Distributional Effects of Climate Change Taxation: The Case of the UK

KUISHUANG FENG,[†,‡]
KLAUS HUBACEK,*[,†,§] DABO GUAN,[‖]
MONICA CONTESTABILE,[⊥] JAN MINX,[‡,#]
AND JOHN BARRETT[‡]

Sustainability Research Institute, School of Earth and Environment, University of Leeds, LS2 9JT, U.K., Stockholm Environment Institute, University of York, YO10 5DD, U.K., Department of Geography, College Park, University of Maryland, Maryland 20742, Cambridge Centre for Climate Change Mitigation Research, Department of Land Economy, University of Cambridge, Cambridge, CB3 9EP, U.K, WWF - U.K., Panda House, Godalming, GU7 1XR, U.K., and Department for the Economics of Climate Change, Technische Universität Berlin, 10623 Berlin, Germany

Received September 29, 2009. Revised manuscript received March 31, 2010. Accepted April 8, 2010.

Current economic instruments aimed at climate change mitigation focus mainly on CO_2 emissions, but efficient climate mitigation needs to focus on other greenhouse gases as well as CO_2. This study investigates the distributional effects of climate change taxes on households belonging to different income and lifestyle groups; and it compares the effects of a CO_2 tax with a multiple GHG tax in the UK in terms of cost efficiency and distributional effects.

Results show that a multi GHG tax is more efficient than a CO_2 tax due to lower marginal abatement costs, and that both taxes are regressive, with lower income households paying a relatively larger share of their income for the taxes than higher income households. A shift from a CO_2 tax to a GHG tax will reduce and shift the tax burden between consumption categories such as from energy-intensive products to food products. Consumers have different abilities to respond to the tax and change their behavior due to their own socio-economic attributes as well as the physical environment such as the age of the housing stock, location, and the availability of infrastructure. The housing-related carbon emissions are the largest component of the CO_2 tax payments for low income groups and arguments could be made for compensation of income losses and reduction of fuel poverty through further government intervention.

1. Introduction

The UK is one of few European countries that have already achieved their Kyoto Protocol targets over the 2008 to 2012 commitment period (*1*) and reduced greenhouse gas emissions by 17.6% below 1990 levels (*2*). In addition, the UK has already set up legally binding reduction targets for a more ambitious long-term strategy and mitigation actions including "greenhouse gas emission reductions through action in the UK and abroad of at least 80% by 2050, and reduction in CO_2 emissions of at least 26% by 2020, against a 1990 baseline" (*3*).

Taxes and emission trading schemes are both market-based policy instruments, which are frequently discussed in the climate change literature (*4–6*). In an emission trading scheme the policy maker sets the amount of carbon to be traded and the price is determined through the market transactions. In a carbon tax scheme the policy maker sets the price for carbon and the amount of carbon emitted is dependent on the response (price elasticity) of producers and consumers, depending on availability of new technologies and their ability to use less carbon-intensive goods and services and a less carbon-intensive energy mix. We focus our analysis on carbon taxes though major parts of our discussion of the distributional impacts largely hold for both instruments. Proponents of carbon taxes highlight their simplicity and transparency (*7, 8*). Recently carbon taxation discussions in the UK have been reinforced by recommendations of the EU Commission (*9*) and the UK Royal Society (*7*).

Apart from some notable exceptions (*10, 11*) current economic instruments aimed at climate change mitigation focus mainly on CO_2 emissions (accounting for 77% of all global anthropogenic greenhouse gas (GHG) emissions in 2004) (*12*), but the Kyoto Protocol also refers to other GHGs (CH_4, N_2O, HFCs, PFCs, and SF_6) as probably any follow-up climate change agreement will. From practical experience with CO_2 taxation it is well-known that acceptability of a CO_2 or GHG tax is strongly influenced by its distributional impacts (*13–16*). However, a number of studies suggest that carbon taxes tend to be regressive in terms of distributional effects on income groups (e.g., refs *17–23)*, that is, households with lower income pay a larger share of their income on carbon tax payments than those with higher income. For example, a study for the U.S. by Hassett et al. (2009) (*21*) shows that consumption of fuel and electricity drives the regressivity of the carbon tax. This potentially raises equity and fairness issues in a climate change debate where authors frequently highlight that those who are mostly responsible and who have the largest capacity to act should carry the majority of the costs (*24, 25*).

Nevertheless, the inclusion of non-CO_2 GHG emissions in a multiple GHG tax provides alternative options to meet both socio-economic and environmental targets (*15*). It is claimed that a multiple GHG tax policy can mitigate climate change with lower costs than a CO_2-only tax policy (*26, 27*), and that a multiple GHG tax can also decrease the regressive effects of traditional carbon taxation on the distribution of income (*15*). On the other hand, in a GHG tax scenario the tax burden might be reallocated differently across economic sectors because a large amount of CH_4 and N_2O are emitted from agricultural processes, whereas CO_2 emissions are mostly generated by fossil fuels combustion in industry, energy supply, and transport (*28*). This may alter the distribution of the tax burden across consumers because of different consumption patterns.

