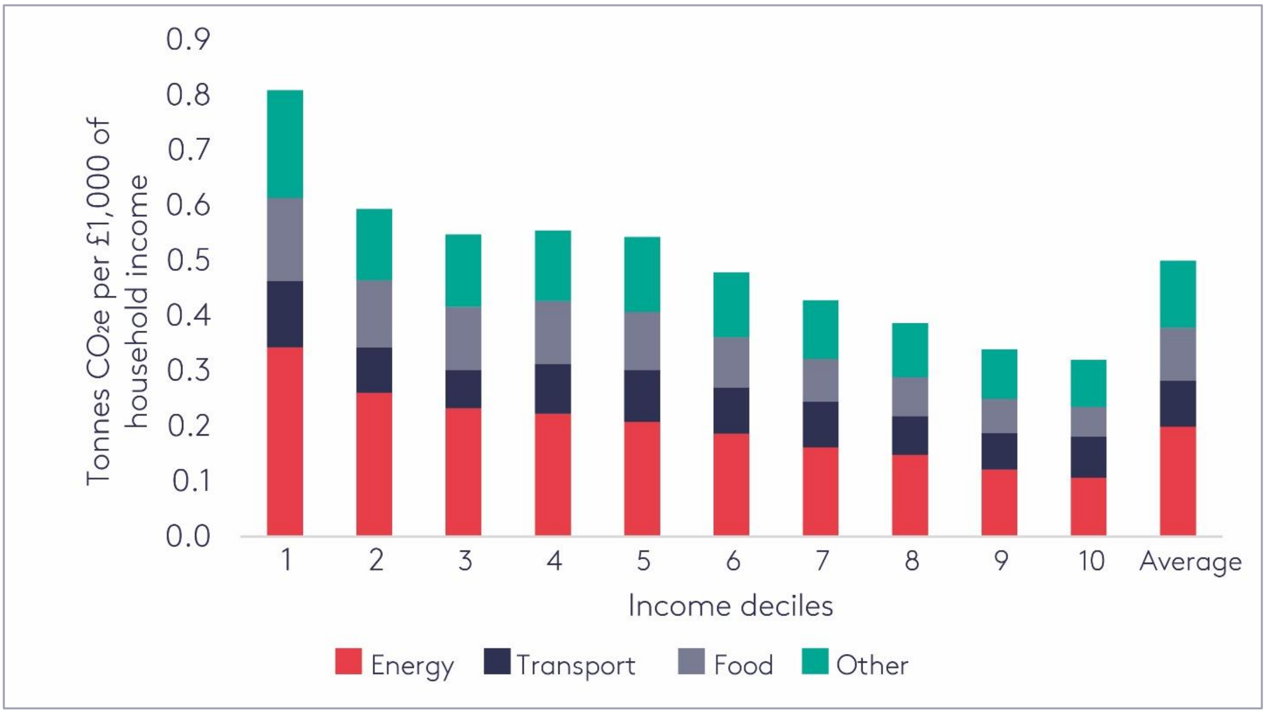
The introduction of a carbon tax has regressive impacts on household bills: poorer households, specifically deciles 1 and 2, spend a much higher proportion of their income on the tax than better-off households, at 3.7 per cent for decile 1 in 2030 compared with 1.3 per cent for income decile 10.

This trend is the same in 2016, 2020 and 2030, but there is a larger impact in 2030 – both in absolute and relative (as percentage of income) terms – as the carbon tax rate rises. In 2016, decile 1 households spend 1.3 per cent of their income on the carbon tax (in this case only energy is taxed by the EU ETS; there is no UK carbon tax) and in 2030 this rises to 3.7 per cent. In the scenario without a UK carbon tax, decile 1 households would spend 2.3 per cent of their income on the EU ETS in 2030. Without revenue recycling all income deciles are negatively affected as their carbon tax payments increase.

Most carbon tax is paid on energy (heating and electricity), with relatively small differences across deciles. While the household income in decile 10 is 9.4 times larger than in decile 1, decile 10 households spend 2.6 times more on carbon tax on energy than decile 1, and this increases to 3.1 times more for food and 6.5 times more for transport (as shown in Figure 4.2). Higher income deciles have a higher tax spend on transport, which is consistent with the findings from the literature review. A carbon tax on transport is therefore not necessarily regressive.

Examining the fairness in the way the impacts of carbon taxes are distributed requires going beyond emissions per household to also take into account the ratio of emissions to income. This is explored in Figure 4.3, which shows that lower income deciles emit more CO_2 per unit of household income – i.e. there is an inverse relationship between income and CO_2 emissions per unit of income, in contrast to the total impact shown in Figure 4.2. This reflects the fact that inequality in income far exceeds inequality in expenditure (Gough, 2011), which is mainly the case for the food and energy sectors, where poorer households (deciles 1 to 3) have a significantly larger emission rate per income than the higher income households (deciles 7 to 10). For transport the rate stays fairly similar across deciles, for reasons discussed above.

Figure 4.3. Household emissions of CO_2e (tonnes) per £1,000 of household income

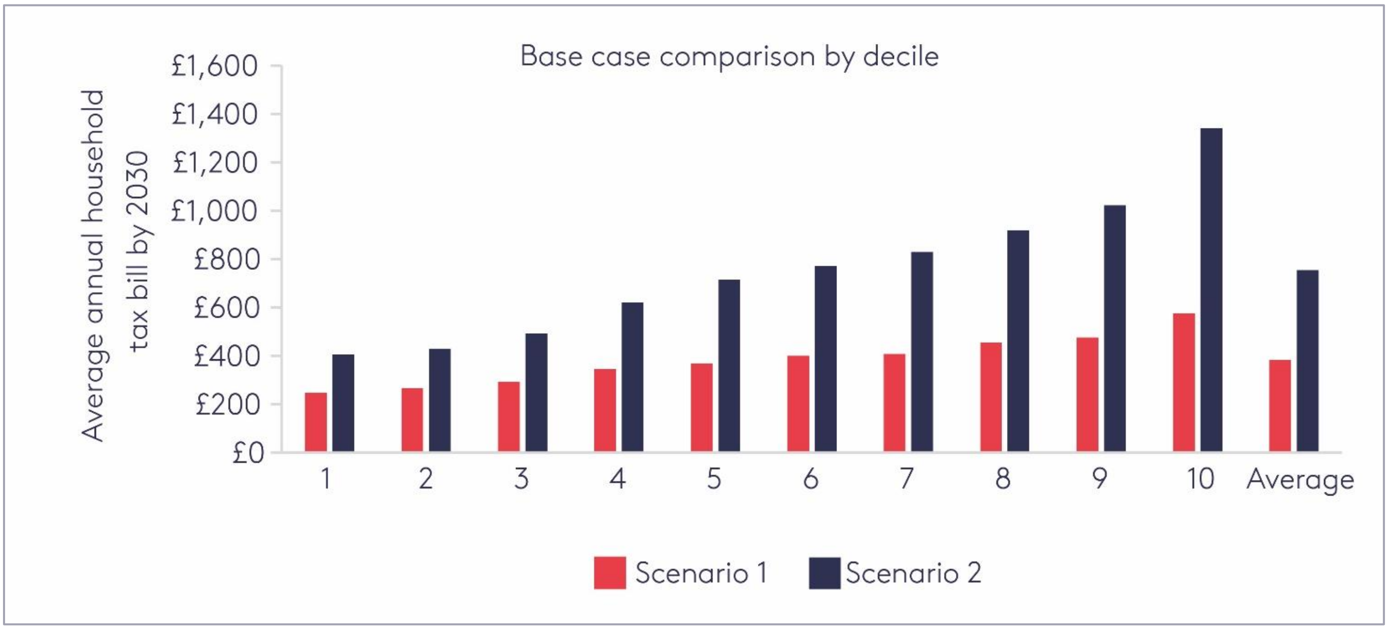


Source: Authors

The impact of the baseline carbon tax by income decile

Here we model and compare the impact on bills in 2030 from existing carbon pricing policy (scenario 1) – which we treat as the baseline tax – and how this would change were the policy to be replaced with a carbon tax starting at £50/tonne of CO_2 in 2020, rising to £75 in 2030 (scenario 2). The results are shown in Figure 4.4.

Figure 4.4. Annual impact on household bills of the baseline scenario 1 (existing carbon tax) compared with a raised carbon tax (scenario 2/central case), by income decile, in 2030



Note: Under scenario 2 the carbon tax starts at £50/tonne of CO_2 in 2020, rising to £75 in 2030. Source: Authors

Conclusions on baseline carbon tax impacts:

- In absolute terms a carbon tax hits higher income deciles the hardest, as they are the largest emitters. This reflects the higher carbon intensity lifestyles of wealthier households.
- Under scenario 2, the tax impact for deciles 5–10 is almost double that of scenario 1. For scenarios 1–4 the impact of scenario 2 is approximately 1.5 times larger.

Tax revenue recycling

For the revenue recycling options (scenarios 7 and 8), more than 70 per cent of the revenue collected needs to be distributed, in both the flat and targeted cases. This is broadly in line with the findings of previous studies. For example, Berry (2019) calculates that flat income redistributive policies require 59 per cent of total revenue raised. Adding energy efficiency policies reduces the revenue collected, as households pay a lower carbon tax by making energy savings on gas and electricity. The Government will collect more revenue if it implements BCAs (scenario 3) or raises the tax level (scenario 4). Using differentiated prices reduces the revenue collected, as some sectors only face a price of £40/tCO_2 in 2020 or £60/tCO_2 in 2030.

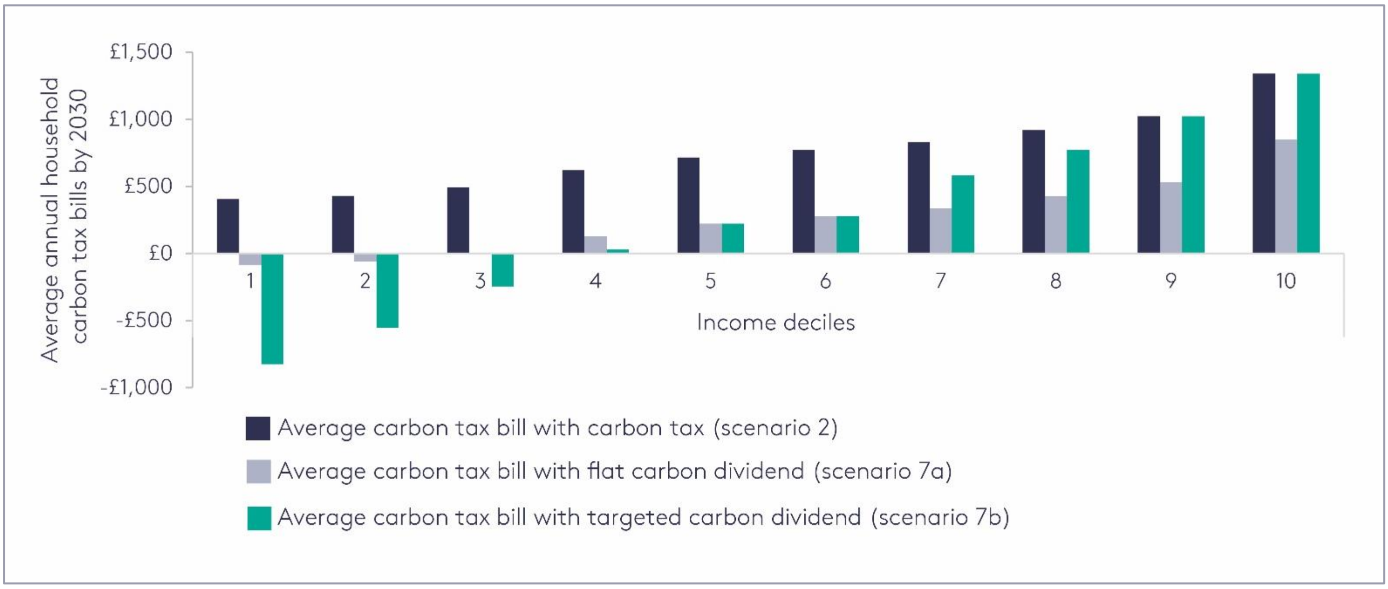
When only compensating deciles 1 to 3 to make the net impact on households zero, only 19 per cent of the collected revenue needs to be distributed. This is in line with findings from Berry (2019), where a transfer targeted at the households in income deciles 1 to 3 required 18 per cent of carbon tax revenue. This is the cheapest option to make the tax progressive. Alternatively, compensating deciles 1–6 so that there is no net impact of the tax for these deciles requires 50 per cent of the total revenue collected to be redistributed. But to achieve this outcome, higher income deciles receive a higher absolute amount. For example, decile 1 receives £404, covering their carbon tax bill, and decile 6 receives £770 (see Appendix B). Table 4.2 shows the amount of revenue raised and needed for each recycling policy.

