

Making the case for personal carbon rations

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Abstract

This paper sets out the case for equal personal carbon rations for household energy use and personal transport. It claims that rationing could provide a fair and effective mechanism to reduce carbon emissions.

Firstly the history of failure of energy efficiency over the past thirty years to deliver actual energy savings in the UK domestic sector is briefly reviewed. Recent policy is simply a continuation of previous policies with no guarantee that it will be any more successful. Further, the UK's apparent reduction in carbon emissions over the past ten years disappears if emissions from international air travel (currently excluded from emissions targets) are included. A new approach to energy and carbon emissions is required if real savings are to be made: carbon rationing could be that approach.

The case for carbon rationing in principle is summarised. However, the main focus is on the practical issues around introducing carbon rationing. New case study data on UK individuals' carbon emissions from household energy and personal transport is presented. This shows a very wide range of personal carbon emissions, varying by more than a factor of ten. The sources of variation, and particularly the importance of air travel, are discussed. The implications of this variation for a scheme of equal personal carbon rations are debated. Finally, other key questions about the practical implementation of personal rations are identified, and progress towards answering them is outlined.

Introduction

Climate change is widely recognised as the most serious environmental problem facing the world. Some would suggest it is the most serious problem of any kind, for example the UK government's chief scientist, David King, said that: "climate change is the most severe problem that we are facing today - more serious even than the threat of terrorism" (King 2004). Worldwide greenhouse gas and carbon dioxide emissions continue to rise, and the atmospheric concentration of CO₂ increased from 354 ppm in 1990 to 376 ppm in 2003 (Keeling and Whorf 2004).

Research news about climate change and its expected effects has, if anything, become more alarming since the 2001 IPCC report which projected possible temperature increases by 2100 of up to 5.8 degrees Celsius (IPCC 2001). For example, two different studies from the UK Hadley Centre have suggested that increased carbon dioxide concentrations in the atmosphere may lead to higher temperature rises than those reported in IPCC's work (Clarke 2003; Murphy et al 2004). This is the very serious global backdrop to the analysis presented here about how to reduce carbon emissions.

This paper focuses on carbon emissions from the domestic sector and energy use for personal transport, including international air travel. Experience from the UK is used to illustrate the need for a new approach to making carbon savings from these sectors. The idea proposed, personal carbon rations, is relevant for all EU countries, since the UK is far from being alone in responding inadequately to the threat of climate change.

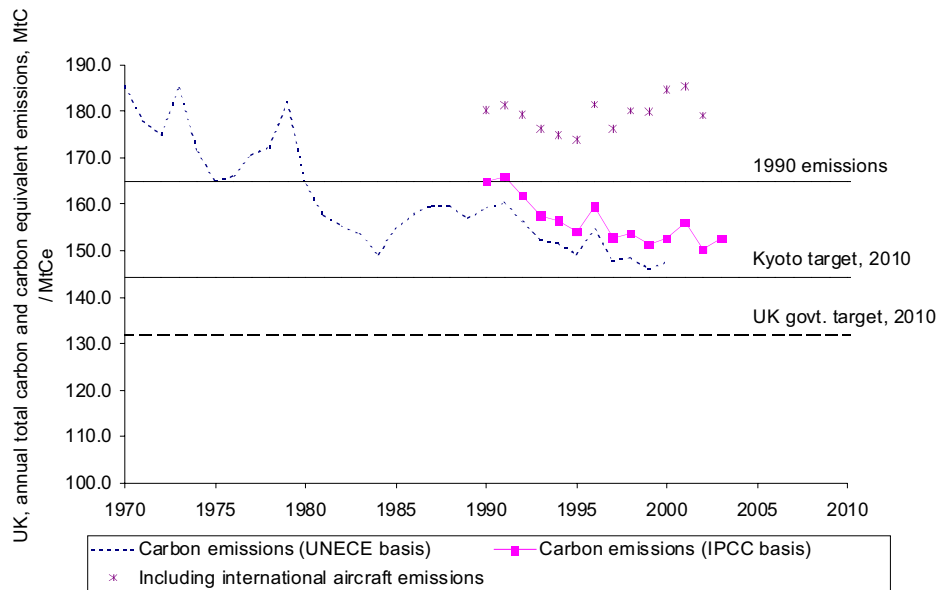


Figure 1. Carbon dioxide emissions from the UK, including international aircraft carbon equivalent emissions, 1970-2003.

Why a new policy approach is needed

This section argues that a new policy approach for savings from the domestic sector and personal transport is needed because insufficient progress has been made in reducing carbon emissions from the EU and in the UK. First of all, the experience in the UK domestic sector over the past thirty years is considered. Then emissions from the whole UK economy are discussed and the impact of adding international airline emissions is demonstrated. Finally, the wider EU experience is outlined.