This study aims to assess and compare the distributional effects of a CO_2 tax vis-à-vis a multiple GHG tax on different segments of society in the UK. In addition, in this study we analyze how the distributional effects of such taxes manifest themselves in space across the UK by using geo-demographic

* Corresponding author phone: +44 (0) 1133431631; e-mail: k.hubacek@leeds.ac.uk.
[†] University of Leeds.
[‡] University of York.
[§] University of Maryland.
[‖] University of Cambridge.
[⊥] WWF - U.K.
[#] Technische Universität Berlin.

10.1021/es902974g

Published on Web 04/29/2010

data. A spatially explicit analysis of tax payment per income and lifestyle group shows how different parts of the UK would be affected and how this might affect "spatial inequality" in the absence of other compensation mechanisms.

2. Materials and Methods

In order to assess and compare the distributional effects of a multi-GHG tax with a CO_2 tax, we estimate the direct and indirect tax payments of UK households for different income and lifestyle groups adopting similar approaches used by Kerkhof et al. (*15*) and Wier et al. (*20*). We carry out the analysis in three steps (see Supporting Information (SI) Figure S1): First, we determine hypothetical tax rates for a GHG tax and a CO_2 tax, respectively, for different carbon reduction levels. Second, we estimate the price changes for different consumption items induced by a GHG and CO_2 tax, respectively. This is achieved by linking the respective tax rates to an environmentally extended input-output model, which allows us to quantify the tax implications based on embodied carbon in consumer products taking account of the whole domestic supply chain. Finally, we couple the price changes for different consumption categories with geo-demographic (*41, 42*) and household expenditure data (*40*) to quantify the tax payments per income group and per lifestyle group in the UK.

2.1. Step 1: Establishing Tax Rates. In the absence of a comprehensive GHG or CO_2 tax in the UK, we establish hypothetical tax rates in this study. The rates are determined by applying marginal abatement cost data from the UK Climate Change Committee (*29*) to the UK emission reduction target with an ambitious 30-percent reduction by 2020 compared to 1990 CO_2 equivalent The abatement cost curves are constructed based on information for the following sectors: agriculture (*34*), industry (*34*), domestic construction (*35*), nondomestic construction (*35*), transport (*36*), and waste treatment (*37*). Based on this information the cost curves were established by ranking emission reduction measures according to their cost-effectiveness. Marginal abatement cost curves are a key tool in environmental economics linking emission reductions and their incremental cost and have become central to the economic assessment of mitigation strategies (*30*). This approach does not try to optimize economic output, but provides a method to implement policy objectives at least-cost (*31*) Under a multiple GHG strategy, the mitigation of different Kyoto gases are interchangeable for achieving UK's reduction target in CO_2 equivalents; thus compared to a single gas (CO_2) strategy, the abatement cost curve in this case includes additional reduction options associated with the other gases.

2.2. Step 2: Tax Induced Price Changes. A GHG or CO_2 tax imposed on industries and households in the UK will change the price of products. To examine these price changes, we use input−output analysis to quantify both direct and indirect effects of CO_2 and GHG taxes for a product accounting for all emissions throughout the domestic supply chain. For example, direct emissions from driving a car are due to the combustion of petrol, whereas indirect emissions from buying the car arise through the production process of the car and all its inputs. Therefore, in the first case, taxes are imposed on the emissions related to the consumption of the product (direct effect), whereas in the second case, taxes are imposed upon the industry responsible for the emissions due to the production of the product (indirect effect). In line with other studies we assume that taxes imposed on industry sectors are fully passed on to the consumer. In order to be able to use consumer expenditure data we need to assume that the purchasing power of consumers across the income groups stays the same (e.g., through some subsidy scheme) (*15*).

The total price change of consumption category k is the sum of direct and indirect price changes:

$$\Delta P_k^{\mathrm{tot}} = \Delta P_k^{\mathrm{dir}} + \Delta P_k^{\mathrm{ind}} \tag{1}$$

Where $\Delta P_k^{\mathrm{tot}}$is the total price change of consumption category k, $\Delta P_k^{\mathrm{dir}}$ is the direct price change of consumption category k, and $\Delta P_k^{\mathrm{ind}}$ is the indirect price change of consumption category K.

Direct price changes are the result of taxation of direct household GHG or CO_2 emissions. The price change after taxation of direct emission of consumption category k is shown in eq 2:

$$\Delta P_k^{\mathrm{dir}} = f_k^{\mathrm{dir}} t \tag{2}$$

Where f_k^{dir} indicates the direct emission intensity of consumption category k (ton CO_2 equivalent of GHG or CO_2 emitted per pound of product output) and t is the tax rate of a comprehensive GHG tax or CO_2 tax.

Indirect price changes are the result of taxation of emissions that are emitted from industry sectors. Equation 3 denotes the direct tax payments per unit of output in industry sector j:

$$d_j = f_j t \tag{3}$$

where f_j is the emission intensity of sector j, and t is the tax rate.