Table 4.2. Amount of tax revenue raised and needed for each recycling policy				
Scenario	Tax revenue raised (£bn) in 2020	Tax revenue recycled (£bn) in 2020	Tax revenue raised (£bn) in 2030	Tax revenue recycled (£bn) in 2030
1	£8.17	n/a	£8.66	n/a
2	£15.17	n/a	£18.72	n/a
3	£27.40	n/a	£36.12	n/a
4	£29.74	n/a	£35.45	n/a
5	£13.51	n/a	£18.72	n/a
6	£11.54	n/a	£14.08	n/a
7a	£15.17	£10.65 (70%)	£18.72	£13.39 (71%)
7b	£15.17	£10.72 (71%)	£18.72	£13.48 (72%)
8a	£15.15	£10.68 (70%)	£18.40	£13.02 (71%)
8b	£15.15	£10.78 (71%)	£18.40	£13.33 (72%)
8c	£15.15	n/a	£18.40	n/a

Note: See Table 3.1 for description of scenarios. Source: Authors

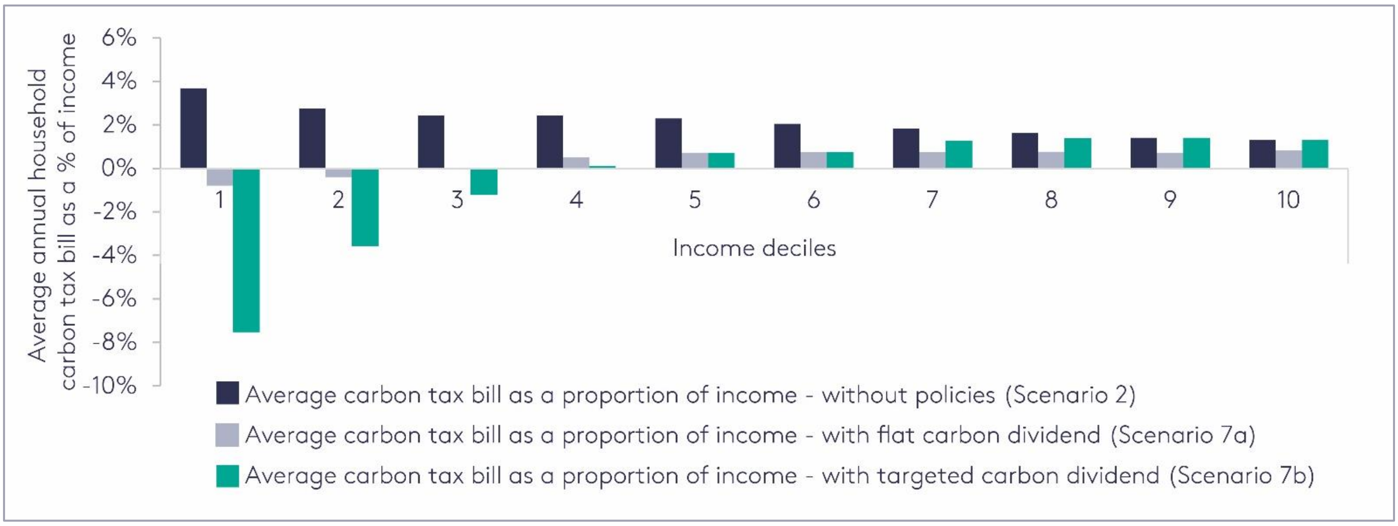
Figures 4.5 a and b show the average annual tax bill in absolute terms and as a percentage of income under different revenue recycling policies for all 10 income deciles.

Figure 4.5a. Average annual household carbon tax bills by 2030 under different revenue recycling policies



Note: See Table 3.1 for details of the scenarios. Source: Authors

Figure 4.5b. Average annual household carbon tax bills in 2030 as percentage of income under different revenue recycling policies



Note: See Table 3.1 for details of the scenarios. Source: Authors

Conclusions on household carbon tax bills and proportion of income spent on carbon tax under different revenue recycling policies:

- Without any revenue recycling policies, higher income households pay more in absolute tax, but this represents a smaller proportion of their total income. The carbon tax is thus regressive. In decile 1, the carbon tax represents 3.7 per cent of household income in 2030, and for decile 10 it represents 1.3 per cent.
- The flat payment equals the tax paid by decile 3 households, which is taken as the benchmark. The revenue recycling drastically affects the net impact of the carbon tax.
- With a similar amount of revenue, the redistribution policy can either be somewhat or extremely progressive: after a flat transfer the tax bill becomes -1 per cent of the income of a household for decile 1, and with a targeted transfer[12] this rises to -8 per cent (Figure 4.5b). Negative percentages mean that these income deciles are left with a net increase in wealth from the carbon tax.
- Transfers reduce the carbon tax paid by the different deciles. For deciles 1, 2 and 3 it even results in negative net carbon tax payments – the redistributed amount received is higher than the tax. The average household tax bill as a proportion of income for the lower income deciles differs widely across the three scenarios. For higher income households the tax bill as a proportion of income remains fairly stable across different scenarios.
- Scenario 7a, with a flat carbon dividend, results in a fairly neutral effect on the distribution of cost across the deciles, whereby the proportion of income spent on energy bills is largely equal across all deciles. A number of studies have found that a neutral cost distribution – all citizens paying the same share of income – increases policy acceptability (e.g. Maestre-Andres et al., 2019).

12 We follow Berry et al. (2019) and assume targeted transfers for the first three income deciles; the identification of households in these income deciles could be undertaken based on tax returns. How these transfers are effectively delivered is out of the scope of this project but could be done through cheques or in-kind payments (e.g. transport passes).

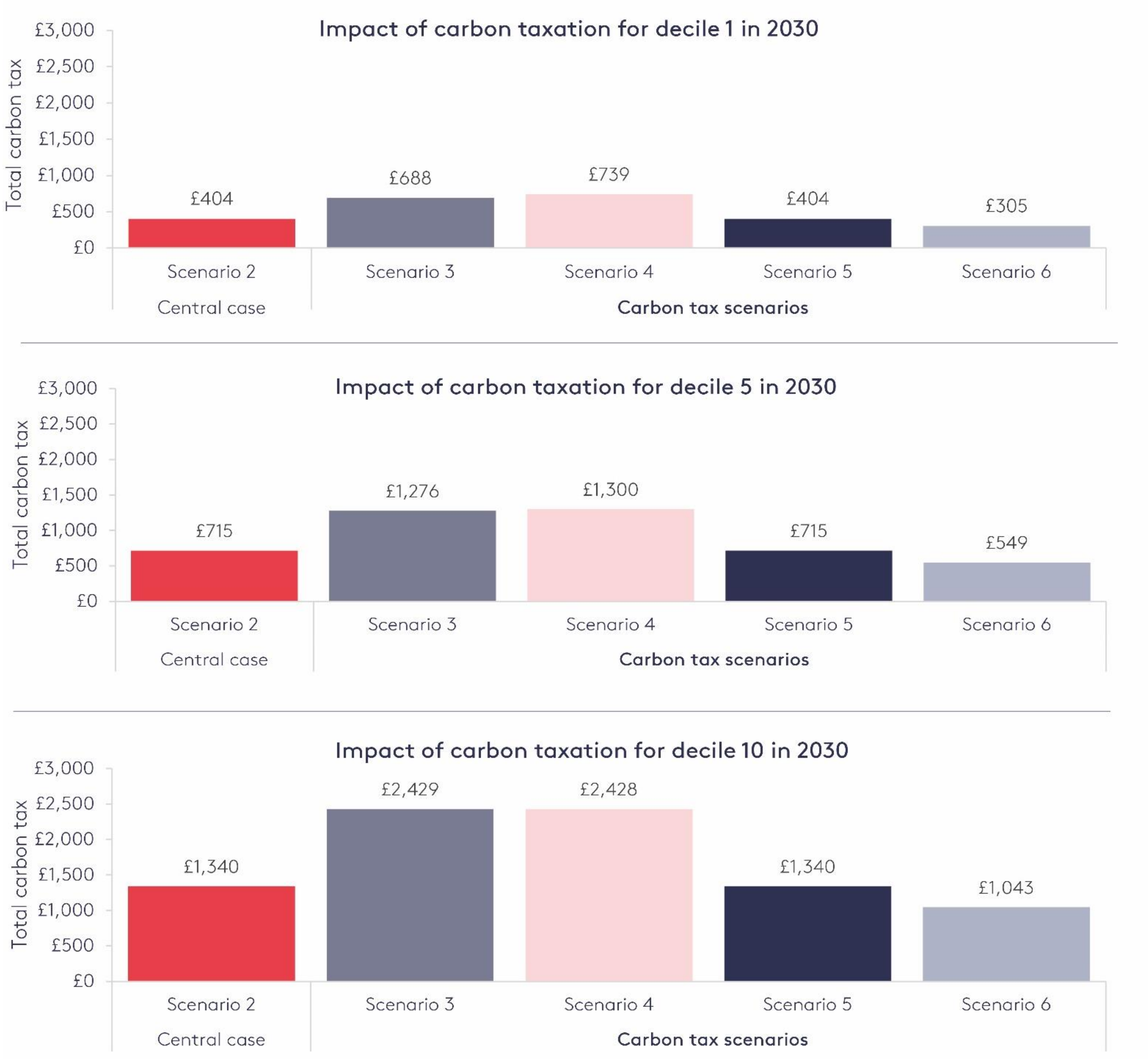
Sensitivity analysis

Carbon tax scenarios without recycling

The sensitivity analysis below takes the impact of scenario 2 on deciles 1, 5 and 10 shown in Figure 4.6 below – i.e. an annual household tax bill in 2030 of £404 – and compares this against the range of other price scenarios that do not include revenue recycling.

Figure 4.6. Sensitivity analysis across income deciles 1, 5 and 10 showing impact of different scenarios in £ per decile

Scenarios	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
	Central case	Carbon tax with BCAs	Higher carbon tax	Phased in for food	Differentiated prices
Tax revenue raised in 2030	£18.72bn	£36.12bn	£35.45bn	£18.72bn	£14.08bn



Source: Authors

Conclusions on the sensitivity analysis of the carbon tax-only scenarios:

- The carbon tax impact is approximately three times as large for households in income decile 10 (the wealthiest) as in income decile 1 (the poorest). This broadly reflects the fact that the average emissions for income decile 10 households are 3.7 times larger than decile 1 households.
- Figure 4.6 shows that scenario 4 has the biggest adverse impact on bills across for deciles 1–9. For income decile 10, scenario 3 has the biggest impact. In contrast, scenario 6, which uses differentiated prices, has the smallest impact and is the only scenario to have a smaller tax impact than the central case (scenario 2).
- When border carbon adjustments are implemented (scenario 3), the carbon tax rises steeply, because extending taxation to imports considerably expands the tax base. Border carbon adjustments have a bigger impact on wealthier households, which may be because these households spend more on imported carbon-intensive goods.
- In scenarios where the most revenue is raised, households face significantly higher impacts from the carbon tax. However, this also releases a large amount of revenue that can be recycled to lower these impacts.

Scenarios with tax revenue recycling

Figure 4.7 on the next page shows our sensitivity analysis of the impacts of recycling scenarios across income deciles 1, 5 and 10.

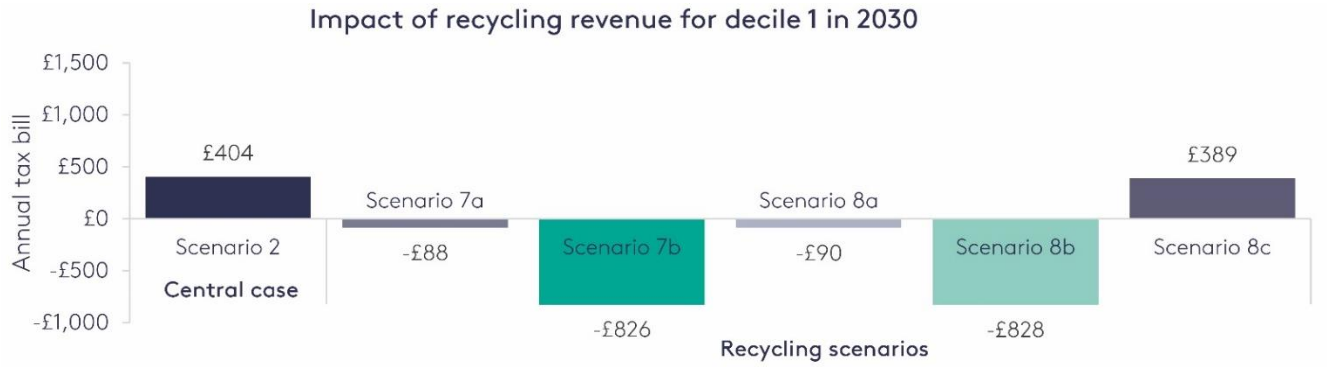
Conclusions on sensitivity analysis of revenue recycling:

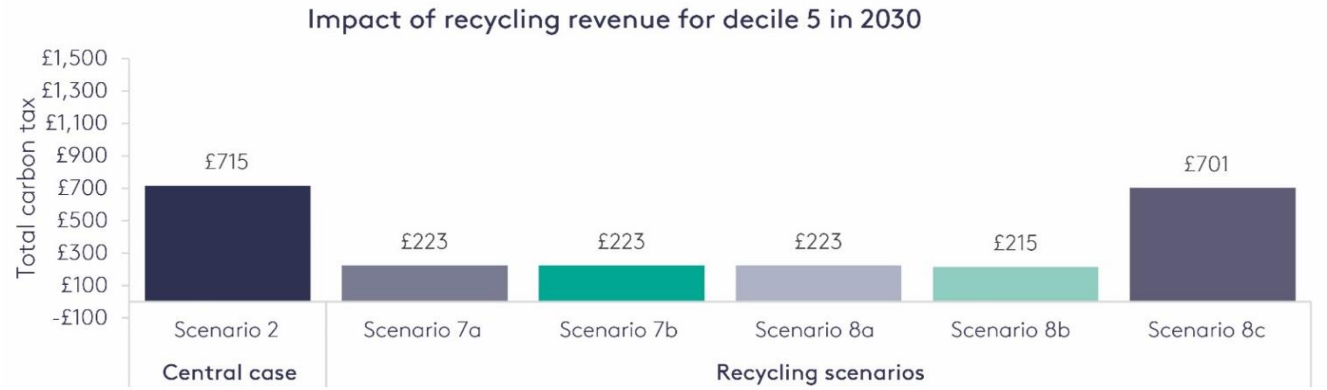
- The negative tax amounts in the recycling scenarios means that after redistribution, decile 1 households receive financial benefits that compensate for more than the impact of the carbon tax.
- With similar amounts of net revenue raised, the impact of the carbon tax varies significantly.
- Scenario 8b, which couples targeted payments with energy efficiency, reduces the tax impact the most for deciles 1–6.
- Recycling revenue solely for energy efficiency (scenario 8c) leaves all income groups significantly worse off compared to other recycling scenarios. However, it still reduces the impact of the carbon tax compared to a scenario with no recycling (scenario 2).
- A flat transfer reduces the impact of the carbon tax the most for high-income households such as those in income deciles 7–10.
- The biggest difference in the impact of the different recycling policies can be seen for deciles 1–3. This is a function of policy design in that these deciles specifically have been targeted. From deciles 4–10 there is far less difference in impact across the different recycling policies.