UK HOUSEHOLD ENERGY USE

Energy consumption in the UK domestic sector is rising. Despite many changes in technology and ownership of household equipment since 1970, patterns of energy use by end use have changed relatively little and the average energy consumption per household has remained about the same (Shorrocks and Utley 2003). Considerable improvements in energy efficiency have not led to net energy savings because other factors, such as higher ownership of central heating and increasing indoor temperatures, led to increases in energy services over the same period. Increasing household numbers have resulted in rising consumption overall.

There are a number of arguments which throw doubt on the theoretical effectiveness of energy efficiency (e.g. Herring 2000), but probably the most convincing evidence is the experience of the UK domestic sector over the past thirty years, where net reductions in energy consumption have not been made despite considerable improvement in efficiency. It is commonly argued that energy consumption would have been much higher without the energy efficiency programmes which were in place (e.g. Shorrocks and Utley 2003). However, while the statement that energy efficiency has not resulted in sector wide savings over the past three decades can be made with certainty, the claim that without

efficiency, energy consumption would have been much higher is necessarily open to debate.

Improving energy efficiency has been, and remains, the dominant government strategy for energy and carbon savings in the domestic sector. The government has recently identified the carbon savings expected to be achieved in each sector and key risks for delivery of energy efficiency goals are identified (DEFRA 2004a). Overall, DEFRA suggests that there is a 'medium' risk that energy efficiency measures will not deliver the required carbon savings. There are many studies which have identified possible energy and carbon savings from domestic energy efficiency, suggesting that suitable technologies are available (e.g. ICCEPT 2002; Johnston 2003; Fawcett et al 2000). However, experience over the past thirty years would suggest instead that in reality there is a very high risk that carbon savings will not be delivered through efficiency alone. This conclusion has also been reached by other researchers considering international experience beyond the UK (Wilhite and Nordgard 2003).

UK CARBON EMISSIONS

Contrary to experience in most countries, UK carbon dioxide emissions have fallen in recent years (see Figure 1). This is in spite of rising energy demand – primary energy demand rose by 10.8% between 1970 and 2003 (DTI 2004). However, only limited encouragement can be taken from this fall in emissions. Firstly, much of the UK's emissions reduction since 1990 is due to a switch towards lower carbon fuels (primarily gas and nuclear power) which cannot be repeated in future, rather than a fundamental transformation towards a lower carbon economy (Eichhammer et al 2001). Secondly, when international airline emissions are taken into account, UK emissions have not actually fallen since 1990, as demonstrated below.

Figure 1 shows two sets of official carbon dioxide emissions data. For earlier years, the only UK figures available

are calculated on an UNECE basis. However, current official UK estimates of greenhouse gas emissions are calculated in line with IPCC reporting guidelines, and figures are available on this basis from 1990 onwards. The difference between the two methods of calculation is relatively small – but neither methodology includes emissions from international aviation. IPCC figures do include domestic emissions from aviation, which have been estimated at 5% of UK aviation emissions, the other 95% being from international travel (Bishop and Grayling 2003). The UK Kyoto target of 12.5% reduction by 2010 and the national target of a 20% reduction in carbon dioxide emissions by the same date are also shown in Figure 1. (The UK government admitted in December 2004 that existing policies alone will not achieve the 20% reduction target (DEFRA 2004b).)

To add in emissions from international aviation, carbon dioxide data from 1990 onwards can be used (ONS & NET-CEN 2004). This information shows carbon emissions from all aviation (domestic and international) to be 10.1 MtC in 2002. This figure is considerably higher than the UK figure of 7.5 MtC for emissions from 'international aviation bunkers' in 2001 (United Nations 2003). The ONS & NET-CEN figure is on a 'national accounts' basis and it excludes fuel purchased in the UK by foreign airlines and includes fuel purchased abroad by UK airlines. Methodological differences may explain the difference between the two figures, but more research would be required to explain why they differ so much. This analysis uses the ONS & NET-CEN data which is the more recent of the two available datasets. Emissions from international aviation from the UK appear higher than they would using the alternative United Nations data.

Importantly, aircraft emissions add more powerfully to the greenhouse effect than the carbon dioxide component alone. The current best estimate is that they have between two and four times the effect of carbon dioxide per tonne of CO₂ emitted (IPCC 2001, RCEP 2002), so carbon emissions have been multiplied by three to give a carbon equivalent figure. Because the global warming effects of other emissions from aircraft, such as NO_x, contrails and particulates are included, this estimate is on a different basis from activities in the remainder of the economy – where carbon emissions alone are counted. However, because the effects of other aircraft emissions are very significant it would be misleading to exclude them. Research continues on how to compare properly the effects of aircraft emissions and those emitted at ground level. There is currently a debate about whether to change from the current 'radiative forcing' basis for comparison of different sorts of emissions, to a 'global temperature potential' basis, which would tend to increase the relative effect of aircraft emissions (Jardine 2005).

When international airline carbon equivalent emissions are added to UK carbon emissions (IPCC methodology), there is little difference in total emissions for 1990 and 2002. This gives a less rosy, but more realistic, view of the UK's progress on reducing carbon dioxide emissions. It also highlights the importance of international airline emissions.

