Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

# The distributional effects of a carbon tax and its impact on fuel poverty: A microsimulation study in the French context

Audrey Berry *Energy Policy*, Volume 124, January 2019

*Centre International de la Recherche sur l'Environnement et le Développement, UMR 8568 Ecole des Ponts ParisTech, CNRS, AgroParisTech, EHESS, CIRAD, 45 Avenue de la Belle Gabrielle, 94130 Nogent-sur-Marne, France*

ARTICLE INFO

*Keywords:*
Carbon tax
Distributional impacts
Fuel poverty
Revenue recycling
Microsimulation

ABSTRACT

This paper studies the distributional effects of France's recently introduced carbon tax. Using a microsimulation model built on a representative sample of the French population from 2012, it simulates the taxes levied on each household's consumption of energy for housing and transport. Without revenue recycling, the carbon tax is regressive and increases fuel poverty. From a policy perspective, this finding indicates that the question of fuel poverty cannot be ignored in the quest for a fair ecological transition. It proposes that some of the revenues from the carbon tax should be redistributed to households. Different designs of cash transfer to support households are then compared. The results show that the inequities of the carbon tax could be offset at reasonable cost relative to total carbon tax revenues. However, adjusting the design of cash transfers to criteria other than income level does not diminish the cost of compensating households. The benefits of finely adjusting cash transfers may therefore be somewhat limited. Most notably, the results show that targeting revenue recycling at low-income households would help to reduce fuel poverty substantially. This study therefore indicates that carbon taxation actually provides an opportunity to finance ambitious policies to fight fuel poverty.

## 1. Introduction

This paper aims to explore the distributional effects of the recently introduced French carbon tax and to design compensatory measures that restore social equity across households. The level of the carbon tax increased from €7/t$CO_2$ in 2014 to €30.5/t$CO_2$ in 2017, and the energy transition law (2015) provides for the carbon tax to rise to €56/t$CO_2$ in 2020 and €100/t$CO_2$ in 2030 in order to meet our climate objectives.[1] In the long-term, the carbon tax should lead to a fall in energy consumption and spending, but during the transition to a low-carbon economy, its consequence for households will be to raise costs for heating and mobility. Taxing carbon increases the cost of fossil fuels, an increase that firms are likely to pass on to consumers in the form of higher prices. This produces a decline in purchasing power that is likely to affect households in their day-to-day practices. Moreover the burden it places on household budgets is expected to be greater for low-income households and those with limited choices (Parry et al., 2005; Fullerton, 2008), for example households with poorly insulated homes or with no alternative to car use. Because they may not have the capacity to adjust their energy consumption, sections of the population are likely to face difficulties in meeting their energy needs. This phenomenon – called fuel poverty – is gaining momentum in France (Charlier et al., 2016; Legendre and Ricci, 2015), and more broadly in Europe (Derdevet, 2013; Bouzarovski et al., 2012; Thomson and Snell, 2013; Guyet, 2014). In France, the Grenelle 2 Act (2010) defines people as living in fuel poverty if they "*experience particular difficulties in obtaining the supply of energy in their homes required to meet their basic needs because of the inadequacy of their resources or of their living conditions*".[2] The number of households in fuel poverty in France rose by 17% between 2006 and 2013, and it now affects more than 20% of households, according to the French National Fuel Poverty Observatory (ONPE, 2016). In light of this, it is essential to ensure that the carbon tax will not further exacerbate the problem of fuel poverty.

Microsimulation modelling is particularly relevant to the analysis of the distributional impacts of certain public policies and tax reforms (Merz, 1991; Spadaro, 2007; Bourguignon and Spadaro, 2006). It is a popular tool for evaluating the distributive impacts of energy/carbon taxation. Most energy/carbon taxes appear to be regressive, as low-income households generally spend a larger share of their income on energy. Yet some studies qualify this result (Parry et al., 2005;

*E-mail addresses:* berry@centre-cired.fr, audrey.berry.pro@gmail.com.

[1] For comparison, in 2016, about 19 countries had implemented a carbon tax or scheduled one for implementation. Their amount varied between US$137/t$CO_2$e (€118/t$CO_2$) for Sweden to less than US$1/t$CO_2$e (€0.9/t$CO_2$) for Mexico.