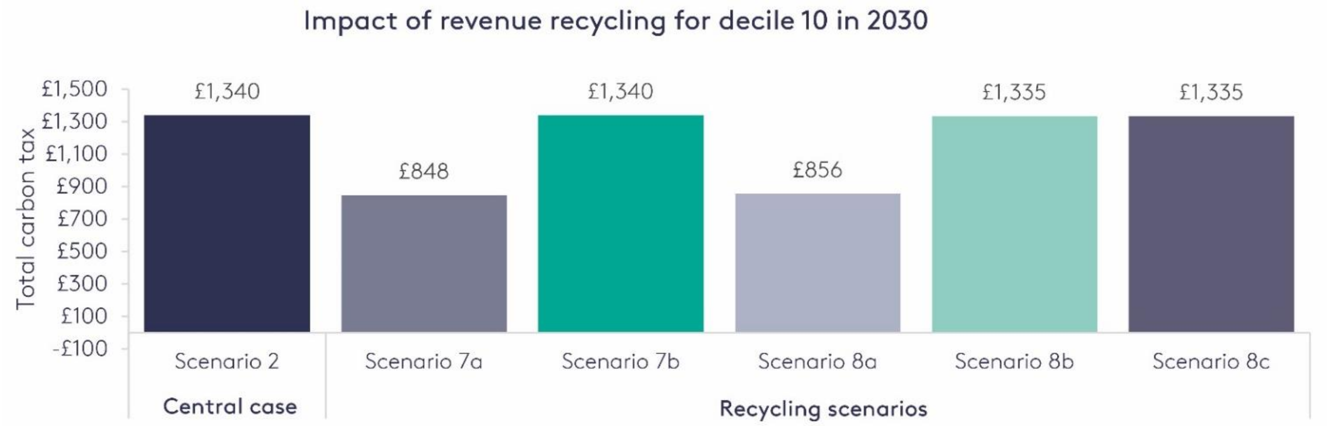
Rebound effects are likely to have minimal impact on household income. For example, if households in decile 1 use the additional income from revenue recycling under scenario 8b to emit an amount of emissions similar to the amount they would have emitted anyway (8.8 tonnes pre-recycle), the household would still be a net beneficiary of the carbon tax by about £388.

Figure 4.7. Sensitivity analysis across income deciles 1, 5 and 10 showing impact of recycling scenarios in £ per household

Scenarios	2	7a	7b	8a	8b	8c
	Central case	Flat transfer	Targeted transfer	Flat transfer + EE policies	Targeted transfer + EE policies	EE policies only
Tax revenue raised in 2030	£18.72bn	£18.72bn	£18.72bn	£18.40bn	£18.40bn	£18.40bn
Tax revenue distributed in 2030	-	£13.39bn	£13.48bn	£13.02bn	£13.33bn	-
Net tax revenue raised in 2030	£18.72bn	£5.34bn	£5.24bn	£5.39bn	£5.07bn	£18.40bn





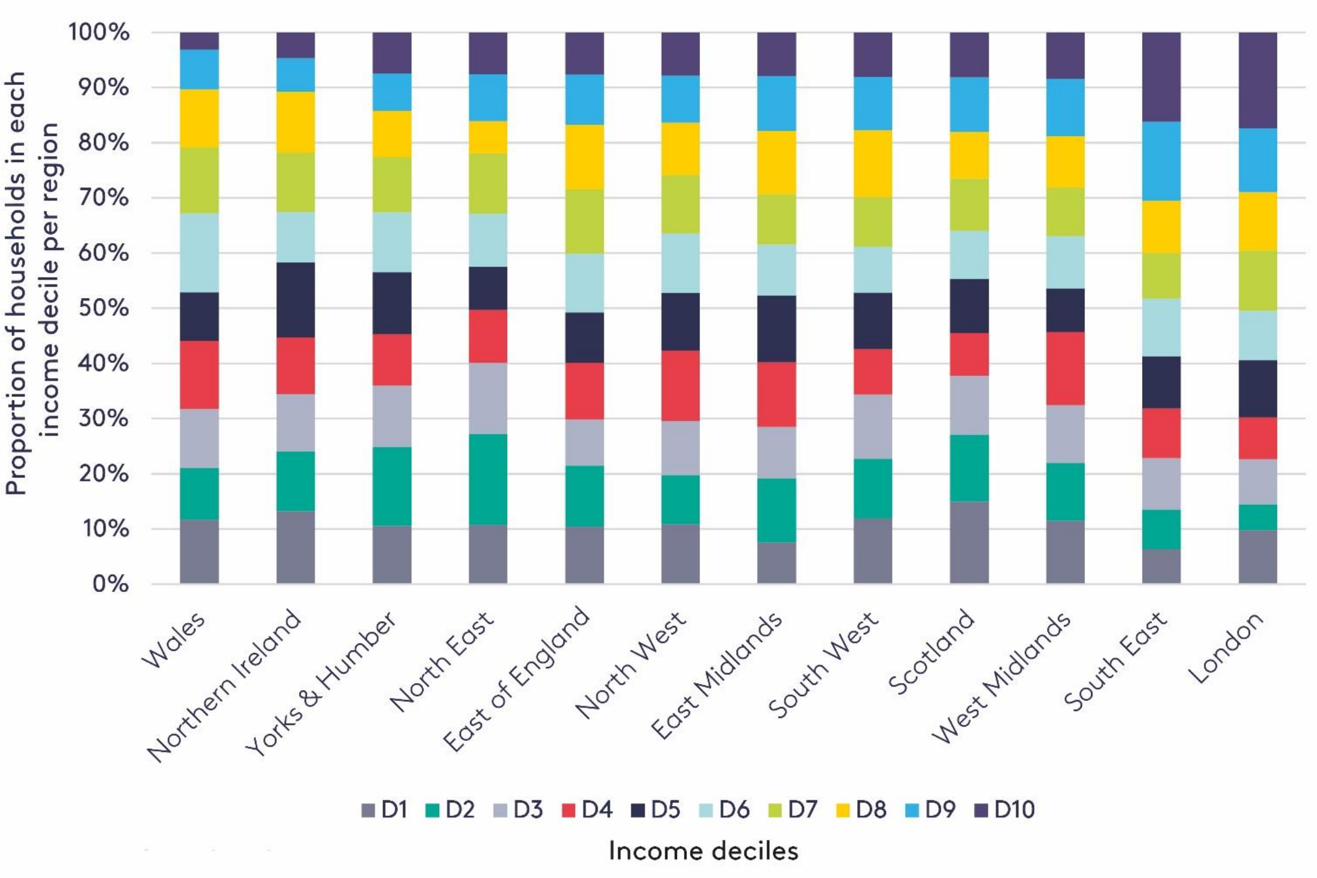


Notes: There is no revenue recycling in Scenario 2. Source: Authors

Variations by geographical location

The distributional impact of carbon tax policy also has a place-based element. Below we examine how income groups are distributed across the UK and how the impact of the carbon tax varies geographically under scenario 2 – our central case (carbon tax without revenue recycling).

Figure 4.8. Distribution of income within UK regions

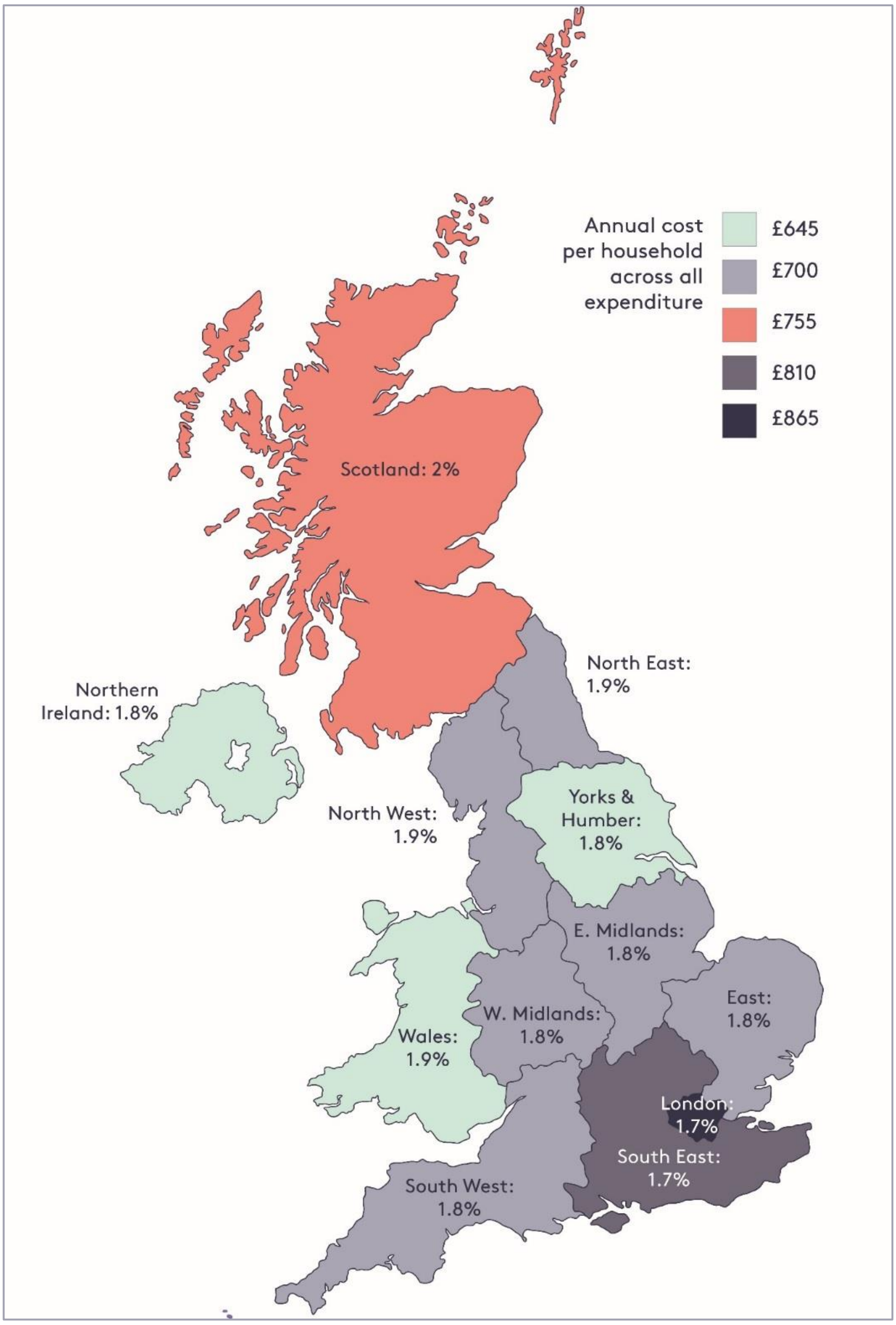


Note: Reading left to right, Wales has the lowest proportion of income decile 10 households and London has the highest proportion. Source: Authors

Figure 4.8 illustrates that London and the South East are the regions with the largest proportions of income deciles 9 and 10 households – the wealthiest. Wales has the smallest proportion of decile 10 households, followed by Northern Ireland and Yorkshire and the Humber. In terms of low-income households, Scotland has the largest proportion of decile 1 households, followed by Northern Ireland. The North East has by far the highest proportions of decile 2 and 3 households.

Figure 4.9 shows which regions experience the greatest impact of the carbon tax, both in absolute and relative terms, and compares this with the location of income deciles shown in the previous figure.

Figure 4.9. Impacts of scenario 2 carbon tax policy across UK regions in 2030: £ per household per year across all expenditure and % increase as a proportion of income



Source: Authors

Figure 4.9 shows some interesting results with the difference between the area with the biggest impact (London) and the smallest impact (Northern Ireland) being £220 per household per year. The greatest impact of the tax, in absolute terms, per household is on households in London, followed by the South East and then Scotland. For the first two regions this is expected as they have the largest proportion of high-income decile households, which leads to more consumption and thus a higher tax. In contrast, Scotland has the largest proportion of low-income households. This should mean a low tax on an income basis but because the climate in Scotland is colder and the country is more rural overall than other parts of the UK, more heating and transport is used and so the tax is high. Examining the impacts in absolute terms highlights that horizontal factors other than income distribution, such as household type (e.g. off-grid rural households, fuel-poor terraced houses – see Report 1) and geography, are important in determining the tax impacts.

The vertical impacts of the carbon tax are illustrated by the percentage of income impact, which ranges from 1.7 per cent to 2 per cent. Although in absolute terms the carbon tax has the biggest impact in London and the South East, as a percentage of income it has the smallest impact in those regions relative to other regions. Again, given that London and the South East have the largest proportion of high-income households, this is an expected outcome. In relative terms the impact of the carbon tax is greatest in Scotland. Similarly, given that Scotland has the highest proportion of lowest income households, this is again an expected outcome.