EU – PROSPECTS FOR REACHING THE KYOTO TARGET

Under the Kyoto agreement, the EU-15 (the 15 pre-2004 member states) have jointly agreed to undertake an 8% re-

duction of six key greenhouse gases by 2010 compared to 1990. According to the latest report from the European Environment Agency (EEA 2004), greenhouse gas emissions from the EU-15 were 2.9% below base year. This means the EU-15 was little more than a third of the way towards achieving the 8% reduction required. On the basis of their emissions in 2002, nine member states were not on track to meet their individual targets by 2010. EEA state that *existing* domestic policies and measures will reduce EU-15 greenhouse gas emissions by only 1% from base year levels by 2010. However, they then go on to say that with additional measures being *planned* by member states a reduction of 7.7% could be achieved and that a further 1.1% reduction is expected via use of Kyoto mechanisms, meaning the EU target will be met by 2010. The considerable savings expected from these various planned measures seem remarkable given the short time available. Given the track record to date it is difficult to be confident that the EU-15 will meet their collective target.

DISCUSSION

Energy efficiency in the UK domestic sector has been shown to have a low likelihood of achieving significant future savings. In the EU-15 significant reliance is being placed on efficiency policies (EEA 2004), but this brief review suggests that without policies for demand reductions, efficiency improvements may not be effective.

The effect of including international air travel emissions in the UK emissions total has been illustrated. International air travel added almost 20% to emissions in 2002. This is expected to increase considerably in future with passenger numbers using UK airports on course to triple by 2030 (DfT 2003). There is every reason to believe this analysis repeated for other EU countries would show a similar effect. It is vital that international air travel is included in targets to reduce carbon emissions as soon as possible given its increasingly important role. It is also necessary to recognise that including international air travel means that even deeper cuts than currently anticipated in emissions from other sectors will be required.

The EU-15 collectively are far less likely to reach their Kyoto target than the UK, which is still expected to meet its 12.5% reduction commitment (EEA 2004). The Kyoto target itself is widely understood to be only a very small step in the right direction, and much deeper cuts in emissions will be required in future if dangerous climate change is to be avoided. Other EU countries are at least as much in need of new mechanisms to reduce demand and limit carbon emissions as the UK.

Carbon rationing as the solution

The solution suggested here to guarantee carbon reductions from the domestic sector is personal carbon rationing. Personal carbon rationing would be a national allowance system covering carbon emissions generated from fossil fuel energy used by individuals for personal transport, including carbon equivalent emissions from air travel, and within the home. This would cover half of all fossil-fuel carbon equivalent emissions from the UK economy, including international air travel. The primary aim of the scheme would be to deliver

guaranteed levels of carbon savings in successive years in an equitable way. It could apply equally well as a national response in other countries. Carbon rations could also be described as 'allowances', 'entitlements' or 'quotas'.

The main features of carbon rationing would be:

- Equal rations for all individuals
- Tradable rations
- Year-on-year reduction of the annual ration, signalled well in advance
- Personal transport and household energy use included
- A mandatory, not voluntary arrangement

A more lengthy description and defence of each of these elements of carbon rationing was included in a previous ECEEE paper (Fawcett 2003). This paper focuses instead on presenting new data and analysis showing how carbon emissions currently vary between different individuals and groups of people, and discusses what implications this has for the carbon rationing proposal.

Personal carbon rationing as a national route to carbon reductions is based on the same principles as one of the proposed global solutions to climate change: 'contraction and convergence' (Meyer 2000). Contraction and convergence (C&C) is founded on two fundamental principles: first, that the global emission of greenhouse gases must be progressively reduced; secondly, that global governance must be based on justice and fairness. It would achieve this by first agreeing a maximum level of CO₂ in the atmosphere. Once this limit has been agreed, it is possible to work out how quickly current global emissions must be cut back to avoid exceeding the limit. This cutting back is the contraction part of contraction and convergence. This would be followed by global convergence to equal per capita shares of this contraction, by an agreed year. C&C is considered by many to be the framework which should succeed the current Kyoto agreement. The detailed implementation of C&C proposed by Meyer (2000) has many influential supporters, including the UN Environment Programme and the European Parliament (Pearce 2002). However, it has not yet been adopted by any European country as their negotiating position.

Concerns about carbon rationing

There is little literature on carbon rationing and related ideas. However, many questions and challenges to carbon rationing have been raised at presentations made by the author. Some of the concerns are about the practical effects of carbon rations, whereas others challenge the principles which underlie the idea. One strand of questions about the effects of rationing relates to how different groups of people would be affected, particularly the less wealthy or older people. This paper presents preliminary evidence showing how personal carbon emissions currently differ between groups and individuals in the UK. The data will enable a better informed debate about some of the issues around the implementation of rationing.

Other common concerns about carbon rationing include:

1. The unfairness of putting the burden of responding to climate change directly on individuals, and the many

difficulties they may have in responding to limited and reducing emissions.