We calculate the total tax payments of industry sectors by input-output analysis, and then we obtain total indirect price changes of consumption categories through linking the supply industries to final consumption categories. This is represented in the eq 4:

$$\Delta P^{\mathrm{ind}} = d(I - A)^{-1} C \tag{4}$$

where ΔP^{ind} is a row vector containing the indirect price changes of consumption categories; d is a row vector of emission tax payments per unit of sectoral output; $(I - A)^{-1}$ is the Leontief inverse matrix (*32*). Here, C is a sector-COICOP transition matrix indicating the supply of the UK-based production sectors of consumption items bought by UK consumers. The coefficients in the transition matrix are expressed as the supply of a sector to a product group divided by the total industrial supply to that product group.

2.3. Step 3: Distributional Effects. The tax payments of households in different income groups and lifestyle groups are a result of the price increase for different consumption items and the specific basket of goods and services different income groups and lifestyle groups consume. Consequently, the total tax payment of a certain income group or lifestyle group can be calculated by the sum of the total price increase for each consumption category times the total expenditure of a certain income group or lifestyle group on each consumption category, as shown in eq 5.

$$V_g = \sum_k \Delta P_k^{\mathrm{tot}} e_{k,g} \tag{5}$$

Where $e_{k,g}$is the total annual expenditure of income group g for consumption category k.

2.4. Data. The data required for this research are from various sources (See SI for a detailed overview).

2.5. Limitations. First, one of the weaknesses of our analysis is that - given the existence of an emission trading scheme in Europe (EU-ETS) - we do not consider how a tax would work in tandem with the EU-Environmental Trading Scheme [In 2003, the European Council formally adopted the Emissions Trading Directive (Directive 2003/87/EC). The

Directive laid out the framework for the European Emissions Trading Scheme (the "EU ETS"). The scheme started in 2005. From this date emissions from the companies covered by the scheme (currently only the power sector and energy-intensive industrial sectors) were capped across 25 European countries]. While such a coexistence would make the assessment of the distributional impacts and the design of an appropriate policy response more complex, we would expect a carbon trading system—on a general level—to have a similar regressive effects (*40*) than a tax. Thus, most of the discussion that follows would apply to both policies. Second, this study assumes that price changes are entirely related to the direct and indirect GHG emissions associated with a particular consumption item. Differences in prices caused, for example, by different pricing strategies a company might apply when passing on the carbon taxes to the consumers are not included. Third, this study does not model the behavioral response of consumers to higher prices and the associated changes in production as well as their price effects. Instead we assume that the purchasing power remains unaffected by the tax and there is no change in technical structure and consumption patterns. We therefore only consider the effect of consumers having to pay higher prices for their goods and services in the short-run. Finally, another shortcoming is that the abatement activities may affect wages, returns to capital and labor supply (as mentioned by Fullerton 2009) (*41*), which cannot be measured by our model. However, even though some of the assumptions we make might appear strong, we believe that they provide helpful simplifications in the context of the analysis presented. Clearly, assessments focusing on the long-run effects of a carbon tax would need to model at least some of the factors outlined in this section explicitly.

3. Results and Discussion

3.1. Tax Rate and Cost-Effectiveness. The abatement cost curves shows quantitatively the most cost-effective options to achieve emission reduction targets and the associated costs across sectors. Both abatement cost curves for various GHGs and CO_2 are shown in SI Figure S2. It appears that the marginal abatement costs of all GHGs are much lower than the marginal cost of a reduction of CO_2 emissions. Therefore, the mitigation of a comprehensive GHG strategy provides relatively cheaper abatement options compared to a CO_2 reduction strategy alone.

The optimal tax rates for a comprehensive GHG and a CO_2 tax are established through the intersection of the abatement cost curves with the respective UK climate change target. The GHG tax rate would be about 56 pounds per ton CO_2 equivalent and 93 pounds per ton CO_2 equivalent for the CO_2 tax in order to achieve a 122 million tons CO_2 equivalent emission reduction (see SI Figure S2). The steep slope of the marginal abatement curve for both comprehensive GHG and CO_2 shows that further incremental emission reductions would lead to a considerable tax increases. Thus, we would expect the problems of acceptability associated with a carbon tax to become more and more prominent. On the other hand, the more stringent the target gets, the better a GHG tax performs against CO_2 tax.

3.2. Price Changes. In general, consumption categories taxed with the CO_2 tax show higher price increases than the same category with a GHG tax because the CO_2 tax rate is higher than the GHG tax rate to achieve the same climate change mitigation target. However, for some consumption categories the results are reversed. For example, *meat, fruit, and vegetables* cause high emission of methane and N_2O due to enteric fermentation by cows and denitrification processes in soils which are ignored under a CO_2 tax scheme and instead taxed under the GHG tax scheme. In addition, *water supply* shows a higher price increase under the GHG tax than the CO_2 tax due to the production of N_2O during nitrogen removal from domestic wastewater. The detailed description of consumption categories can be found in the SI.

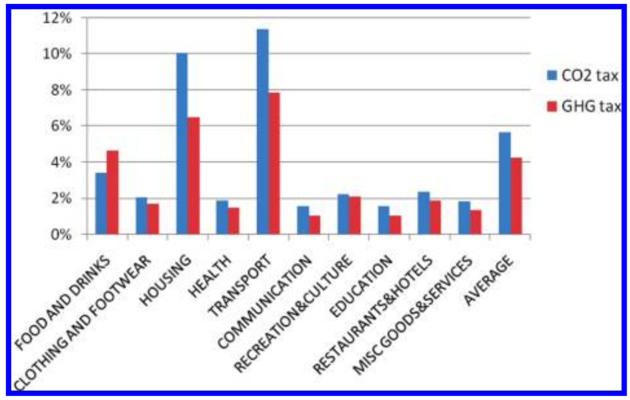

FIGURE 1. Price changes after CO_2 and GHG taxation for 10 aggregate consumption categories.