[2] https://www.legifrance.gouv.fr/eli/loi/2010/7/12/2010–788/jo/texte.

https://doi.org/10.1016/j.enpol.2018.09.021 Available online 08 October 2018

**Table 1**
Review of existing micro-level studied on French data.

| Authors | Year of study | Country | Income measurement | Scope of the tax | Behavioural responses | Revenue recycling |
|---|---|---|---|---|---|---|
| Nichèle and Robin | 1995 | France | Total consumption | "Heat and lighting" and "Purchase and use of vehicles" | Yes (uniform) | No |
| Ruiz and Trannoy | 2008 | France | Disposable income | Total consumption affected by VAT and excise duties, including on fuels (TIPP) | Yes (uniform) | Yes |
| Berri et al. | 2014 | France | Total consumption | "Private transport" and "Public transport" | No | No |
| Clerc and Marcus | 2009 | France | Disposable income | Domestic energy, Fuels | Yes (differentiated) | No |
| Bureau | 2011 | France | Disposable income | Gasoline, Diesel | Yes (differentiated) | Yes |
| CGDD | 2016 | France | Disposable income | Network gas, Heating oil, Gasoline, Diesel | No | No |

Fullerton, 2008). A review of existing literature shows that the observed differences can in part be explained by the modelling choices. Before the recycling of tax revenues and on the basis of annual income, most environmental taxes appear regressive. However, when the use of permanent income, the impact of the price of goods for which energy is an input, the impact of income factors and the recycling of tax revenues are taken into account, the level of regressivity is found to be mitigated (Poterba, 1991; Hassett et al., 2007) Behavioural modelling leads to more mixed results depending on the sensitivity to energy prices of poor households relative to rich households (Grainger and Kolstad, 2010) (Beck et al., 2015; Rausch and Schwarz, 2016; West and Williams, 2004). An increasing number of studies also discuss in more detail the relative impact of different revenue recycling options: lowering pre-existing taxes, increasing pre-existing social transfers, or introducing differentiated and/or targeted cash transfers (Labandeira et al., 2006; Brännlund and Nordström, 2004; Wadud et al., 2009; Callan et al., 2009). Results tend to differ according to the precise design of the taxes and/or transfers considered for recycling.

To my knowledge, at the time of writing, there exist six published micro-level studies based on French data (Table 1) (West and Williams, 2004; Brännlund and Nordström, 2004; Cronin et al., 2017; Clerc and Marcus, 2009; Bureau, 2011; CGDD, 2016). Analysis of these studies confirms the regressive nature of an energy or carbon tax in the French context, in the absence of any revenue recycling. This review raises three points on which there is no consensus or which have not been dealt with in France, which this paper will address. First, transport fuel consumption has spread across income deciles in recent decades, and it may be that there have been changes in the relative regressivity of taxing carbon on transport fuels and on domestic energy. Second, to date, these studies have focused on regressivity and may neglect losers among households with similar incomes. In particular, none has addressed the impact of an energy/carbon tax on fuel poverty, and one can ask to what extent the carbon tax could push households into this condition. Third, there is still debate in France over the use of carbon tax revenues, and there are questions to be asked about how much revenue recycling is needed to compensate households for the negative impacts of the carbon tax.

The objective of this paper is twofold. Firstly, I measure the distributional impacts of taxing carbon on households' direct energy use for housing and transport. In particular, I quantify the regressivity of the carbon tax and the increase in fuel poverty associated with it. To do this, I developed a microsimulation model to evaluate fiscal policies that affect energy taxes in France, including the carbon tax. It simulates the impact of the carbon tax at the individual household level and enables its distributional consequences to be accurately assessed. The model is built on the Phebus survey (2012), which provides the most recent and detailed data available in France on energy consumption both for housing and transport. Secondly, I look at how households can be compensated by redistributing carbon tax revenues through cash transfers. I design several alternative scenarios in order to assess which are the most effective in correcting the inequities found and, in particular, in offsetting the regressivity of the carbon tax and in reducing its impact on fuel poverty. I quantify the cost of these measures in terms of the carbon tax revenues collected. One of the originalities of this paper is therefore to analyse the link between carbon taxation and fuel poverty. By increasing the cost of using carbon-intensive energy, the carbon tax heavily affects household budgets and exposes part of the population to the risk of fuel poverty. Nevertheless, I will show that the revenue generated by the carbon tax provides an opportunity to finance ambitious public policies to combat fuel poverty. This study therefore sheds new light on the potential use of the carbon tax to tackle the issue of fuel poverty and offers an empirical application in the French context.