2. The inequality of giving people equal rights to carbon emissions / allowing trading so that richer people can buy the right to emit more carbon.
3. Carbon rationing is an unnecessary policy - carbon taxation should be the preferred solution.
4. The administrative challenge and the cost of implementing such a system.
5. The (im)possibility of getting public or political support for such a radical idea.

The first three challenge the principles on which rationing is based – and these have been defended previously (e.g. Fawcett 2003). The first two points will be discussed in light of the data presented, but the alternative of carbon taxation will not be discussed in this paper. There is currently research underway in the UK looking at the administrative and cost implications of a carbon rationing system, however this work is still in its early stages and results are not yet available (Anderson and Starkey 2004). Gaining public or political support for a scheme like carbon rationing is far from assured – researching the idea in further detail is part of the process of testing the concept before trying to gain wider support.

Case study data on individual carbon emissions

There is currently no published data on personal carbon emissions on an individual basis. To rectify this gap, empirical data has been gathered from a number of individuals in the UK and their emissions for 2003 have been calculated. This case study data was collected in order to undertake analysis on the variation in personal carbon emissions, and to identify how different components of energy use contribute to this variation. The aim was not to try to explain the variation in terms of underlying factors, such as individual income, household size or access to different transport options. Analysis of emissions according to a variety of such factors is given later in the paper on the basis of secondary data.

METHODOLOGY

The questionnaire used to collect the case study data was a simplified carbon audit, based closely on that developed with Mayer Hillman (Hillman & Fawcett 2004). In order to make the carbon audit relatively easy to complete, the questions were kept to a minimum. Respondents were asked to use energy bills to provide information on gas, electricity and other household fuel usage in 2003. For travel, respondents were asked to estimate the distance travelled by each motorised mode, or to give a description of the routes travelled.

In total a sample of 35 people was achieved, with 32 returning usable questionnaires. Potential respondents were approached from a variety of household sizes and with different heating fuels – two factors which are known to influence household carbon emissions. Respondents were not

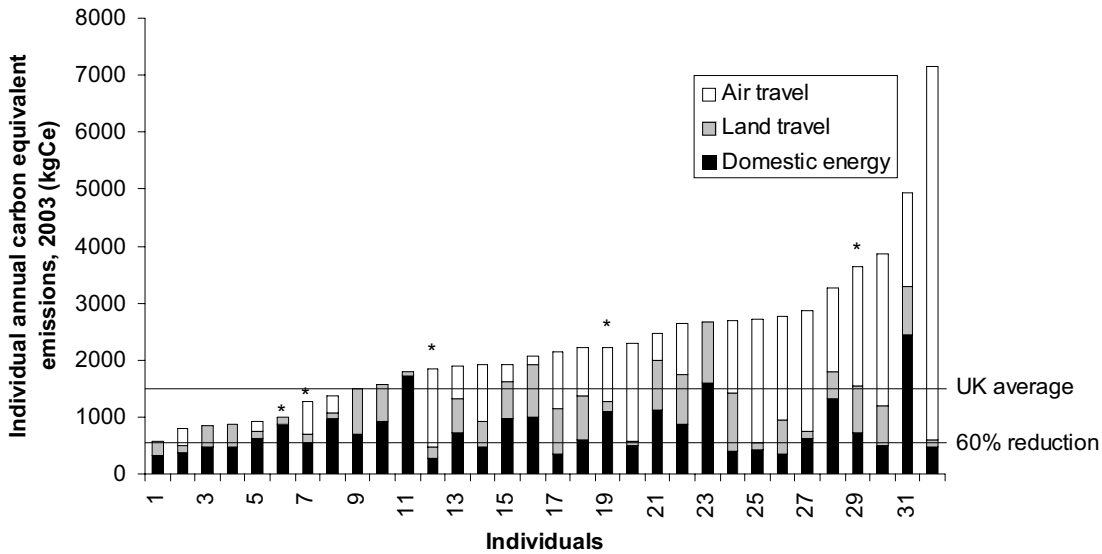


Figure 2. Individual annual carbon equivalent emissions by source, UK, 2003.

asked to provide details of their properties such as age, construction type or insulation level, as the sample size was too small to make use of such information. In addition, very detailed national data is already available on the amount of household energy used by properties and households with different characteristics (e.g. DETR 2000). The characteristics of the sample compared with the UK population are described later. Clearly, however, a sample of 32 is in no way representative of the UK population. From the start, the decision was made not to try and achieve a large enough sample to be representative, because this would be beyond the resources of the author.

The energy use and distance travelled figures reported by respondents were converted into carbon emissions (and carbon equivalent emissions for air travel, created by multiplying carbon figures by three, as discussed earlier) using the best available data derived from government statistics (Hillman and Fawcett 2004). Respondents were not asked to state what model of car they drive, and subsequent calculations are based on the carbon emissions per kilometre for an average petrol car or an average diesel car. This is because there is not sufficient data to use actual emissions figures for individual cars: carbon emissions figures are only available for new car models, under test conditions. This use of averages means that the variation between individual carbon emissions will be underestimated. Travel by sea and by motorbike have not been included, because they are relatively minor travel modes. In addition, figures for carbon emissions from travel by sea are not readily available. This means emissions for the four respondents who either travelled by sea or motorbike will be underestimated.