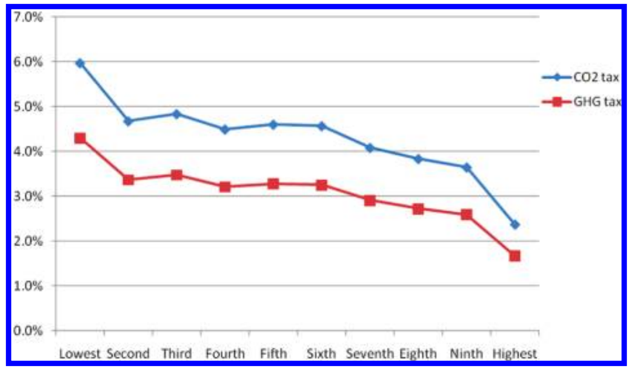

FIGURE 2. Tax payment as percentage of income by income deciles in the UK (£93/ton CO_2 equivalent for CO_2 tax and £56/ton CO_2 equivalent for GHG tax).

An overview of the price changes across 10 aggregate consumption categories are provided in Figure 1. (For a detailed description of 10 aggregate consumption categories see SI Table S3). The results show an average price increase across all consumption categories of 5.6% under a CO_2 tax and 4.3% under the GHG tax. The average price increase of consumption categories in GHG strategy is therefore 1.3 percentage points lower for the same environmental gain. When shifting from a CO_2 to a GHG tax the price increase for *housing* and *transport* would drop by 3.5 percentage points, whereas the one for *food and drinks* would increase by 1.3 percentage points. In addition, the price increases for other consumption categories, such as *clothing and footwear*, *health*, and *education* would drop by approximately 0.5 percentage points when taxing CO_2 rather than GHG.

In general, a shift from a CO_2 tax to a GHG tax will reduce the tax burden and will spread the burden differently across consumption categories, such as decreasing the load on energy-intensive products and increasing payments on food products.

3.3. Distribution of Tax Burdens. *3.3.1. Distributional Effects on Income Groups.* Figure 2 shows that low income households pay a larger share of their income for a CO_2 tax or GHG tax than high income households. From Figure 2 we can also see that tax payments as a percentage of annual income by income deciles are considerably lower when shifting from a CO_2 tax to a GHG tax. In the case of a CO_2 tax, the lowest income group pays about 6.0% of their income for the tax and the highest income group would only pay about 2.4%. Under a GHG tax, the lowest income group pays 4.3% of their income for the tax, whereas the highest income group would pay 1.7%. Although the regressive impacts

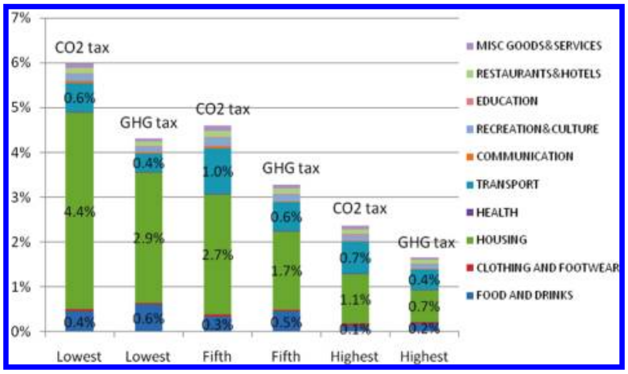

FIGURE 3. Tax payments as percentage of annual income, differentiated between 10 aggregate consumption categories, by lowest, medium, and highest income groups. Note: the lifestyle groups are ordered from low to high income.

remain, the degree is less pronounced under the GHG tax scheme compared to the CO_2 tax scheme.

The CO_2 and GHG tax payments for different consumption categories by low, medium and high income groups are shown in Figure 3. The figure shows that the regressivity of a CO_2 tax is caused by the high tax burden on *housing*, which contains most of tax payments on electricity and gas. The CO_2 tax payments for *housing* contribute more than 70% of total tax payments in the lowest income group and about 40% of total tax payments in the highest income group. The high tax burden for the lowest income group can be explained by the fact that low income households spend a larger fraction of their income on heating and electricity than high income households. However, the tax burden on *housing* decreases from 4.4 to 2.9% in the lowest income group when shifting from a CO_2 tax to a GHG tax, whereas it declines from 1.1 to 0.7% in the highest income group. The lowest income households spend a roughly 4 times larger share of their income on CO_2 or GHG tax payments for *housing* than the highest income households. A shift from a CO_2 to a GHG tax represents essentially a shift in tax burden from energy intensive products to food products; the regressive effect would be reduced, and overall tax payments would be lower.