The rest of the paper is organised as follows. The second section describes the microsimulation model, the data, and the indicators used to evaluate the distributional impacts of the carbon tax. The third section presents the distributive impacts of the carbon tax. The fourth section explores alternative scenarios of redistribution to compensate households for the negative impacts of the carbon tax. The fifth section sums up and concludes the paper.

## 2. Methods

This study is based on a microsimulation model that simulates the taxes levied on the energy consumption of households for a representative sample of the French population. It assesses the aggregate and distributive impacts of reforms in energy taxation and compensatory measures already implemented or under review. Though the model is static and fails to account for general equilibrium consequences, it offers a good approximation of the short-term impacts of a given policy. There were four elements to the design of the microsimulation model, described in the following subsections:

- a database containing a sample of representative households, with the relevant variables for the problem studied;
- a modelling of the energy tax system – to derive household energy expenditure;
- a modelling of households behaviour;
- the indicators to measure the distributional impacts.

### *2.1. The database*

The model is built on the Phebus 2012 survey, which provides the most recent data on energy consumption available in France. The Phebus survey was conducted for the French government with the objective of informing public policies on household energy consumption and on housing renovation. A sample of 5405 households, representative of the principal residencies in Metropolitan France, were interviewed about their energy consumption for both housing and transport, as well about the characteristics of their dwellings, including energy performance. The survey also contains detailed information on their energy habits and the socio-demographic characteristics of each occupant. The survey unit was the household.

For the purpose of this paper, households with disposable income, domestic energy consumption and fuel consumption in the top 0.5% as well as those with disposable income and domestic energy consumption in the bottom 0.5% of the distribution are excluded, in order to rule out outliers. The filter on low fuel consumption is not applied, as not all members of the population use a motorised vehicle. In addition, households whose spending on rent or mortgage is unknown are excluded. The estimation sample therefore contains 5122 households. The survey contains sample weights, which are used to weight the observations in the different simulation scenarios.

This is the only known microsimulation model based on the Phebus survey at the time of writing. At least two other microsimulation models applied to energy exist in France: the French Ministry of the Environment's (CGDD) Prometheus model and the Institute of Public Policies (IPP) TAXIPP. These models derive volumes of energy consumed from household energy expenditure and apply statistical matching techniques from separate databases to cover both domestic and transport energy. By contrast with these models, the model I use in this paper directly includes information on the volumes of energy consumed and incorporates both energy for domestic use and for transport at the household level. It is therefore a more precise model for analysing the distributional effects of carbon taxation in France. Moreover, this study is based on the most recent data, especially data on transport, compared with Prometheus and TAXIPP, which use transport data from the 2008 ENTD (national transport and travel survey).

## 2.2. The energy tax system

### 2.2.1. Modelling the carbon tax

In the model, the carbon tax is applied in addition to the taxes on energy that were applied in 2012. The carbon tax follows current implementation rules. It affects all energy sources – including network gas, heating oil, diesel and gasoline – except electricity,[3] which is already covered by the European carbon market (EU ETS). It corresponds to an excise duty levied on the volume of energy consumed. The rate applied for each type of energy is based on its carbon content[4]:

$$\text{Carbon tax rate}\left(\frac{€}{\text{unit}}\right) = \text{carbon tax}\left(\frac{€}{\text{tCO2}}\right)*\text{carbon content}\left(\frac{\text{tCO2}}{\text{unit}}\right)$$

In 2012, a carbon tax of €30.5/$tCO_2$ would have represented between 8% and 15% of energy prices at the time, including pre-existing taxes. The energy source for which the impact on price is the highest is network gas. Because gasoline and diesel bear the highest level of pre-existing taxes, the impact of the carbon tax on their selling price is the lowest (5.3% and 6.5% respectively). The results for each type of energy are summarised in Table 2.

### 2.2.2. Modelling energy expenditure

In the microsimulation model, energy expenditures are estimated for each household taking account of the types of energy they use, their consumption levels and the types of energy contracts and options chosen. Prices per kWh, litre or tonne, as well as subscription charges, are expressed free of tax. The energy type and contract type are assumed to remain unchanged in the different scenarios (subscribed level of power, type of contract, type of energy for heating, type of fuel for transport). Volumes consumed, taxes and prices before tax are taken at their 2012 level. The model simulates the different taxes that apply to energy consumption under French legislation: TICPE for diesel, gasoline and heating fuel, TICGN for network gas, and TCFE for electricity (see Appendix A for a description of the French energy taxation system).