For those people who had chosen renewable electricity tariffs (five out of 32), their emissions from electricity were set to zero. There is a complex debate about the value of signing up to a renewable energy tariff and the extent to which this results in ‘additional’ renewable energy (FOE

2004). However, well designed renewable energy tariffs should provide additional renewable energy beyond that which is already legally required, and on this basis it is assumed that renewable electricity customers have zero carbon emissions. The carbon emissions from electricity in the UK in 2003 were 0.136 kgC/kWh (based on DTI (2004)), and this figure has been used in calculations for all non-renewable tariff electricity.

RESULTS

Individual carbon emissions have been summarised into domestic energy use, land travel (travel by car, bus and train) and air travel, and are presented in Figure 2. The columns with stars above them are those where the individual has chosen a renewable electricity tariff.

The data show a huge range of personal carbon emissions with the highest emitter being responsible for twelve times the emissions of the lowest (Table 1). They also show the huge variation in the way individuals’ carbon emissions are made up. For Respondent 32, 92% of carbon emissions came from leisure air travel, by contrast Respondent 11 did not travel by air and 95% of their emissions were from household energy use. Of the sample of 32, eight did not travel by air in 2003, and their total emissions were on average just over half those of the group which did fly. The data demonstrate 23 respondents (72% of the total) were responsible for above average UK carbon emissions for 2003.

Table 1 demonstrates the ratios between the highest and lowest carbon emissions by type of energy use, with air travel varying the most between individuals – by a factor of 46 between those who did travel by air. The lowest variation between individuals was for household energy use – although a factor of nine still seems surprisingly high.

Some of the characteristics of the case study sample are compared with UK averages in Table 2. The UK average carbon emissions figures are based on values for 2001, which

Table 1. Comparison of lowest and highest values from case study individuals.

	Ratios lowest: highest values
Total carbon equivalent emissions	1:12
Carbon emissions from household energy use per individual	1:9
Carbon emissions from household energy <i>per household</i>	1:8
Carbon emissions from land transport	1:19
Carbon equivalent emissions from air travel (for people who have undertaken air travel)	1:46

Table 2. Comparison of sample characteristics with UK averages.

	UK average, 2001/02	Case studies sample
Total personal carbon equivalent emissions per person (kgCe)	1 560	2 270 (45% higher than UK av.)
Carbon emissions from household energy use (kgC)	700	780 (11% higher than UK av.)
Carbon emissions from land transport (kgC)	430	480 (12% higher than UK av.)
Carbon equivalent emissions from air travel (kgCe)	420	1010 (140% higher than UK av.)
Average household size *	2.3	2.1
One person households *	31%	31%
Households with children *	27%	16%
Households with one or two retired people (or over 60) *	30%	31%
Households using gas as main heating fuel	80%	84%
Households with renewable electricity tariff	Estimated at 50 000 in 2002, 0.2% of UK households	16% (5 individuals)

Sources: Household characteristics: Rickards et al. 2004, green electricity: FOE 2004

* Values for GB population (which does not include Northern Ireland)

is the last year for which official carbon emissions figures are available separately for household and transport energy use.

The comparisons show that carbon emissions from household and personal energy use for the case study samples were similar to the national average, however carbon equivalent emissions from international air travel were almost two and half times the national average. In total, average case study emissions are 45% higher than the UK average. Note that the UK average carbon equivalent emissions figure includes children (who must have lower than average adult carbon emissions as they cannot drive), whereas no children were included in the case studies.

In terms of household size, the case study sample average was lower than the GB average, this was largely due to the small number of households with children which were included in the survey. The proportion of one-person households and retired households were similar to the national average, as was the proportion of households with gas as the main heating fuel. Households choosing a renewable electricity tariff were considerably over-represented compared with the UK population.

Respondents were invited to contact the author with follow-up comments or questions after receiving feedback on their carbon audits. A number of comments were received, most of which either expressed surprise that their emissions were so high, or that the recipients had plans to reduce their emissions (usually by reducing flying / travel by car).

REDUCING CARBON EMISSIONS IN THE CASE STUDY GROUP

Of the case study sample, 23 out of 32 had higher than average carbon emissions. So what would the options be for these 23 individuals if they wanted to reduce their emissions to the national average? The highest priority is reducing air travel. Eighteen of the 23 had higher than average emissions from air travel, compared with 15 with higher than average land travel emissions, and 10 with greater than average domestic energy emissions. By reducing air travel alone, 14 out of 23 could reduce their emissions sufficiently to reach the national average. Many of this 14, while reducing their air travel from present levels, would still be able to travel considerable distances by air and stay below the average, e.g. case studies 12, 20, 25, 27 and 32. In addition, long distance rail or driving can be used as a lower carbon alternative for reaching European destinations. It is perhaps not surprising that reducing air travel is the most single important carbon reduction measure given that the case study sample as a whole has unusually high emissions from air travel.