3.3.2. Distributional Effects on Lifestyle Groups Considering Location. Apart from income groups, we also apply the model to lifestyle groups using a geo-demographic database of consumption activities. Lifestyle groups are not only classified by income, but also by various other socio-economic factors as well as the physical environment. People belonging to different lifestyle groups have different consumption patterns and thus differences in carbon emissions. The detailed description of each lifestyle group (e.g., "Symbols of Success", "Welfare Borderline", "Municipal Dependency", etc.) can be found in SI Table S4. Moreover, the spatial context they live in partially determines the extent to how difficult they can respond to price changes. Therefore, the effects of carbon taxes and what these would mean for different lifestyle groups would be very different.

Figure 4 shows GHG tax and CO_2 tax payments as a percentage of income per lifestyle groups. The lower income lifestyle groups such as Welfare Borderline, Municipal Dependency, and Blue Collar Enterprise [For a complete list and description of lifestyle groups see http://guides.business-strategies.co.uk/mosaicuk/html/main/animation.hta http://www.xxx.co.uk/ and a summary in the SI] pay a greater share of their income to a CO_2 tax and a GHG tax than lifestyle groups with high living standards such as "Symbols of Success" and "Happy Families". Symbols of Success would pay slightly less than 5% of their income on a CO_2 and 3.3% on a GHG tax, whereas Municipal Dependency would pay more than 7% of their income under a CO_2 and 5% under a GHG tax. Across

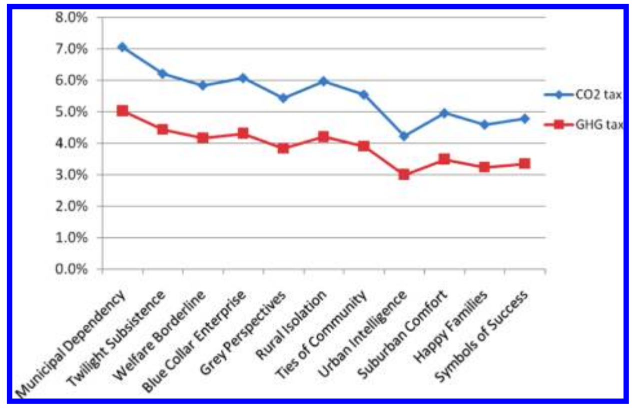

FIGURE 4. Tax payment as percentage share of annual income by lifestyle group in the UK in 2004, in an order from the poorest group to the richest group (£93/ton CO_2 equivalent for CO_2 tax and £56/ton CO_2 equivalent for GHG tax). Note: the lifestyle groups are ordered from low to high income.

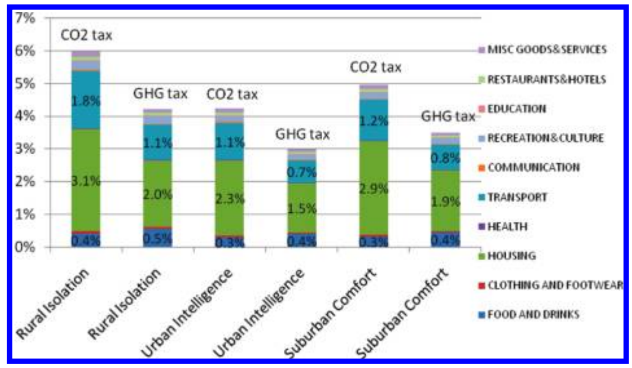

FIGURE 5. Tax payments as percentage of annual income by selected lifestyle groups, differentiated between 10 aggregate consumption categories.

groups we see that a GHG tax is distributed more equally than a CO_2 tax.

In order to compare the typical rural and urban lifestyles and consumption patterns we further decompose the tax burden across consumption categories for the lifestyle groups Urban Intelligence, Suburban Comfort, and Rural Isolation (see Figure 5). It shows that there is also inequality of a CO_2 or GHG tax burden across lifestyle groups from urban to suburban and rural areas. Rural Isolation households pay a much higher share of their income for a CO_2 and GHG tax than Suburban Comfort households (about 0.8%age points higher) and Urban Intelligence households (about 1.7%age points higher). This can be explained by the high tax burden on *housing* (48% of total tax payment) and *transport* (26% of total tax payment) due to their relatively high demand for heating, electricity, and transport. Urban Intelligence and Suburban Comfort households have fairly easy access to public transport services compared to Rural Isolation households. When shifting from a CO_2 tax to a multi-GHG tax the tax burden for *housing* and *transport* decreases significantly, especially for the Rural Isolation group leading to a more equal distribution of the tax burden across lifestyle groups (see Figure 5). Rural Isolation households pay 30% less tax through shifting from a CO_2 to a multi-GHG tax, although tax payment on *food and drinks* increases by about 1 percentage point, such an increase is much smaller than the reduction on *housing and transport*

Crucially for the analysis of the effects of a CO_2 or GHG tax, consumers have different abilities to respond to the tax and change their behavior due to various socio-economic factors, location, and the availability of infrastructure. Lifestyle groups such as "Suburban Comfort" or "Rural