Table 4.3 examines how the tax impact differs when broken down into impact across energy, food and transport costs.

Table 4.3. Absolute and relative carbon tax impact by UK region in 2030

Region	Food tax (£)	Energy tax (£)	Transport tax (£)	Total (£)	Percentage of income
North East	85.44	375.02	140.51	600.97	1.6
North West	94.94	382.85	130.18	607.97	1.5
Yorkshire and the Humber	86.74	352.97	115.16	554.87	1.5
East Midlands	95.65	366.87	122.80	585.31	1.4
West Midlands	89.72	372.44	107.31	569.31	1.4
East of England	91.70	372.80	119.17	584.28	1.5
London	83.63	354.64	270.56	708.83	1.4
South East	98.47	388.81	161.72	648.99	1.3
South West	91.68	336.10	124.50	552.28	1.4
Wales	89.39	372.06	80.97	542.43	1.5
Scotland	90.17	377.68	160.80	628.64	1.6
Northern Ireland	104.80	283.57	99.40	487.77	1.4

Source: Authors

When the carbon tax impact is broken down into its sectoral constituents (energy, food and transport) there is a large disparity in impact across the regions. For food, the impact of the carbon tax is smallest in London where it is £21.17 less than in Northern Ireland, where the tax impact is greatest. While the impact on food bills is greatest in Northern Ireland, energy bills there are the least affected of all the regions by quite a margin. Energy bills are impacted the most in the South East of England. The biggest impact on transport costs occurs in London by quite some margin – £109 more than in the South East, which is the second most affected region. The difference between London and Wales, which is the least affected region in terms of transport impact, is £190.

Further analysis could focus on modelling the impacts of carbon tax policy at a constituency level and overlay this with potential job impacts from the zero carbon transition.

Overarching findings from the income distribution analysis

The overall impact of a carbon tax of £50/tCO_2 in 2020 and £75/tCO_2 in 2030 on UK households, without redistribution of tax revenues, is regressive.

A carbon tax at these rates on energy, food and transport sees households in the bottom three income deciles spending a higher proportion of their income, ranging from 2–4 per cent, on the tax than better-off households, with the top three income deciles spending 1–2 per cent of their income on the tax.

Among the sectors, the carbon tax on transport is in fact progressive (as the share of income spent on transport increases with income), while the tax on energy is the most regressive.

Based on current expenditure patterns, UK households pay the highest amount of tax on energy, which accounts for 42 to 62 per cent of the total. While the average household income in decile 10 is nine times larger than in decile 1, decile 10 spends 2.9 times more on carbon tax on energy than decile 1, increasing to 3.3 times more for food and 5.8 times more for transport.

The redistribution of carbon tax revenues switches the tax from being regressive to progressive.

In both scenarios of flat and targeted transfers, the absolute tax payable by the bottom three income deciles is either zero or negative (with a negative cost meaning they receive compensation rather than paying the tax). There are greater reductions in the average carbon tax payment as a proportion of income from the central case for lower income deciles, dropping from 0 to -8 per cent, whereas the proportion remains similar for higher income deciles, around 0.8 to 1.3 per cent.

While both flat and targeted redistribution scenarios are progressive, there are important differences in the net impact of the carbon tax between deciles.

Reflecting the design of the policy, flat transfer scenarios result in a 2 percentage point difference in the tax as a proportion of income between the highest and lowest income deciles, and this gap widens to almost 9 percentage points in the targeted case.

Across all income deciles, the scenario with the redistribution of tax revenues and realisation of energy efficiency savings creates the smallest net impact in terms of household costs.

In this scenario, lower income households benefit from compensation and higher income households pay less tax relative to the central scenario in which there is no redistribution. In comparison, the scenarios of the carbon tax with border carbon adjustments or a higher carbon tax relative to the central scenario have the highest impact in terms of tax payable for all deciles.

The various recycling policies have different impacts across income deciles.

For example, scenario 8b – which combines targeted cash dividends with energy efficiency improvements – has the least impact on deciles 1–5. Scenario 7a – carbon tax with flat dividend – has the least impact on deciles 5–10. Scenario 8c – carbon tax with energy efficiency and no revenue recycling – has the greatest impact on deciles 1–7, and scenario 7b – targeted cash dividend – has the greatest impact for decile 10.

In contrast to the recycling policies, one price scenario has the biggest impact across deciles 1–9: scenario 4, a higher level tax on all sectors with no revenue recycling.

Scenario 3 – a carbon tax with border carbon adjustments – has the second biggest impact across all income deciles but also generates significant amounts of revenue, which could be further used to mitigate the impact. Scenario 6 – differentiated carbon tax rates by sector – has the least impact on bills across all deciles.

5. Conclusions and recommendations

This study has assessed the impact on households of imposing a carbon tax of £50 per tonne of carbon dioxide in 2020, increasing to £75 per tonne of carbon dioxide in 2030, across the different income deciles and regions of the UK. More specifically, we have tested if there is a recycling scheme that leaves low-income groups better off while driving the transition to net-zero emissions by 2050 to meet the UK's new legislated target.

Household bills, revenue-raising and recycling

Our results reconfirm that without recycling revenues, the introduction of a carbon tax has regressive impacts on household bills. Lower income households, specifically those in deciles 1 and 2, spend a much higher proportion of their income on the tax than higher income households (deciles 7–10). This trend is the same for 2016, 2020 and 2030, but there is a larger impact in 2030 – both in absolute and relative (as a percentage of income) terms – as the carbon tax rate goes up.

On average the top decile emits 3.7 as much CO_2e as the bottom decile across food, transport, energy and 'other' sectors. In line with the literature, we find the main difference across income deciles in emissions terms is in the transport sector: high-income households tend to use emit more from transport use than lower income households at a ratio of 6:1. A tax imposed on transport is therefore not necessarily regressive, whereas a tax on energy is the most regressive as the ratio is the order of magnitude is just 2.9.

The anticipated revenue raised by implementing these policy changes will depend on households' behavioral responses to higher prices. If households do not change the quantity of carbon intensive energy and food they consume and the type of transport they use, we estimate that this policy package will raise significant revenue. Before recycling, the study projects revenues ranging between £14 billion and £36 billion in 2030 depending on the level of the tax, which sectors it applies to, when it is introduced and whether or not the price is augmented with border carbon adjustments. When BCAs are included, this generates the most revenue, although this also has the biggest carbon tax impact for households across all deciles.

We have demonstrated that recycling the revenue via household dividends can mitigate any bill increases arising specifically from the carbon tax for income deciles 1–3 so that there is either no net impact of the tax or households are better off. Of the revenue generated, 70 per cent is needed to prevent regressive impacts of carbon taxation. This demonstrates that recycling revenues via household payments can be a powerful means to offset some of the regressive social impacts of carbon taxes in the UK, particular for low-income groups.

This then leaves 30 per cent of the revenues, equal to about £5 billion, which can be allocated in different ways, such as to mitigate the impacts of a carbon tax on higher income groups if desired or to be invested in green infrastructure.

It is important to recognise some limitations to our approach. We do not have data on price elasticities of energy, food and transport across the distribution of expenditure, which are important when trying to understand the distributional effect of the carbon price policy we outline. That said, it is likely that elasticities are lower in the bottom deciles (Advani and Stoye, 2016) – the groups we are focusing on are deciles 1–3 – and therefore we are more likely to accurately capture costs for these households. However, this limitation may result in an overstatement of the costs of the policy for wealthier households.

This report aims to inform the debate about how to design carbon taxes to increase public acceptability. The numbers presented are helpful to provide a snapshot of the effect on consumers today and in 2030. The numbers presented are a static representation of cost and revenue and must be revised over time, to reflect the dynamic nature of economies, allowing for behaviour change and technological and process innovation.

We use simple and transparent assumptions, which show that the impacts on bills and revenues raised are not trivial and therefore warrant further analysis to fully understand the substitution effects of different carbon prices on households.

Enhancing public and political acceptability

Recycling revenue as a compensatory policy does not, alone, provide a sufficient means to increase the acceptability of carbon taxes.

As stated in Report 1, understanding voter aversion to carbon taxation is critical for navigating the political economy of carbon tax policy. Carratini et al. (2018) offer additional and pragmatic ways in which this can be done, which include phasing in carbon taxes over time and clearly communicating how the revenue will be used.

Our study also recognises that the salience of carbon pricing varies from sector to sector and therefore must be supported by complementary policies. The appropriate balance between regulation, taxes and subsidies will need careful thought. But carbon pricing will be central to achieving net-zero emissions and not only provides an efficient mechanism by which to do so, but also the financial means to fund the zero-carbon transition and ensure it is equitable. Our study presents insights into how governments may wish to do this.

High-level recommendations

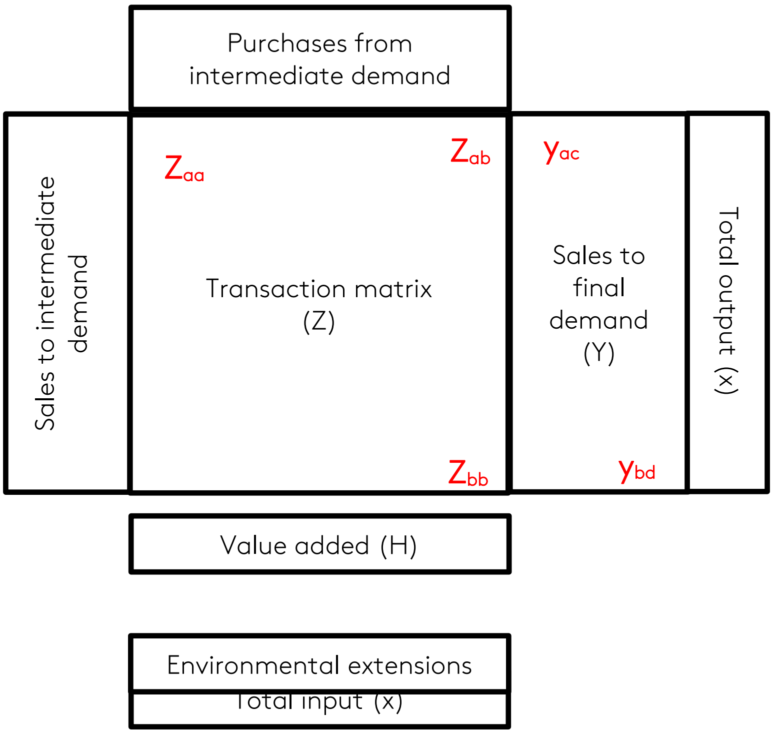
- The carbon tax level in the UK needs to be raised. A carbon tax consistent with net-zero emissions by 2050 would start at £50 per tonne of carbon dioxide.
- Conventional fiscal thinking that sees all revenue treated as general tax must change to ensure that the impacts of carbon pricing are distributed fairly and that the policy becomes more politically and socially acceptable. Carbon tax revenues should be explicitly used to correct undesirable distributional outcomes.
- Interventions focused on recycling revenue to households can make a substantial difference to the distributional impact of carbon pricing. Depending on the design of the revenue recycling, we show that distributing between 19 and 70 per cent of revenues to households via a uniform or targeted cash transfer can ensure that carbon tax policy is progressive.
- Using income and consumption differentials is a useful way to identify and understand the implications of carbon tax policy. However, it is important to identify specific political entities within them, where opposition to carbon taxes may be particularly strong.
- When assessing the impact of carbon taxation, government must also assess both 'vertical' and 'horizontal' effects – that is, the differing effect of the tax on high- and low-income households and on households with similar incomes but different consumption patterns. Assessing these effects will ensure that carbon pricing can be designed to prevent regressive outcomes.

Appendix A: Methodology

Household carbon footprints calculated using input-output analysis

Input-output models (IOM) have been adopted by environmental economists for their ability to make the link between the environmental impacts associated with production techniques and the consumers of products. The Leontief Input-Output model (Figure A1) is constructed from observed economic data and shows the interrelationships between industries that both produce goods (outputs) and consume goods (inputs) from other industries in the process of making their own product (Miller and Blair, 2009).

Figure A1. Basic structure of a Leontief Input-Output Model



Consider the transaction matrix Z: reading across a row reveals which industries a single industry sells to and reading down a column reveals who a single industry buys from. A single element, zij, within Z, represents the contributions from the ith sector to the jth industry or sector in an economy. For example, z_{aa} represents the ferrous metal contribution in making ferrous metal products, z_{ab}, the ferrous metal contribution to car products and z_{bb} the car production used in making cars. Final demand is the spend on finished goods. For example, y_{ac} is the spend on ferrous metal products by households as final consumers whereas y_{bd} is the spend on car products by government as final consumers.

The total output (xi) of a particular sector can be expressed as:

$$x_{i=}z_{i1} + z_{i2} + \cdots + z_{ij} + y_I \qquad (1)$$

where yi is the final demand for that product produced by the particular sector. If each element, zij, along row i is divided by the output xi , associated with the corresponding column j it is found in, then each element in Z can be replaced with:

$$a_{ij} = \frac{z_{ij}}{x_j} \qquad (2)$$

to form a new matrix A.

Substituting for (2) in equation (1) forms:

$$x_{i=}a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{ij}x_i + I \qquad (3)$$

Which, if written in matrix notation is $= Ax + y$. Solving for y gives:

$$x = (I - A)^{-1}y \qquad (4)$$

where x and y are vectors of total output and final demand, respectively, I is the identity matrix, and A is the technical coefficient matrix, which shows the inter-industry requirements. $(I - A)^{-1}$ is known as the Leontief inverse (further identified as L). It indicates the inter-industry requirements of the ith sector to deliver a unit of output to final demand. Since the 1960s, the IO framework has been extended to account for increases in the pollution associated with industrial production due to a change in final demand (Miller and Blair, 2009).