Of the nine case study individuals who cannot reduce their emissions to the national average even if they cut out all air travel, all but one has higher than average emissions for both land travel and domestic energy use. On average their household energy emissions are 90% higher and their land travel emissions are 66% higher than the national aver-

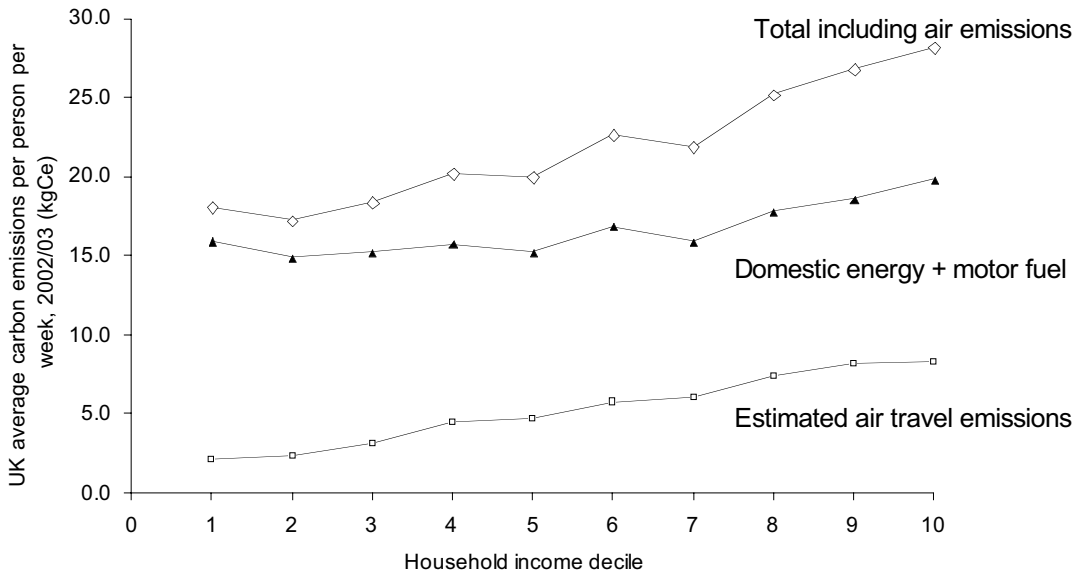


Figure 3. UK average weekly carbon emissions per person from private transport, gas and electricity use, and estimated air travel emissions by household income decile, 2002/03. Sources: ONS 2004, DTI 2004, DEFRA 2001, AA 2004.

age. This suggests they will have to address both patterns of household energy use and land travel. There are many options for doing both.

Carbon emissions by different groups in the UK

This section uses analysis of secondary data to investigate how carbon emissions vary by household characteristics. First of all, the analysis undertaken to estimate carbon emissions by different income groups is explained in some detail. Following this, other work undertaken looking at emissions by age, household size and other characteristics is summarised.

EMISSIONS BY INCOME

There is no data available on total personal energy use by income. The best available proxy data on a combination of domestic energy and road transport fuel use by income is expenditure information. Data from the UK Family Expenditure and Food Survey (ONS 2004) gives expenditure data for both domestic energy and motor transport fuels by income decile, where decile 1 is the 10% of households with the lowest income and decile 10 is the richest 10%. This expenditure data can be translated into carbon emissions by using fuel price and fuel carbon intensity data. However, to do this a number of assumptions have to be made. For example, it is assumed that households with different incomes pay the same price for household and motor fuels, which is known to be an over-simplification (Boardman and Fawcett 2002). Another assumption is that all motor fuel is petrol, because it is not possible to get a split of expenditure between petrol and diesel. Despite the simplifications involved, and

the fact that travel by public transport is not included, use of expenditure data gives a reasonable approximation of emissions from household energy and personal travel on land. Other researchers have also used this approach (e.g. Dresner and Ekins 2004, Francis 2004).

There is no good proxy data for air travel by income. It is known that air travel is predominantly undertaken by the richer members of society, with, for example, three quarters of all low cost flights being taken by the top three social classes (Bishop & Grayling 2003). However, more detailed information is not available. The available expenditure data relates to holidays, and this cannot be translated into air miles, given the many components which make up the cost of a holiday. As a proxy measure, it is assumed here that carbon equivalent emissions from air travel are in the same proportion between different income groups as emissions from motor fuels. This may well underestimate the differences in air travel patterns between rich and poor.

By combining this data, estimates of weekly individual carbon emissions by household income decile can be illustrated (Figure 3). This shows that on average, individuals in lower income deciles have lower carbon emissions than those in higher deciles. The difference between lower and higher income people is primarily driven by car and air travel, which increases considerably with income. Thus, based on this evidence, carbon rations would not unfairly disadvantage the poor.