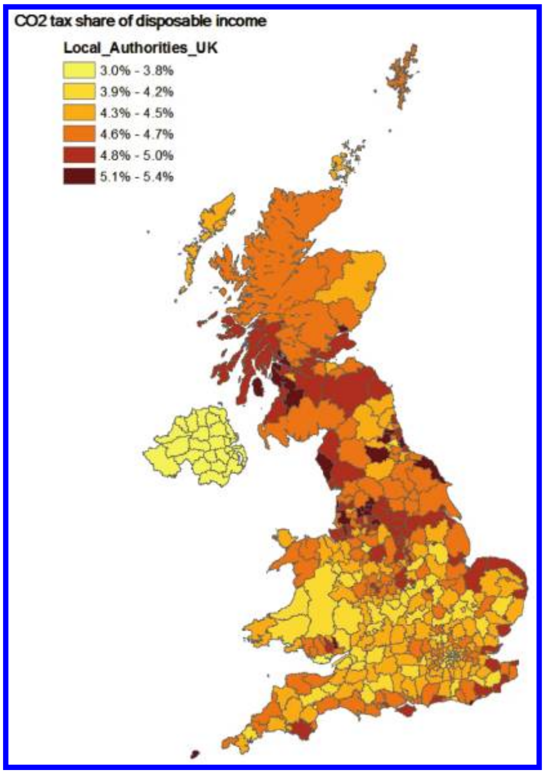

FIGURE 6. CO_2 tax share of disposable income across 434 local authorities in the UK.

Isolation", for example, are much more dependent on their cars than households grouped under "Urban Intelligence" and are hit much harder by increased fuel prices. Households in the lifestyle groups "Welfare Borderline" and "Municipal Dependency" have much fewer options to react to increased costs for operating their houses than "Symbols of Success", because they often do not own the houses they live in and often do not have the means to undertake larger retro-fitting exercises.

Because our data is spatially referenced, that is, we know where people of different lifestyle types live; we can also analyze how parts of the UK are affected differently by the tax. Even though we will restrict ourselves to a short demonstration of results rather a complete analysis in order to conserve space, there are a variety of analytical options, which we will leave to future research. Figure 6 shows CO_2 tax shares of disposable income across 434 local authorities (*42*) in the UK [local authority is local government in the United Kingdom. In total, there are 434 local authorities in the UK. 354 of these are in England, 26 in Northern Ireland, 32 in Scotland and 22 are in Wales]. Local authorities in North England and Scotland would be affected most by a CO_2 tax, and the average CO_2 tax share of disposable income would be more than 4.5% in these two regions. This is mainly driven by the fact that particularly poor lifestyle groups—often depending on usually badly insulated council houses—such as "Welfare Borderline", "Municipal Dependency", and "Twilight Subsistence" make a large share of the population. Moreover, these regions show a higher proportion of rural lifestyles (e.g., Rural Isolation); peoples' homes tend to be further away from the working place, shops, pubs, schools, and community facilities. Finally, the winter temperatures in Scotland and North England are usually higher than in other regions of the UK, thus causing higher heating bills which would impact such households stronger by a CO_2 tax. Therefore, the spatial analysis of distributional impacts clearly indicates the areas to which the UK government should pay attention.

3.4. Policy Implications. This paper indicates that both a multi-GHG tax and a CO_2 tax are regressive, that is, lower income groups would have to pay a higher share of their income on the tax unless additional redistributional measures are taken. However, the GHG tax would be distributed more equally across groups than the CO_2 tax. This is due to the fact that low income households spend a larger share of their income (12%) on food than high income groups (4%). Differences are even more pronounced for other essential consumption categories related to housing where the share of total income would be about 43% for low income households compared to only about 8% for high income households. Thus a shift from a CO_2 tax to a multi GHG tax with a reduction of tax payment on housing would more than compensate for the increase of tax payment for food in the case of low income households.

Notwithstanding the environmental benefits of shifting taxes toward a resource-base approach, social barriers represent a big issue for the government; it is a widely shared view among economists and policy analysts that one big obstacle of a carbon tax is represented by the tax being a regressive one (*14, 43*). Alternative ways of designing and implementing the tax have to be considered on the basis of evidence showing how they can improve performance in terms of socio-economic impacts without jeopardizing the rationale for the tax (i.e., focus on the environmental goal).

Government might need to make sure that sufficient compensation is given to low income households in order to reduce their tax burden and secure social acceptability. (This assumes that a fairer income distribution is indeed a government policy. There are other regressive taxes, most notably the value-added tax (VAT)). The compensation can be introduced by either giving special emission allowance which would defeat the purpose of a carbon tax or through reducing other types of taxation or creating other transfer payments specifically for lower income groups (*20*). A number of examples exist, for example in The Netherlands, where progressivity has been built into a "green tax system" such as exemption for income tax for lower income brackets (*16, 44*). In terms of sectoral effects of a carbon tax we found that electricity production would be the most affected sector. In order to reduce the carbon intensity of electricity production, the government might subsidize renewable energy production through technologies such as wind farms and solar power or encourage such production through feed-in tariffs (*45*).

The situation is a bit more complicated with regards to GHG and food. Most of the GHG emissions are associated with methane emissions for meat production, especially cattle, and only a limited amount of technological options are available (especially with regards to the digestion system of cattle which can only partly be influenced through changes in feeding practices). In general, an increase in CO_2 efficiency in agriculture is fairly limited. Moreover, food consumption is a sensitive issue as it represents a large consumption item for lower income groups; besides, meat consumption can only be replaced by switching to a more vegetarian diet and this opens the door to cultural issues or questioning habits.