Consider, a row vector f of annual CO_2 emissions generated by each industrial sector:

$$e = f\hat{x}^{-1} \qquad (5)$$

is the coefficient vector representing emissions per unit of output13. Multiplying both sides of (4) by e' gives

$$e'x = e'Ly \qquad (6)$$

and simplifies to

$$F = \hat{e}L\hat{y} \qquad (7)$$

where F is the CO_2 emissions in matrix form, allowing consumption-based emissions to be determined. F is calculated by pre-multiplying L by emissions per unit of output and post-multiplying by final demand. This calculation shows how a unit change in final demand y, increases the emissions by all industries to satisfy this change. We diagonalize emissions per unit of output and final demand to ensure that the result is a square matrix. This result format allows calculation of product footprints by summing the columns and calculation of emissions by source by summing the rows.

This system can be expanded to the global scale by considering trade flows between every industrial country in the world rather than within a single country. This type of system requires a multiregional input-output (MRIO) table. A MRIO is used for the calculation of the household income decile carbon footprints used in this study. The UKMRIO database is a 15 region system which models global trade by the UK, Brazil, Russia, India, China, South Africa, USA, Japan, Rest of the European Union, Rest of Europe, Rest of the OECD, Rest of Africa, Rest of Americas, Rest of Asia, Rest of the Middle East. For this study, carbon footprints are reported showing the emissions which are sourced in the UK, the EU and the rest of the world.

The UKMRIO database contains a single column y_h for expenditure by all UK households. The living costs and food survey is used to disaggregate this column into the expenditure by 10 household income groups. This means that to find the carbon footprint of decile one (F_1), we calculate:

$$F\_1 = \frac{\hat{e}L\widehat{y\_1}}{n\_1} \qquad (8)$$

where $\mathbf{y\_1}$ is the expenditure by all households in the first income decile and $\mathbf{n\_1}$ is the number of households in income decile one.

A note on household income groups, uncertainty and equivalisation

How representative are the income deciles used in the study?

The Office for National Statistics (ONS) uses household characteristics data to calculate the number of households in the whole of the UK that are representative of each of the single sample households who filled in the living costs and food survey. The characteristics of an individual sample household are compared to total UK data taken from the UK census. As an example, the first household in the 2016

13 $\hat{}$ denotes matrix diagonalisation and $'$ denotes matrix transposition

household has a weight of 4,774 meaning that the ONS has concluded that there are 4,774 households in the UK of this type. The weights sum to 27 million – the number of UK households in 2016.

In this study we weight the data accordingly so that we are in essence working with a model of 27 million data points. We split these 27 million data points into 10 equal sized income deciles, so the first decile represents 2.7 million households.

Have the household income groups been equivalised?

In their study looking at the carbon footprints of different household income groups, Gough et al. (2011) use the McClements Equivalence Scale to apply a weight to each household member in order to give a total equivalence number for the household. The household gross income is then divided by this total equivalence number to produce the equivalised gross income. They find that equivalisation drastically alters the composition of each income decile. For example, one-person retired households account for 41 per cent of households in the lowest income decile, but when income is equivalised the share falls to 10 per cent.

After some careful consideration we concluded that for the framing of our study, producing equivalent sized households is not necessary. Unlike the Gough (2011) study, we do not report at the per capita measure. All of our findings are reported at the household unit. Low-carbon policies in the UK are funded through taxing the household's energy bill and so operate at the household unit. Converting to equivalent sized per capita households would mean that we would lose sight of real-life costs to households under the scenarios investigated because these costs would be reported on an equivalised per capita basis. Admittedly, our approach will overestimate and underestimate the ability of households to pay because a cost of 5 per cent of annual household income may be easier for a one-person retired household to pay than for a family of six with the same income. Ultimately, when designing a carbon taxation policy, the UK Government will not be able to equivalise the costs to households based on their composition so it would have been unnecessary for us to try to make calculations on how each household should pay in a fairer system. But our findings need to be viewed carefully to determine if the same proportional cost is fair for households in different circumstances. We cannot be completely sure that applying the McClements Scale will ensure that households can now be considered to be equivalent because there are many more facets to a household's ability to pay than its size.

Appendix B: Additional figures

Extended overview of tax scenarios for UK income deciles 2–4 and 6–9

Figure A2. Overview of carbon tax scenario impacts for income decile 2 in 2030

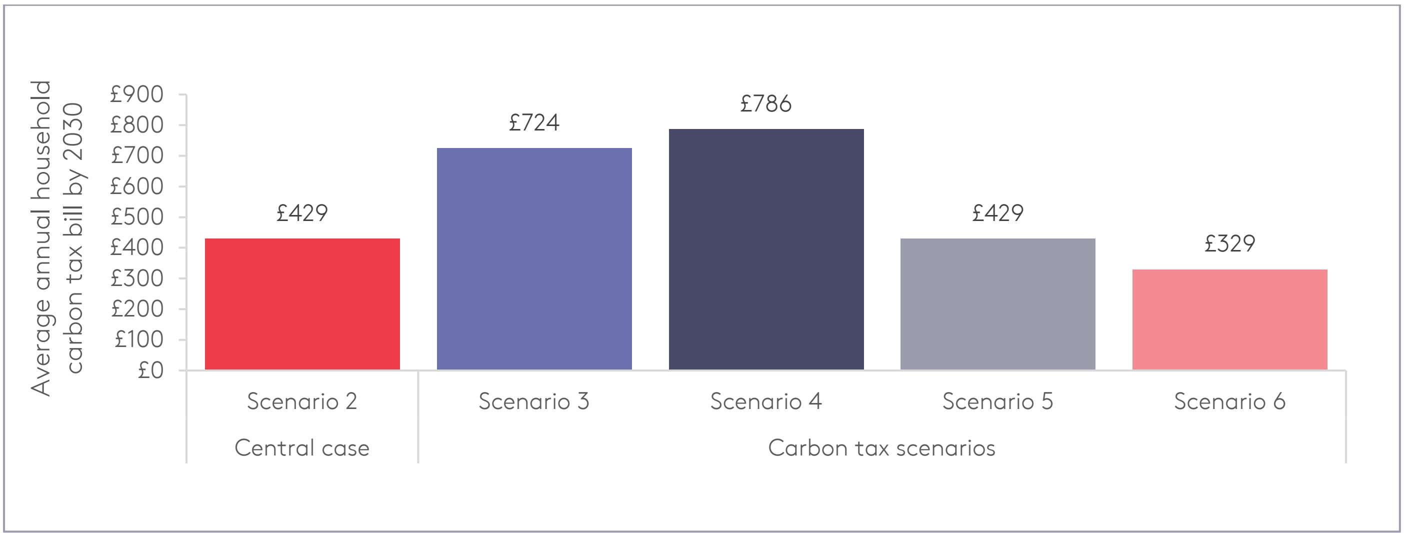


Figure A3. Overview of carbon tax scenario impacts for income decile 3 in 2030

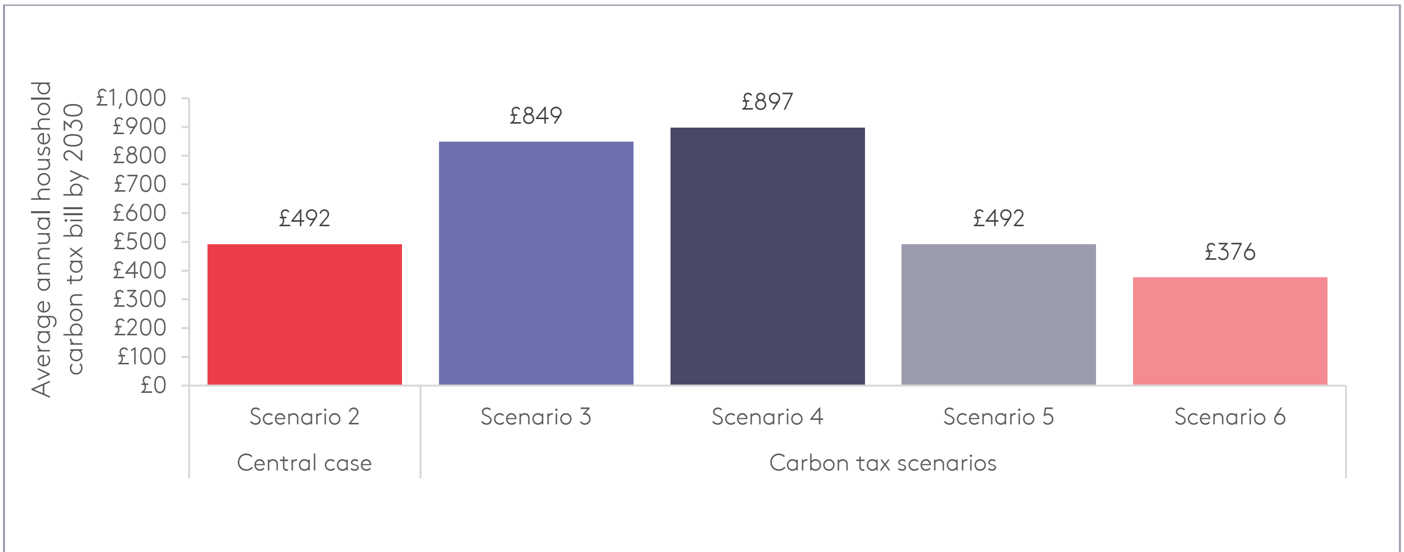


Figure A4. Overview of carbon tax scenario impacts for income decile 4 in 2030

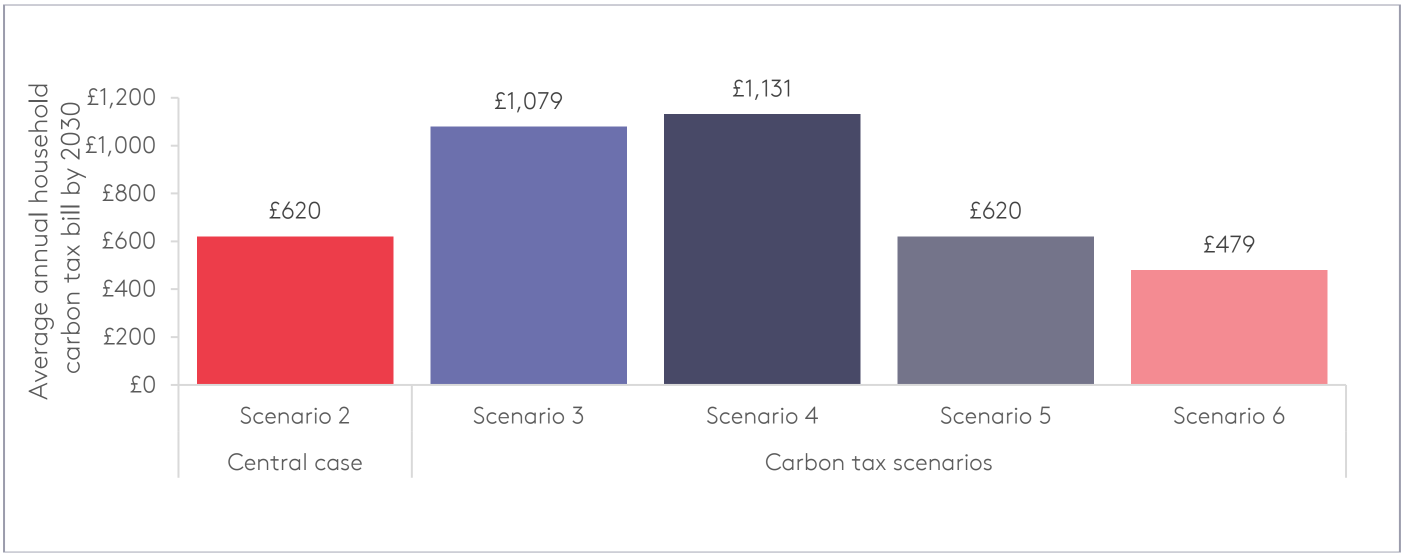


Figure A5. Overview of carbon tax scenario impacts for income decile 6 in 2030

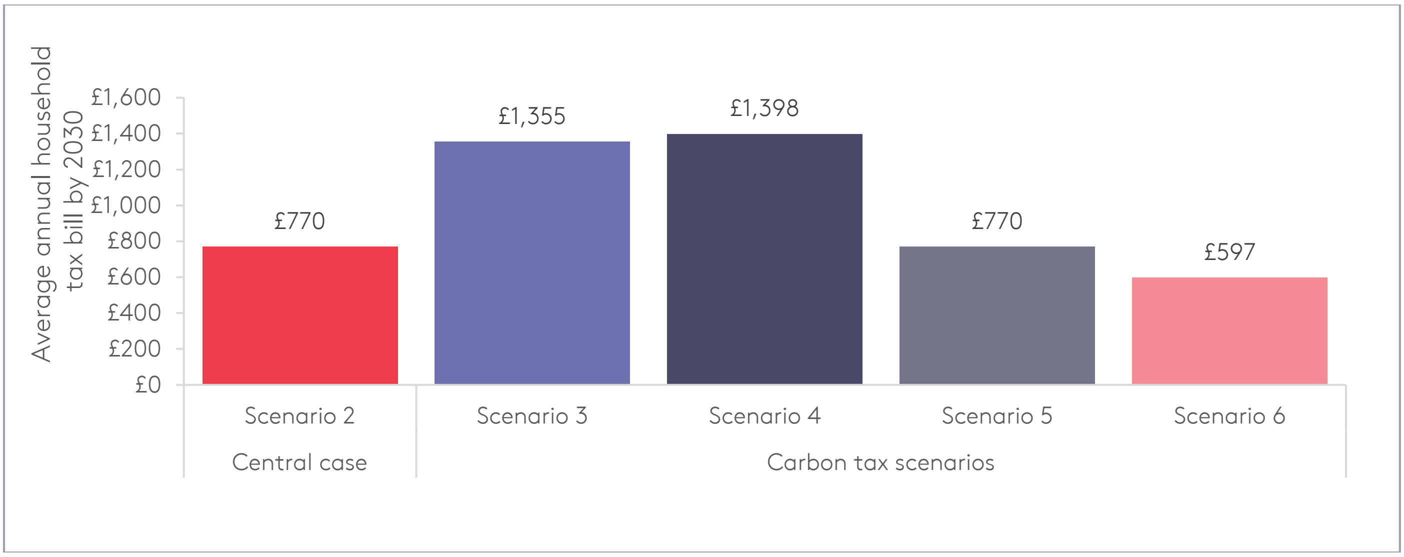


Figure A6. Overview of carbon tax scenario impacts for UK income decile 7 in 2030