EMISSIONS BY HOUSEHOLD SIZE

There is strong evidence that carbon emissions from household energy vary considerably by household size (the number of people in a household). Fawcett et al (2000) showed that somebody in a one-person household, regardless of income, uses around twice as much electricity and gas

Table 3. Annual greenhouse gas emissions per person by age of head of household, UK, 2001.

Age	Household size	Domestic energy use (tCe)	Land travel (tCe)	Air travel (tCe)	Total (tCe)
Under 30	2.2	0.5	0.4	1.0	1.9
30 to 64	2.8	0.6	0.4	0.4	1.4
65 and over	1.7	0.9	0.2	0.2	1.4

Based on: Francis 2004 with adjustments to air travel figures to give carbon equivalent data, DWP 2002

Table 4. Characteristics which influence personal carbon emissions.

	Personal carbon emissions →			
	Low			High
Main heating + hot water fuel	Wood, solar water heating or other renewables	Gas	Oil	Coal / solid fuel, electricity
Heat loss of building fabric	Low			High
Size, age and form of property	Small, new, flat or terraced	Average, mid 20 th century, semi-detached		Large, old, detached / bungalow
Use of household energy	Careful, modest temperatures + warm clothes			Profligate, many gadgets, high temperatures
Travel patterns	Short distances, few or no flights			Long distances, by car, many flights
Income	Low			High
People per household	Four +	Three	Two	One
Age of head of household		Greater than 30		Less than 30

Source: Fawcett, 2005

and therefore produces twice the carbon emissions as somebody in a three-person household. More recent analysis demonstrated a similar result. Francis (2004) shows that for all greenhouse gas (GHG) emissions from domestic energy use, individual emissions for one, two and three plus person households are in the ratio 100:71:41. Neither piece of research distinguished between the effects of additional children as distinct from adults.

Equivalent data for land travel show that individual emissions for one, two and three plus person households are in the ratio 100:115:85. Unfortunately air travel data are not collected by household size. Putting the land travel and household energy use data together gives a combined individual emissions ratio for one, two and three plus person households of 100:81:52. Unless people living alone fly very much less than those in larger households, it is likely that average total personal greenhouse gas and carbon emissions reduce with increasing household size.

EMISSIONS BY AGE

Francis also carried out analysis of household GHG differentiated by the age of the head of the household. This has been combined with GB data on the size of households by age of the head of household from the Family Resources Survey (DWP 2002). This combination results in the figures in Table 3. The data show interesting differences in patterns of energy use, with older households travelling much less by land and by air than younger ones, but having higher domestic energy emissions. Consequently households with a head aged 65 or over have the same emissions per person as those

headed by people 30-64. Younger households have higher emissions, and these are dominated by air travel. However, given the previously identified weaknesses of air travel data, it would be best to view these figures somewhat cautiously.

SUMMARY OF FACTORS WHICH INFLUENCE INDIVIDUAL CARBON EMISSIONS

In addition to the variation of carbon emissions according to householder characteristics, it is known that energy use, and thus carbon emissions, vary with fuel choice, the efficiency of dwellings and their energy-using equipment, travel patterns and so on. The factors that will influence personal carbon emissions are summarised in Table 4.

The differences identified here according to individual, household and housing characteristics in combination lead to the very different emissions between individuals found in the case study data.

Discussion

VARIATION IN CARBON EMISSIONS BETWEEN INDIVIDUALS AND GROUPS

Original case study data on personal carbon emissions has been presented. Valuable insights have emerged from this sample of thirty two people. The most striking finding is the range of carbon emissions encountered, with the highest carbon emissions being twelve times the lowest. Compared with the average UK carbon emissions for personal travel and household energy use, the lowest emissions in the sur-

vey were 37% of the average, with the highest being 4.6 times the average. Highly unequal individual contributions to climate change are being made at present in terms of direct energy use. Another surprising insight is the extent to which patterns of carbon emissions differ, with the ratios of household: land travel: air travel emissions varying widely.

As well as differences between individuals, the systematic differences between various groups have been explored. Expenditure data has been used to show that individual carbon emissions for household energy use and personal private transport increase with income decile. Analysis has shown that people in one-person households use considerably more household energy per person than those in multi-person households. Others likely to have higher than average emissions are: households headed by an under-30 year old; users of solid fuel and oil heating; those living in large, detached or inefficient houses; frequent flyers and high mileage car users; and those who prefer very warm rooms to warm clothing.

Emissions are likely to vary in another way – over time for the same individual. Many individuals' emissions are likely to vary considerably from year to year, particularly for those who travel by air. The secondary data analysis offers hints that carbon emissions profiles may vary over a person's lifetime, as activities and energy use alter with age and life stage.

WHAT DOES THIS MEAN FOR CARBON RATIONING?