An extra dimension is added when analyzing the burden with regards to people's lifestyles and associated lock-in effects. For example, households grouped as "Rural Isolation" pay much higher carbon tax than the "Suburban Comfort" and "Urban Intelligence" households due to their relatively high demand for heating, electricity and transport as a result of their rural location. This is due to the relative sparse public transport infrastructure in remote locations and thus higher reliance on cars. Thus people who live in the countryside might be "locked" into their transport emissions to some extent. Also, the houses in rural area are usually larger and more exposed requiring more electricity and heating. Low-income people might be locked into their emission patterns from housing because they do not own the dwelling, which might be in poor condition and they might not have the means to finance retrofit measures easily. As electricity, heating, and transport are part of basic needs, the social barriers represent a big issue for the government. To tackle these issues the government may want to subsidize household energy conservation activities as well as the use of energy efficient products in order to motivate environmentally friendlier lifestyles and at the same time reduce both the tax burden and living costs.

It is politically difficult to introduce a tax that would increase the problem of "fuel poverty" that the UK Government sees as a very important issue. The use of a carbon tax in isolation from other policy measures would cause many of the problems highlighted above. For example, retrofitting houses has been identified as a key policy that will contribute over 50% of the 80% reduction required for the housing sector (*46*). Therefore, the income generated from a carbon tax could be used to fund large-scale retrofitting of houses, starting with households most affected by the tax.

Finally, it is important that all areas of government policy and investment are incentivizing a low carbon society. For example, infrastructure development has a strong role to play in shaping our consumption patterns. Our ability to access low carbon modes of transport is a good example. The need for spatial planning to deliver the infrastructure that allows and increases low carbon mobility solutions must go hand in hand with a carbon tax and/or trading scheme.

Acknowledgments

The Research grant from WWF-UK (GB083001) is gratefully acknowledged.

Supporting Information Available

Detailed description of the input-output model, supplementary figures to explain the approach, and more figures and tables presenting the results. This material is available free of charge via the Internet at http://pubs.acs.org.

Literature Cited

(1) UNFCCC. *The Kyoto Protocol to the Convention on Climate Change*, Climate Change Secretariat/UNEP, UNEP/IUC/98/2; United Nations Framework Convention on Climate Change, 1998.

(2) ONS. *Environmental Accounts: Atmospheric Emissions Bridging Table, IPCC*, 11 June 2009 ed.; Office for National Statistics:, UK: 2009.

(3) Climate Change Act 2008, Key Provisions/Milestones; Department for Environment, Food, and Rural Affairs: London, 2008.

(4) EEA. *Using the Market for Cost-Effective Environmental Policy. Market-Based Instruments in Europe*, Report No 1/2006; European Environmental Agency: Copenhagen, Denmark, 2006.

(5) *EU Action against Climate Change: The EU Emissions Trading Scheme*; European Commission: Belgium, 2009.

(6) Garnaut, R. *The Garnaut Climate Change Review—Final Report*; Cambridge University Press: Cambridge, 2008.

(7) *Economic Instruments for the Reduction of Carbon Dioxide Emissions*; The Royal Society: London, 2002.

(8) Mann, R. The case for the carbon tax: How to overcome politics and find our green destiny. *Environ. Law Rep.* **2009**, *39*, 10118.

(9) Grajewski, M. Europe presses Washington to do more on climate *Reuters News*, October 2, 2009.

(10) CCX *Project-based Credits-"offsets"-in Chicago Climate Exchange*; Chicago Climate Exchange: 2007.

(11) Whitehead, J. (2007), An emission trading scheme for New Zealand, Speech delivered by the Secretary of the Treasury, 8 August, http://www.treasury.govt.nz/publications/media-speeches/speeches/pdfs/spch-08aug07.pdf (last accessed: April 20, 2010).

(12) Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2007: Synthesis Report*; IPCC Secretariat: Paris, 2007.

(13) Baranzini, A.; Goldemberg, J.; Speck, S. A future for carbon taxes. *Ecol. Econ.* **2000**, *32*, 395–412.

(14) Ekins, P. European environmental taxes and charges: Recent experience, issues and trends. *Ecol. Econ.* **1999**, *31*, 39–62.

(15) Kerkhof, A. C.; Moll, H. C.; Drissen, E.; Wilting, H. C. Taxation of multiple greenhouse gases and the effects on income distribution: A case study of the Netherlands. *Ecol. Econ.* **2008**, *67*, 318–326.

(16) Vermeend, W.; Van der Vaart, J., *Greening Taxes: The Dutch Model*; Kluwer: Deventer, 1998.

(17) Callan, T.; Lyons, S.; Scott, S.; Tol, R. S. J.; Verde, S. The distributional implications of a carbon tax in Ireland. *Energy Policy* **2009**, *37* (2), 407–412.

(18) Hamilton, K.; Cameron, G. Simulating the distributional effects of a Canadian carbon tax. *Can. Public Policy* **1994**, *20*, 385–399.