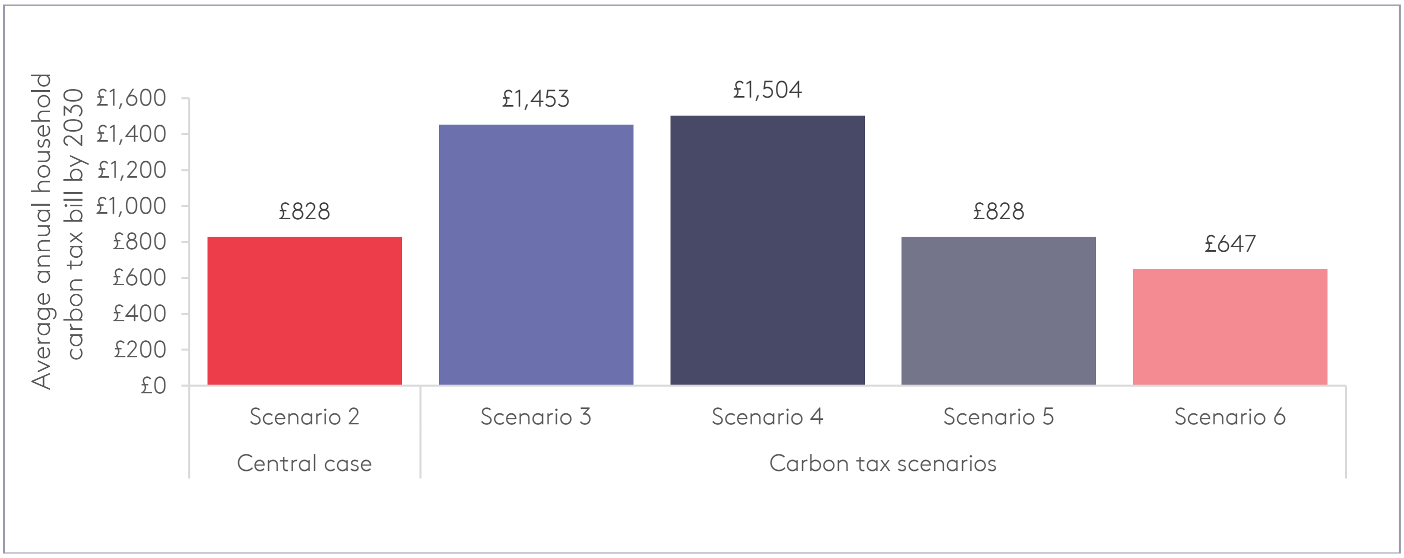


Figure A7. Overview of carbon tax scenario impacts for UK income decile 8 in 2030

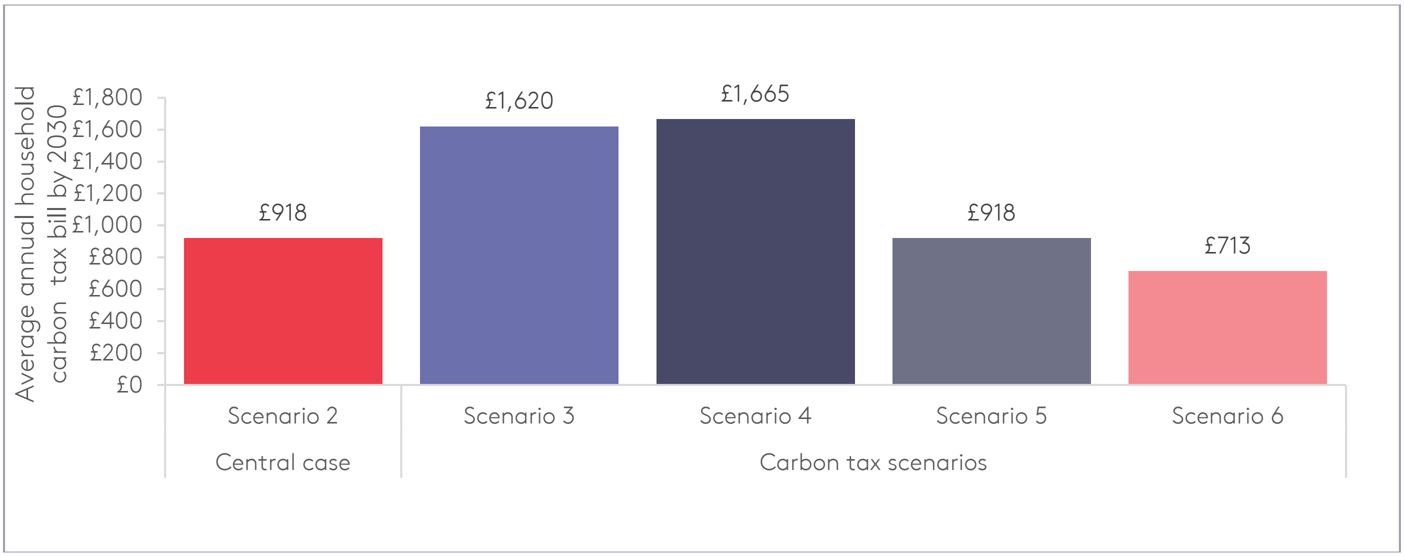
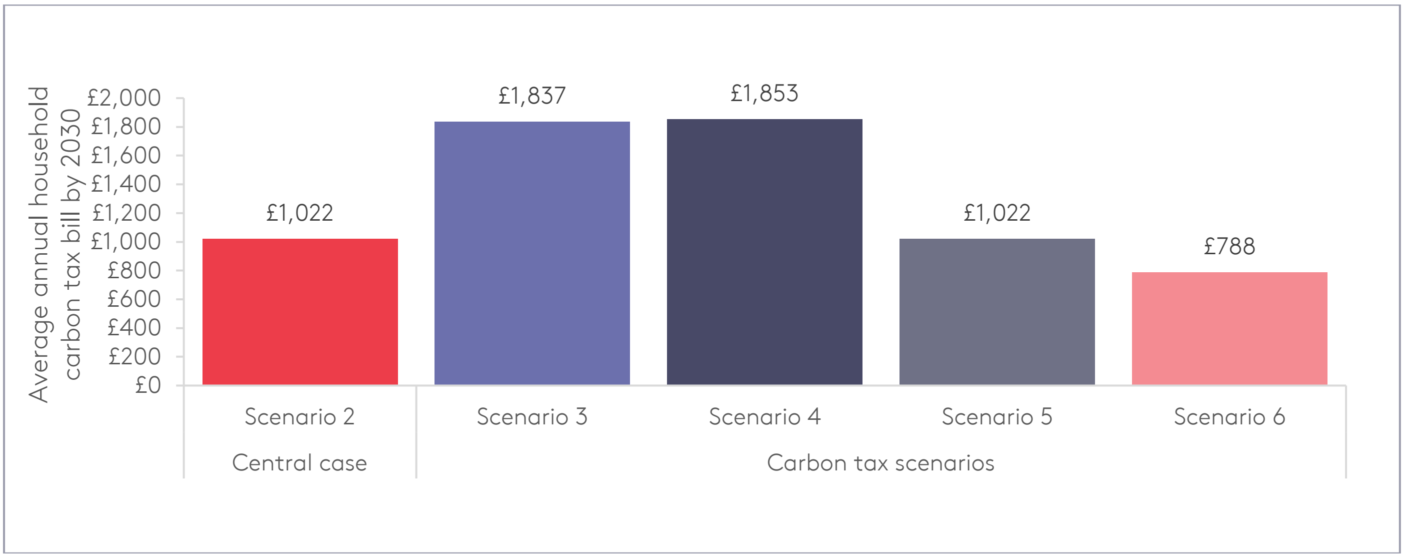


Figure A8. Overview of carbon tax scenario impacts for UK income decile 9 in 2030



Extended overview of recycling scenarios for UK income deciles 2–4 and 6–9

Figure A9. Overview of carbon tax revenue recycling scenario impacts for income decile 2 in 2030

Figure A10. Overview of carbon tax revenue recycling scenario impacts for income decile 3 in 2030

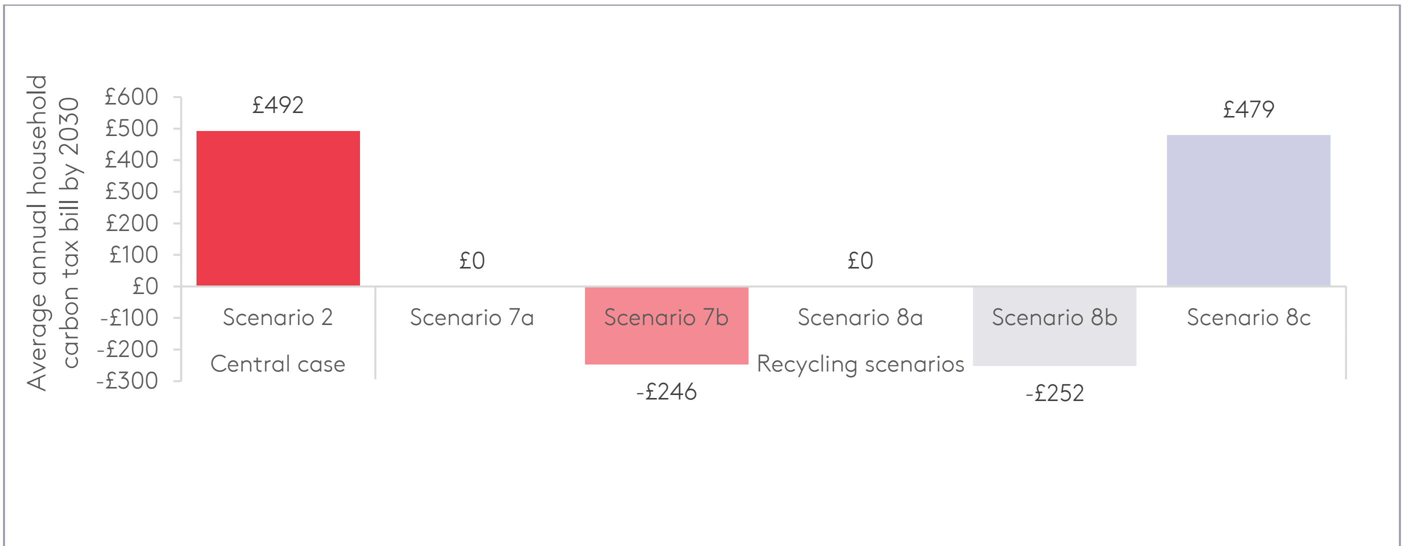


Figure A11. Overview of carbon tax revenue recycling scenario impacts for income decile 4 in 2030

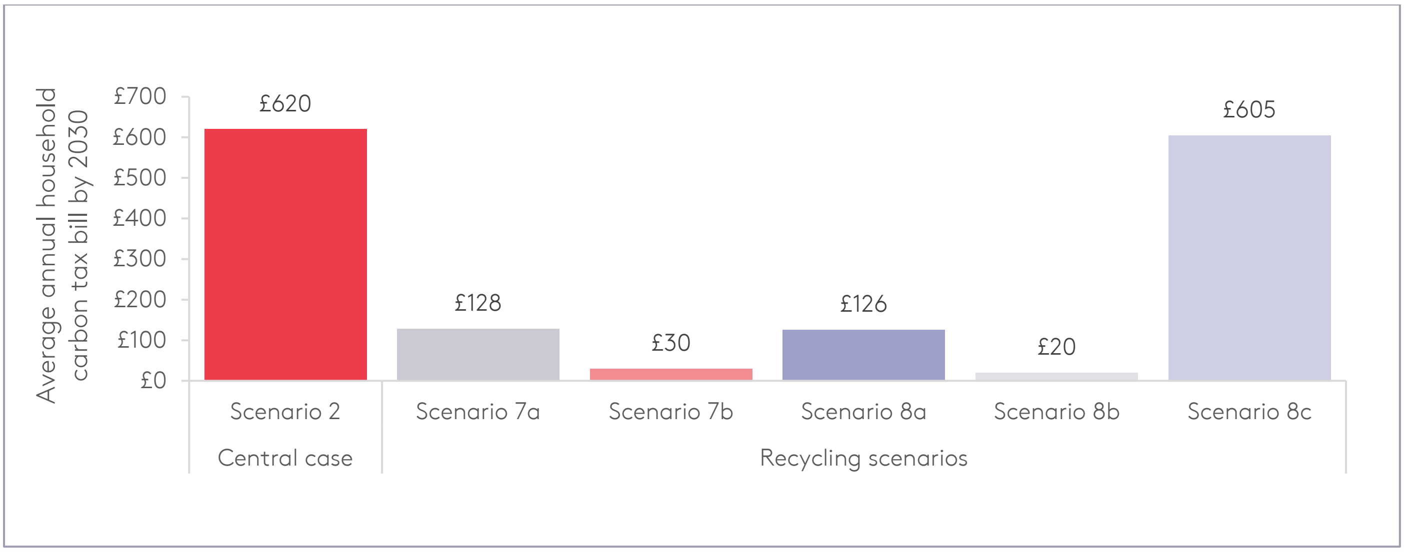


Figure A12. Overview of carbon tax revenue recycling scenario impacts for income decile 6 in 2030