The considerable variation in individual emissions shown by the case study data has a number of consequences for the practical implementation of carbon rations:

- Under carbon rationing, trading of rations will be very important and most people will want to buy or sell spare rations. A system under which people were not permitted to buy and sell rations would be extremely difficult to justify.
- There are likely to be considerable numbers of people, particularly those who fly long distances and want to continue to do so, who will have difficulty in reducing emissions to the national average.
- The responses to carbon rationing are likely to vary hugely depending on how personal emissions are made up. In the examples highlighted earlier, Respondent 32 would need to cut down air travel considerably, whereas all of Respondent 11's actions should be directed towards improving the efficiency of their home, using lower carbon fuels and reducing domestic energy use via behavioural changes.

The use of secondary data has allowed an estimate of current carbon emissions by income group. This evidence has suggested that carbon rationing would not disadvantage the poor on average, in fact initially they should gain from the introduction of rations as they would have a surplus to sell. However, in their detailed work on household energy use by income decile, Dresner & Ekins (2004) found that average expenditure figures by decile hide a considerable variation in energy expenditure and energy use between individuals in the same decile. Those at the 80th percentile in the lowest decile consume nearly nine times as much energy as the 20th

percentile of the decile. Thus, some people in the lower income deciles will have very much higher emissions than the average in these groups, and they are likely to be disadvantaged under a system of carbon rationing.

It could be argued that because certain categories of people, e.g. one person households, tend to have higher than average emissions, they should be given higher than average allowances. But as Table 4 indicates there are many factors which determine whether a person has higher or lower emissions. Judging which factors influencing personal emissions should be compensated for through a differentiated ration scheme would be extremely difficult. Should people living in larger homes have greater emissions allowances? What about those who live a long distance from their work place? Even if a workable scheme for calculating individual rations could be devised based on some idea of 'need' for emissions (and that seems extremely unlikely), the result could be that some individuals might be given a ration ten times that of others. It would very difficult to make a case for such an unequal rationing system. There is a strong argument in principle for giving every adult an equal carbon emissions allowance, what Table 4 and the case study data indicate is that there are also strong pragmatic and practical reasons for doing so.

However, giving equal allowances to all would mean that some of the more vulnerable members of society who have high carbon emissions would be penalised under carbon rationing. Some of these people are already suffering from 'fuel poverty' in the UK, that is they would have to spend more than ten percent of their income to get adequate energy services. Inevitably a policy as radical as carbon rationing will have winners and losers, however if too many of the losers are those who already suffer from lack of energy services, and who have low capacity to adapt to rationing then this could be problematic. Rather than abandoning carbon rationing as an idea, what is required is further work to identify how many vulnerable people would be disadvantaged, and to work on designing compensatory mechanisms outside of the rationing scheme.

Conclusions

Action to reduce carbon emissions in the UK and EU has been inadequate given the scale of the problem of climate change. Too much faith is being placed in 'solutions' such as energy efficiency which, without a cap on demand, have been proved to be ineffective in the past. Emissions from the UK and EU are currently underestimated because international air travel is not included. In the UK this adds around 20% to total carbon emissions, a proportion which is likely to increase if the projected high growth in airline emissions is not prevented. It is doubtful that the EU-15 will achieve even their modest 2010 Kyoto target (which does not include airline emissions). Given this background, a more radical approach is needed to make carbon savings.

Carbon rationing is argued to offer a fair and effective way of reducing carbon emissions, which would be applicable in all EU countries. Personal carbon rations for household and personal transport energy use, including air travel, would cover about half of carbon equivalent emissions from the UK economy. UK case study data has demonstrated a very

wide range of annual emissions, which varied by a factor of twelve for a small sample of people. Secondary data analysis identified some of the key factors which produced such a wide variation. Together these data reinforced the practical case for giving equal carbon emissions to all adults, as the very high degree of variation for a wide range of reasons would make designing an alternative system very complex, if not impossible. In general, carbon rations should be socially progressive. However, equal emissions will mean that some vulnerable individuals are likely to suffer under carbon rationing. It should be possible to design some compensatory mechanisms, but there is no doubt carbon rations will give rise to winners and losers. Given the highly unequal impact individuals are currently having on the climate it could hardly be otherwise. Trading would need to be part of any rationing system given the wide variation in emissions. Those who bought additional rations would pay extra, in line with the 'polluter pays' principle which underlies much of EU environmental legislation.

This analysis has increased the evidence base for discussion about the practical implementation of carbon rations. It should also provide useful data for those interested in carbon taxation and its possible effects. However, further research is still required. In particular, detailed carbon audits need to be carried out on a larger sample of people in the UK. The same exercise would be required in other EU countries. In addition, more analysis would be needed to identify potential winners and losers under carbon rationing and to outline a variety of responses which could help people reduce their emissions. To reinforce the case for carbon rations, the wider benefits to society of carbon rationing should be listed, e.g. fewer road casualties, due to lower use of motorised transport. Carbon rationing is a powerful idea, further research is needed to make its impacts clearer, and to demonstrate that while radical, it can be a positive response to climate change.

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