(19) Grainger, C. A.; Kolstad, C. D. Who pays a price on carbon. In *NBER Working Paper Series*, No. 152349; National Bureau of Economic Research: Cambridge, MA, 2009.

(20) Wier, M.; Birr-Pedersen, K.; Jacobsen, H. K.; Klok, J. Are CO_2 taxes regressive? Evidence from the Danish experience. *Ecol. Econ.* **2005**, *52*, 239–251.

(21) Hassett, K. A.; Mathur, A.; Metcalf, G. E.; The incidence of a, U. S. Carbon tax: A lifetime and regional analysis. *Energy J.* **2009**, *30* (2), 155–177.

(22) *Climate Change: Economic Instruments and Income Distribution*; OECD: Paris, 1995.

(23) Speck, S. Energy and carbon taxes and their distributional implications. *Energy Policy* **1999**, *27*, 659–667.

(24) Baer, P.; Athanasiou, T.; Kartha, S.; Kemp-Benedict, E., *The Greenhouse Development Rights Framework*; The Heinrich Boll Foundation, Christian Aid, EcoEquity and the Stockholm Environment Institute: Berlin, 2008; Vol. 1.

(25) Commission on Growth and Development. *The Growth Report: Strategies for Sustained Growth and Inclusive Development*; World Bank: Washington DC, 2008.

(26) Manne, A. S.; Richels, R. G. An alternative approach to establishing trade-offs among greenhouse gases. *Nature* **2001**, *410*, 675–677.

(27) Weyant, J. P. Overview of EMF-21: multigas mitigation and climate policy. *Energy J.* **2006**, *27*, 1–32.

(28) UK National Accounts - The Blue Book; Office for National Statistics: Newport, South Wales,2006.

(29) *Supporting Research for Building a Low-Carbon Economy—The UK's Contribution to Tackling Climate Change*; Committee on Climate Change: London, 2008.

(30) McKitrick, R. A derivation of the marginal abatement cost curve. *J. Environ. Econ. Manage.* **1999**, *37*, 306–314.

(31) Baumol, W. J.; Oates, W. E. The use of standards and prices for protection of the environment. *Environ. Econ.* **1971**, *73* (1), 42–54.

(32) Leontief, W. *Input-Output Economics*; Oxford University Press: Oxford, 1986.

(33) Moran, D.; Macleod, M.; Wall, E.; Eory, V.; Pajot, G.; Matthews, R.; McVittie, A.; Barnes, A.; Rees, B.; Moxey, A.; Williams, A.; Smith, P. *UK Marginal Abatement Cost Curves for the Agriculture and Land Use, Land-Use Change and Forestry Sectors Out to 2022, with Qualitative Analysis of Options to 2050*, Report to the Committee on Climate Change; Committee on Climate Change: London, 2008.

(34) Pye, S.; Fletcher, K.; Gardiner, A.; Angelini, T.; Greenleaf, J.; Wiley, T.; Haydock, H. *Review and Update of UK Abatement Costs Curves for the Inudstrial, Domestic and Non-Domestic Sectors*; AEA Energy & Environment: Didcot, 2008.

(35) Spencer, C. *Building a UK Transport Supply-Side Marginal Abatement Cost Curve*; Committee on Climate Change: London, 2008.

(36) Hogg, D.; Baddeley, A.; Ballinger, A.; Elliott, T. *Development of Marginal Abatement Cost Curves for the Waste Sector*, Report to Committee on Climate Change; Department for Environment, Food, and Rural Affairs and Environment Agency: London, 2008.

(37) *Family Spending and Family Expenditure Surveys*; Office for National Statistics: Newport, South Wales, 2006.

(38) Harris, R.; Sleight, P.; Webber, R., *Geodemographics, GIS and Neighbourhood Targeting*; John Wiley & Sons: Chichester, 2005.

(39) Mosaic United Kingdom—The Consumer Classification for the UK; Experian: Mosaic UK, 2008.

(40) Dinan, T.; Rogers, D. L. Distributional effects of carbon allowancetrading: how government decisions determine winners and losers. *Nat. Tax J.* **2002**, *2*, 199–221.

(41) Fullerton, D., *Distributional Effects of Environmental and Energy Policy: An Introduction*. Ashgate: Aldershot, UK, 2009.
(42) *Carbon Dioxide Emissions at Local Authority and Government Office Region Level in Department for Environment*; Department for Environment, Food, and Rural Affairs: London, 2006.
(43) Herber, B. P.; Raga, J. T. An International Carbon Tax to Combat Global Warming: An Economic and Political Analysis of the European Union Proposal. *Am. J. Econ. Sociol.* **1995**, *54* (3), 257–267.
(44) *Environmental Taxes, Implementation and Environmental Effectiveness*; European Environmental Agency: Copenhagen, 1999.
(45) Mitchell, C.; Bauknecht, D.; Connor, P. M. Effectiveness through risk reduction: A comparison of the renewable obligation in England and Wales and the feed-in system in Germany. *Energy Policy* **2006**, *34* (3), 297–305.
(46) Barrett, J.; Dawkins, E. *Carbon Footprint of the Leeds City Region*; Environment Agency: UK: 2008.

ES902974G