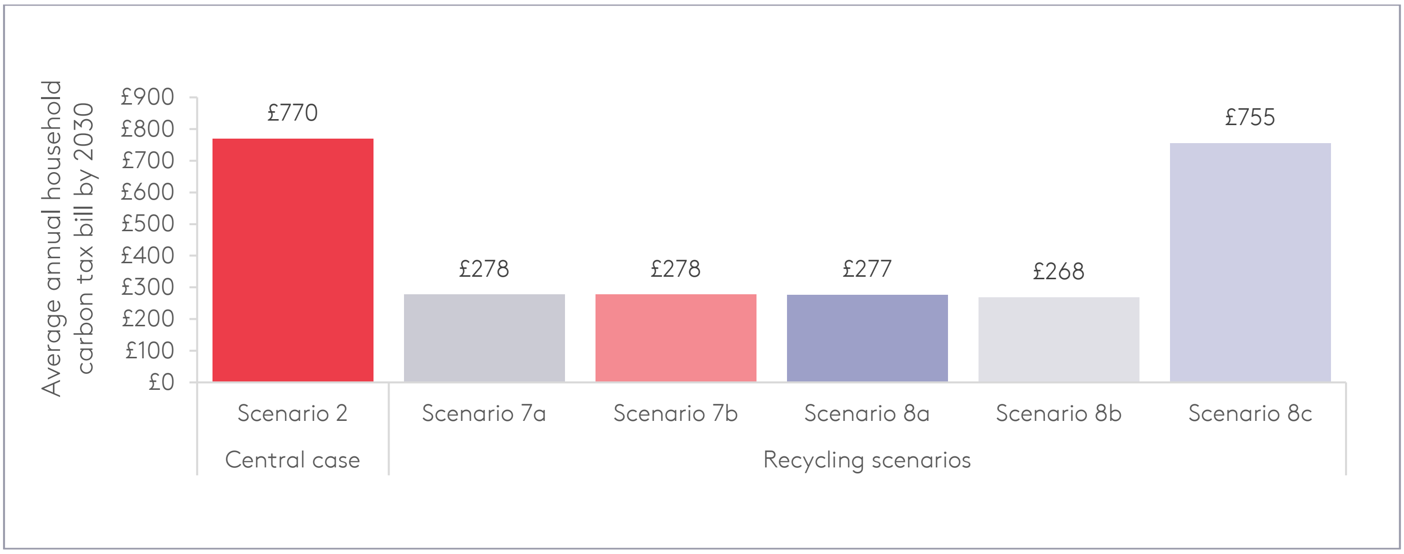


Figure A13. Overview of carbon tax revenue recycling scenario impacts for income decile 7 in 2030

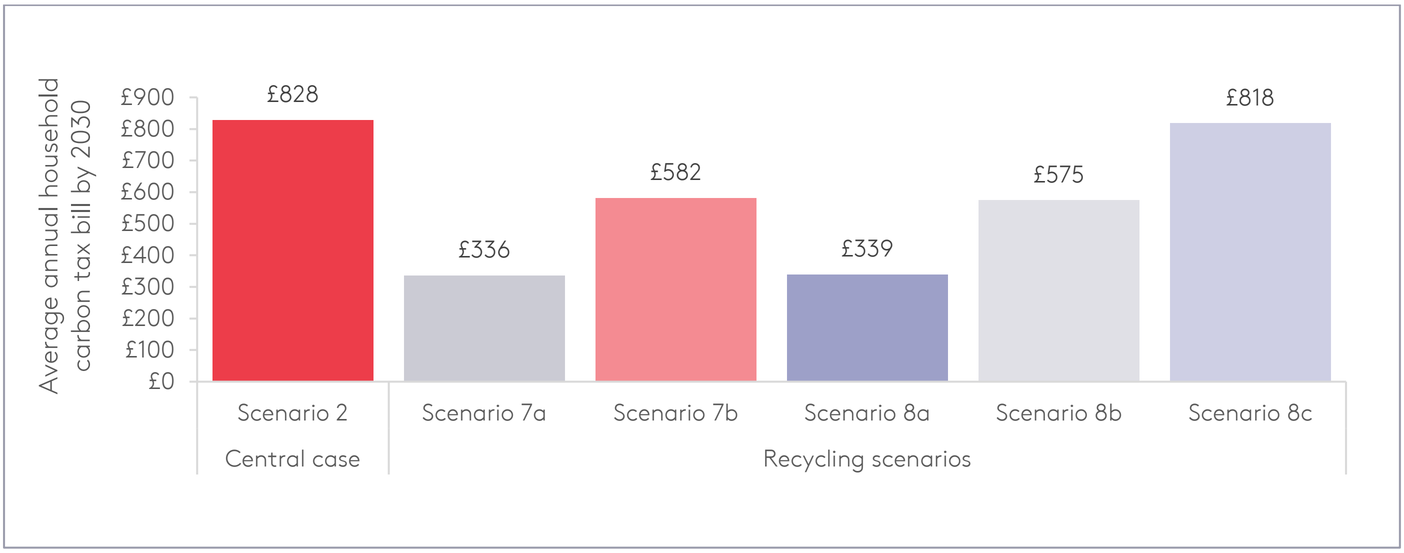


Figure A14. Overview of carbon tax revenue recycling scenario impacts for income decile 8 in 2030

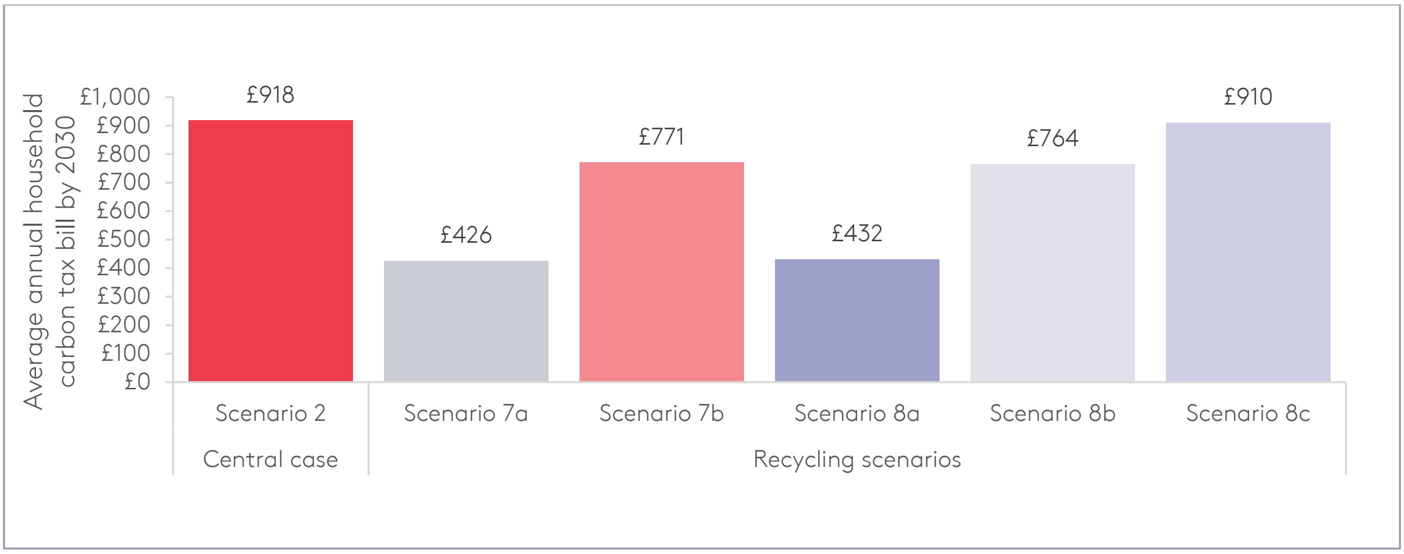


Figure A15. Overview of carbon tax revenue recycling scenario impacts for income decile 9 in 2030

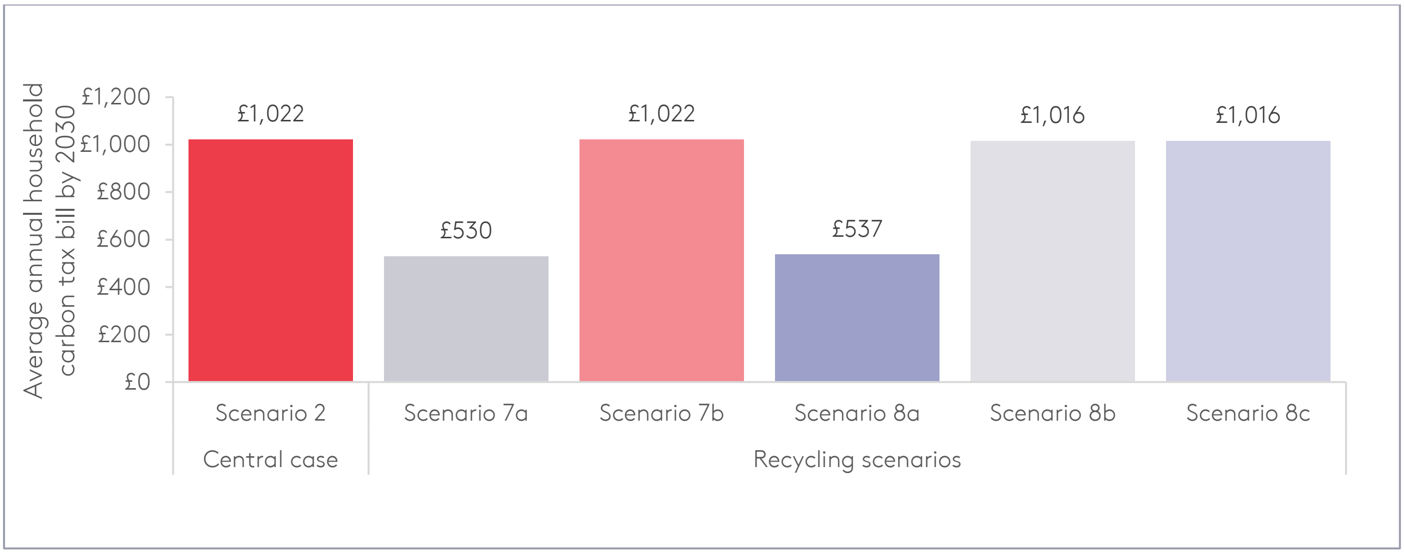


Figure A.16. Relative impact (compensation as a share of carbon tax bill) for the four recycling scenarios by decile in 2030