[3] Electricity is subject to a carbon price through the European carbon market, but the price per tonne of CO2 is much lower. It has remained around €5–8/tCO2 since 2012. Moreover electricity has a low carbon content in France, so that the carbon component in the price per kWh is negligible – about €0.003/kWh, i.e. 0.02% of the consumer price in 2012.

[4] Carbon content corresponds to direct emissions for production (upstream) and combustion in France. It is available online at: http://23dd.fr/images/stories/Documents/PV/Ademe_Metro_Chapitre_2_Energie.pdf.

**Table 2**
Carbon content and carbon tax rate according to the type of energy.

| | Carbon content tCO2* | Carbon tax rate Carbon tax = €30.5/$tCO_2$ | % increase in energy prices Compared to 2012 sale prices (including pre-existing taxes) |
|---|---|---|---|
| 1 t of heating oil | 3.483 | €106.23/ton | 9.3% |
| 1 MWh of network gas | 0.238 | €7.3/MWh | 12.4% |
| 1 l of diesel | 0.00297 | €0.091/l | 6.5% |
| 1 l of gasoline | 0.00282 | €0.086/l | 5.3% |
| 1 l of LPG | 0.00187 | €0.057/l | 6.5% |

* Source : Guide des facteurs d'émissions, v6.1, Ademe, http://23dd.fr/images/stories/Documents/PV/Ademe_Metro_Chapitre_2_Energie.pdf.

Carbon taxation is introduced as described in the previous section.[5] Then a standard rate of VAT – Value Added Tax – is applied to the cost associated with consumption, and a reduced VAT rate is applied to the subscription charge. This reduced VAT rate applies to basic necessities, day-to-day consumption and to certain favoured sectors. The modelling of energy expenditure is presented below for each type of energy[6]

**Electricity/Network gas**

$$\begin{aligned}\textit{Energy spending (including all taxes)} = & \textit{ Subscription cost [type of contract]}\\ & \times(1+\textit{reduced VAT}) + \textit{Volume consumed}\\ & \times\ (\textit{cost per kWh} + \textit{TIC} + \textit{carbon tax})\\ & \times(1+\textit{standard VAT})\end{aligned}$$

**Petrol/Diesel/LPG/Heating Oil/Wood**

$$\begin{aligned}\textit{Energy spending (including all taxes)} = & \textit{ Volume consumed}\\ & \times\ (\textit{cost per litre ortonne} + \textit{TIC} + \textit{carbon tax})\\ & \times\ (1+\textit{standard VAT})\end{aligned}$$

**Energy costs (collective heating): natural gas/heating oil/district heating**

$$\begin{aligned}\textit{Energy spending (including all taxes)} = & \textit{ Volume consumed}\\ & \times\ (\textit{cost per litre ortonne} + \textit{TIC} + \textit{carbon tax})\\ & \times\ (1+\textit{standard VAT})\end{aligned}$$

## 2.3. Household behaviour

Price elasticity of energy demand is introduced into the model, so households respond to rising energy prices by decreasing the volume of energy they consume. The values for the price elasticity of energy demand are estimated from the Budget des Familles 2011 (2011 Family Budget) survey on the basis of Engel curves (see Appendix B for more details). They correspond to short-term elasticity. They account for a decrease in consumption while household equipment stock remains the same, on the assumption that households cannot quickly replace their heating system or vehicle. Price elasticity values are differentiated by energy type and income decile.

## 2.4. Indicators to measure the distributional impacts

### 2.4.1. Measuring tax progressivity

The distributional effects of carbon taxation refer to how the burden of the tax is distributed across households. A tax will be said to be progressive

[5] In the legislation, the carbon tax is directly integrated into existing taxes on energy consumption: TICPE and TICGN already include the amount of carbon tax. Yet this does not affect the scenario studied, since in 2012 the carbon tax had not yet been implemented.

[6] Table C2, in Appendix C, presents a comparison of household energy expenditure for each type of energy as estimated in the microsimulation model and as reported by households in the survey. Results show the modelling is very satisfactory.

if the tax to income ratio rises with income, regressive if it falls with income (Fullerton and Metcalf, 2002). In other words, a progressive tax system is more favourable to lower-income households, while a regressive tax system is more favourable to higher-income households. Different indexes have been developed to summarise distributional effects. They have the advantage of encapsulating the overall effect of a tax in a single number. The Suits Index of tax progressivity – the index most widely used in the literature on the distributional effects of energy/transport taxation – measures how far a tax system deviates from proportionality (Suits, 1977). The value of the Suits Index ranges from + 1 (extreme progressivity where the entire tax burden is borne by the richest household), through 0 (neutral where the tax burden is strictly proportional to income) to −1 (extreme regressivity where the entire tax burden is borne by the poorest household). Its mathematical representation is:

$$Suits\ Index = \sum_{households} \frac{1}{2} * (T(y_h) + T(y_{h-1})) * (y_h - y_{h-1}) \Big)$$

where $y_h$ is the accumulated percentage of total income of all households with an income lower or equal to household h, and $T(y_h)$ is the cumulative percentage of those same households' total carbon tax.