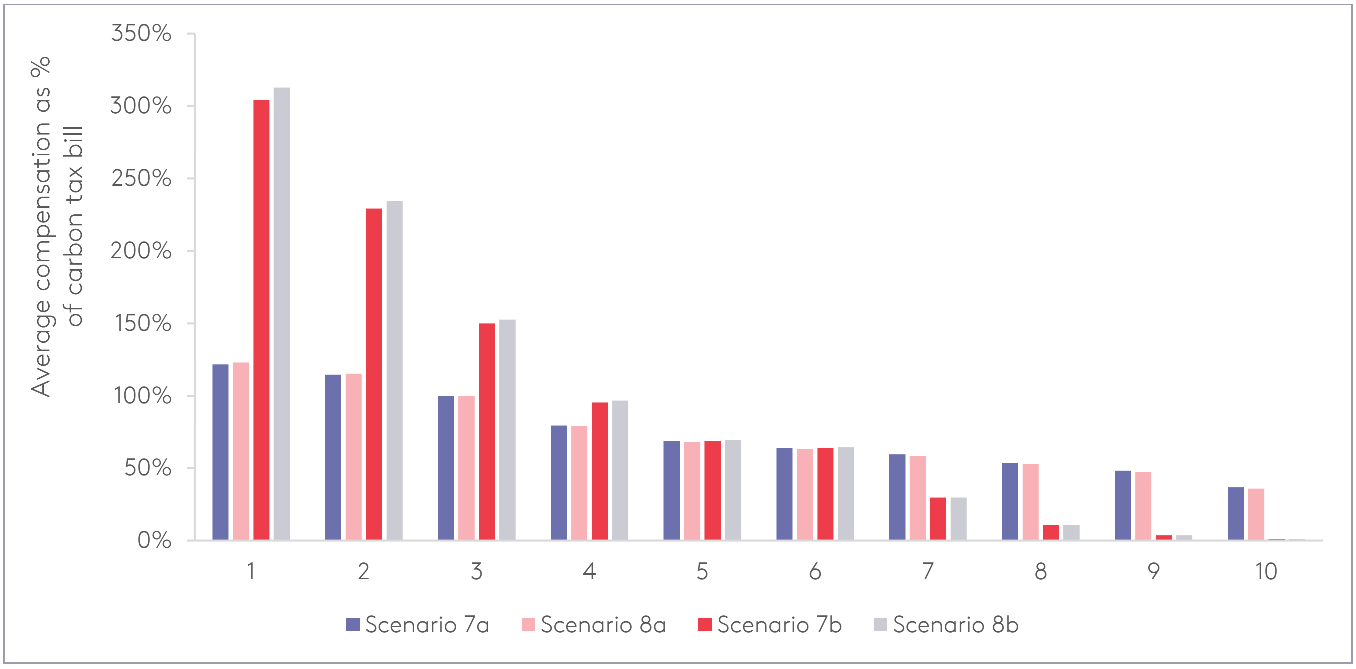
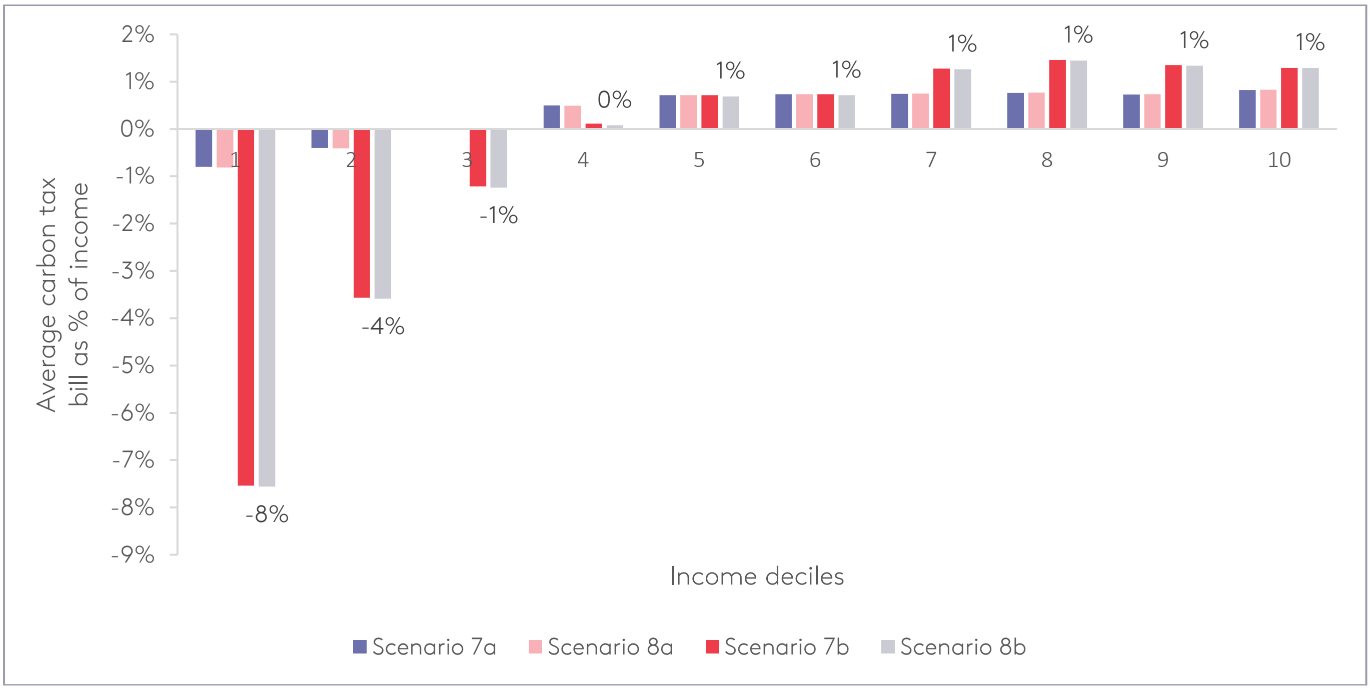


Figure A17. Average carbon tax bill as a proportion of income across the four recycling scenarios, by income decile, in 2030



Extended overview of recycling scenarios: net-zero impact for deciles 1–6

In the following scenarios revenue is recycled in such a way that deciles 1 to 6 have a net-zero impact of the carbon tax. This means that the tax they have to pay is 100 per cent covered by the targeted transfer. Deciles 7 to 10 do not receive any transfer and have to pay their complete tax bill. For this recycling scenario 50 per cent of the total revenue collected needs to be redistributed.

	Income decile									
Year: 2030	1	2	3	4	5	6	7	8	9	10
Total carbon tax bill (£)	404	429	492	620	715	769	828	918	1,022	1,339
% money given back	5.86%	6.22%	7.13%	8.99%	10.37%	11.16%	0%	0%	0%	0%
Money returned (£)	404	429	492	620	715	770	-	-	-	-
Net impact (£)	-	-	-	-	-	-	828	918	1,022	1,339

In the case of such a recycling scenario the carbon tax remains semi-regressive, as higher income deciles receive a higher absolute amount. For example, decile 1 receives £404 covering their carbon tax bill and decile 6 receives £770. Compared with the lower income deciles, the tax is progressive for deciles 7 to 10 as they have to pay a higher share of their income than the lower income deciles. However, decile 7 pays a higher share (1.8 per cent) than decile 10 (1.3 per cent). As this scenario only uses 50 per cent of total revenue collected, more revenue can be redistributed to make the recycling scenario completely progressive.

Figure A.18. Average annual household tax bills by 2030 under different revenue recycling policies

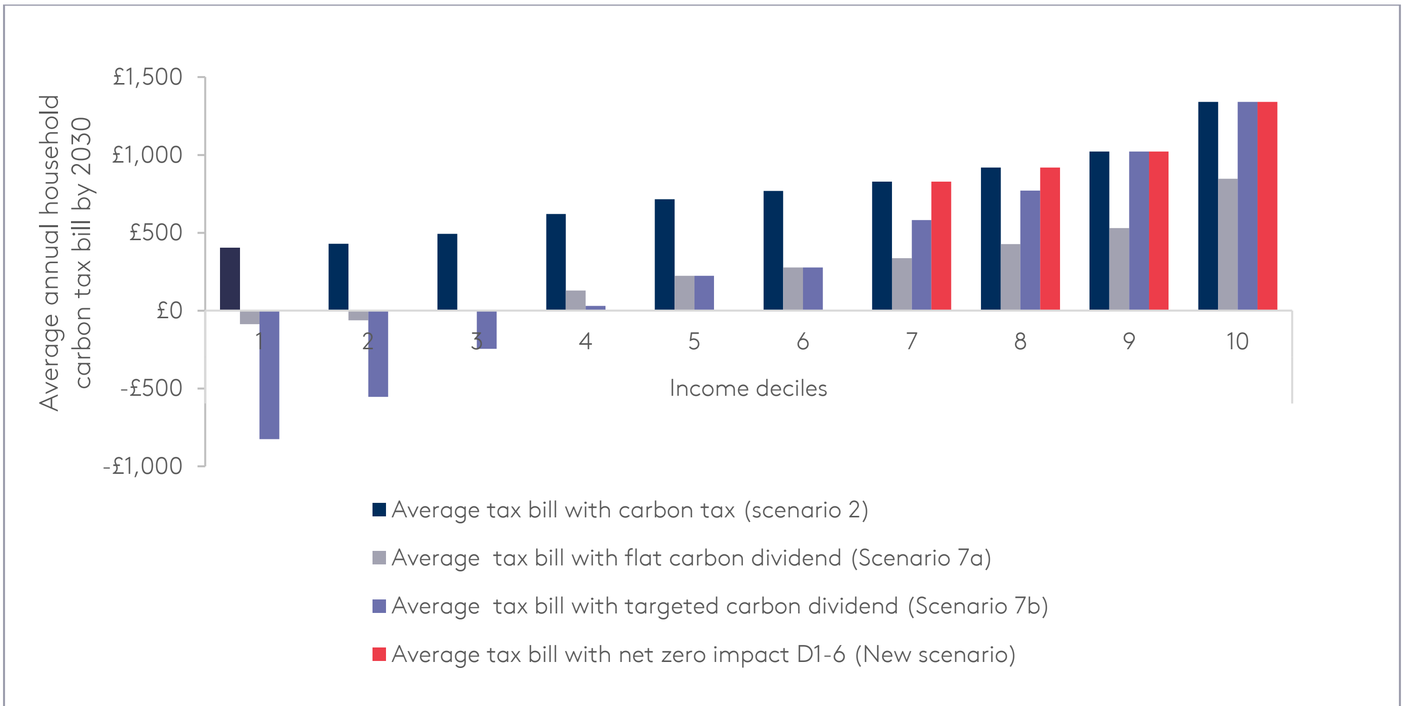
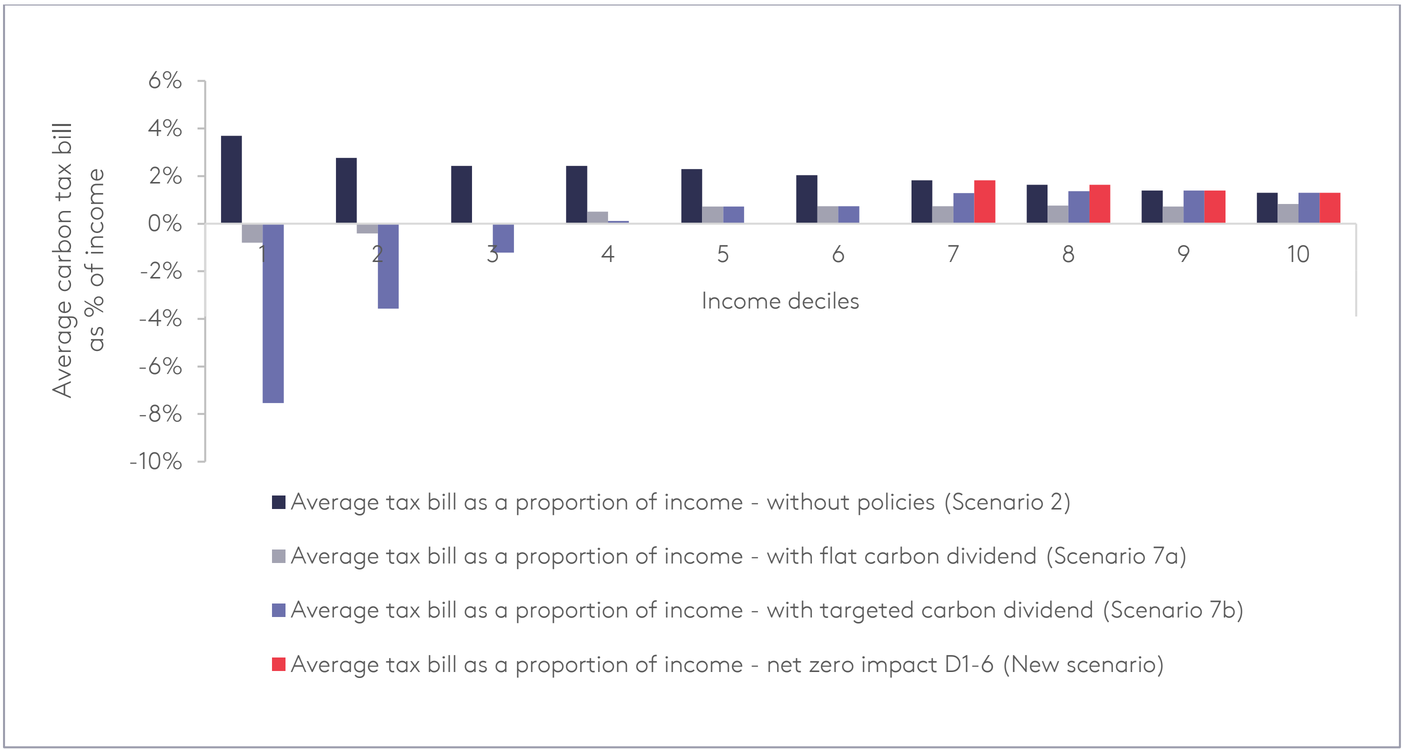


Figure A.19. Average annual tax bills in 2030 as percentage of income under different revenue recycling policies



2016 Carbon footprints (tonnes CO_2e) by region and income group

Carbon footprints 2016												
	North East	North West	Yorks & Humber	East Midlands	West Midlands	East of England	London	South East	South West	Wales	Scotland	Northern Ireland
Food	3.07	3.33	3.08	3.45	3.23	3.25	3.14	3.59	3.32	3.15	3.23	3.62
Fuel	10.46	10.75	9.97	10.63	10.53	10.54	10.31	11.21	10.26	10.53	10.85	9.17
Transport	2.99	2.85	2.56	2.77	2.43	2.66	5.92	3.57	2.88	1.87	3.49	2.26
Other	2.46	2.65	2.80	3.40	3.95	2.84	3.09	3.82	3.41	2.53	2.33	2.46
TOTAL	18.98	19.58	18.41	20.25	19.14	19.29	22.45	22.20	19.86	18.08	19.90	17.50

Carbon footprints 2016										
	Decile 1	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Decile 10
Food	1.65	1.90	2.32	2.91	3.28	3.44	3.51	3.95	4.55	5.49
Fuel	6.38	6.91	7.73	9.23	10.18	11.02	11.36	12.81	13.50	16.47
Transport	1.32	1.29	1.40	2.30	2.95	3.16	3.80	3.96	4.80	7.69
Other	0.91	0.64	1.35	1.77	2.81	2.98	3.46	3.99	5.10	7.08
TOTAL	10.27	10.74	12.80	16.21	19.22	20.60	22.12	24.71	27.95	36.73

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This report models the impact of a range of carbon tax scenarios on energy, food and transport bills across income deciles in the United Kingdom. In terms of compensatory policies it compares the effectiveness of carbon tax dividends and energy efficiency measures in ensuring equity.

It is one of two reports that informs:

(i) The UK public debate on carbon pricing for net-zero, including HM Treasury's review of how the transition to net-zero will be funded and where the costs will fall.

(ii) The design of the UK's post-Brexit carbon pricing regime.

The companion report, *Distributional impacts of a carbon tax in the UK, Report 1: Analysis by household type*, models the impact of carbon taxation across different household types with compensatory measures.

Published in March 2020 by the Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, London School of Economics and Political Science, and Vivid Economics.