*2.4.2. Measuring fuel poverty*

The multidimensional nature of fuel poverty makes measuring it a difficult task for researchers and arouses debate about which indicator(s) should be used to evaluate it. Among policymakers, however, fuel poverty is usually measured with an energy to income ratio, and corresponds to households that spend more than a certain share of their income on energy. In housing, the 10% ratio has been the most widely used so far (CGDD, 2016). Alternatively, the threshold is sometimes set at twice the median ratio in order to account for changes in energy prices over time. More recently, Hills (Hills, 2012) developed the Low Income High Costs (LIHC) indicator, which has since become the official definition of fuel poverty in the UK. According to this new definition, households are considered fuel poor if "*they have required fuel costs that are above the contemporary median level; and were they to spend that amount, they would be left with a residual income below the official poverty line*".

In this paper, I adopt the indicators defined by the French National Fuel Poverty Observatory. Three indicators are used to quantify fuel poverty (ONPE, 2016). They consist of the 10% ratio, an adapted version of the low-income high-cost approach, and a subjective indicator that identifies households that report feeling cold. By contrast with the UK indicators, because of limited knowledge of the characteristics of France's housing stock, French official indicators refer to actual energy expenditure and not to modelled energy expenditure. In this paper, I assess the impact of carbon taxation on the first two indicators defined by ONPE. Because the third indicator is self-reported, it cannot be directly assessed. The first indicator identifies households that spend more than 10% of their income on energy, among households belonging to the three lowest income deciles.

$$(1)\ \frac{Energy\ expenditure}{Disposable\ income} > 10\%$$

The second indicator, called the BRDE (Bas Revenu Dépenses Elevées – low income high spending), is an adapted version of the LIHC approach. A household is fuel poor if its energy expenditure is higher than the national median, and its residual income net of energy expenditure is below the poverty line. Energy expenditure here is adjusted to the composition of households – i.e. divided by the number of consumption units[7] – or to the size of the dwelling – i.e. divided by the number of square metres. Residual income refers to disposable income after housing costs. The poverty line is set at 60% of the national median residual income per consumption unit.

$$(2)\ \frac{Energy\ expenditure}{Number\ of\ CU\ or m^2} > Median$$

$$(3)\ \frac{Residual\ income - \quad Energy\ expenditure}{Number\ of\ CU} < Poverty\ line$$

These indicators make it possible to assess the impact of the carbon tax on fuel poverty in the domestic sector. The effect on fuel poverty in the transport sector is not evaluated in this paper. First, France has no official indicator of fuel poverty in the transport sector in France. Second, because of the great diversity in travel needs and unequal access to alternatives, simply transposing existing indicators from the domestic sector to the transport sector would not be satisfactory (Berry et al., 2016). For these reasons, this paper limits its analysis of the impact of the carbon tax on fuel poverty to the domestic sector.

## 3. The distributive impacts of the carbon tax

### 3.1. Energy consumption in France

Before turning to the distributional effects, this subsection gives an overview of household energy consumption patterns in 2012, the reference year. Households spent on average €2972 a year on energy, of which €1557 were for housing and €1414 for mobility. Energy expenditure increases with income: the richest 10% spent €3778 whereas the poorest 10% spent €2220. However, the proportion of disposable income spent on energy decreases with income. In 2012, energy expenditure represented 16.4% of the disposable income of the poorest 10% as compared with 5.3% of the disposable income of the richest 10%, and 10.1% on average for the population as a whole. Thus low-income households allocate a larger share of their income to energy. It is worth noting that the decline in energy expenditure with income is greater for domestic energy, while transport fuels account for a similar share of disposable income for middle-class households, ranging between 4% and 5% for deciles 3–8. This is partly explained by the fact that car ownership increases with income and that richer households generally own more powerful cars.[8]

Since energy taxes are levied on the volume of energy consumed, similar patterns can be expected for spending on energy taxes. In the case of the carbon tax, however, the distribution of its cost will also be influenced by other factors, such as the type of energy used for heating and the type of fuel used for mobility (Table 3). In housing, France is unusual in having promoted the use of electric heating since the 1970s, with the development of nuclear energy. In 2012, 31% of households used electric heating as their main heating mode. In addition, 28% of households used network gas, 11% used heating oil, 8% used wood, and 19% lived in dwellings heated by collective systems, which can run on natural gas, heating oil or district heating. Similarly, with regard to cars, until recently France strongly promoted the use of diesel vehicles, by taxing diesel at a much lower rate than petrol. In 2012, more than half the population used diesel. In particular, 40% of households drove only diesel vehicles (no petrol vehicle), 16% drove both diesel and petrol vehicles, 22% drove only petrol vehicles (no diesel vehicle), and 22% spent nothing on vehicle fuel, because they either did not own or did not use a car. These factors will be critical when analysing the distributional impacts of the carbon tax.

[7] The size of a household's Consumption Unit (CU) is based on the most widely used equivalence scale (the OECD scale): the first adult counts for 1, other persons aged 14 or above count for 0.5 each, and children under 14 count for 0.3 each. It is used to compare the standard of living of different types of households.

[8] In Appendix C, Figs. C1 and C2 plot household energy expenditure and energy to income ratio by income deciles. In addition, Table C3 presents some descriptive statistics for the main variables used in the study.

**Table 3**
Share of population by type of heating and type of motorisation in 2012.

| | Type of heating | | | | | |
|---|---|---|---|---|---|---|
| | Electricity | Network gas | Heating oil | Wood | Collective heating | Other |
| Share of total population | 30.7% | 27.7% | 11.2% | 8.1% | 18.8% | 3.5% |

| | Type of motorisation | | | |
|---|---|---|---|---|
| | 1 + Diesel & 0 Gasoline | 1 + Gasoline & 0 Diesel | 1 + Gasoline & 1 + Diesel | No car |
| Share of total population | 39.9% | 21.7% | 16.5% | 21.9% |

### 3.2. The impact of the carbon tax on energy bills

A carbon tax set at €30.50/t$CO_2$ is estimated to increase annual household energy expenditure by €187 on average for housing and for transport, of which €157 is the carbon tax and €30 additional VAT (VAT on the carbon tax), in the absence of behavioural responses. It would have represented almost 5.3% of household energy expenditure in 2012, the reference year for the model, before the introduction of the carbon tax. The mean impact is greater for transport fuel than for domestic energy. Energy expenditure increases by €103 for mobility (€86 for the carbon tax excluding VAT) and by €84 for housing (€71 for the carbon tax excluding VAT). Yet the impact on energy expenditure varies greatly across the population. It depends on several factors: income, but also household composition, occupational status, heating type, residential location, etc. 42% of households are not affected by carbon tax in the domestic sector (mostly those using electric heating or wood), 22% are not affected in the transport sector (those who do not use an internal combustion vehicle), and one in ten are not affected at all. Conversely, one household in ten experience an increase in energy expenditure of more than €240 a year either in the domestic sector or the transport sector, and one in ten a total of more than €400 a year.

The average impact increases with income deciles. The poorest 10% pay €132 carbon tax per household on average (including VAT). This is half what the richest 10% pay (€256 per household) and two thirds of what the average household in the population pays (€187 per household).

### 3.3. The regressivity of the carbon tax

To account for differences in standards of living, the impact of the carbon tax is analysed in terms of tax to income ratio: this corresponds to the amount of carbon tax paid (excluding VAT) as a share of disposable household income. Low-income households clearly bear the proportionally highest burden of tax, with a tax to income ratio of 0.81% on average for the poorest 10% of households, compared with 0.30% for the wealthiest 10% (Fig. 1). This means that the impact on the poorest 10% is 2.7 times greater than on the wealthiest 10%, and 1.5 times greater than on the average household (0.52%). Low-income households are the most affected by the carbon tax for both housing energy (which represents 0.44% of their income) and for transport energy (0.37%). The tax burden then decreases steadily with income in the domestic sector. This is less clear in the transport sector, where the impact on middle-class households remains high – deciles 3–6 show similar tax to income ratio – compared with the richest households. This means that middle-class fuel consumption increases at the same pace as income, which can be explained by longer driving distances, by a shift towards the car in modal share, and by ownership of larger vehicles. The Suits Index measures the progressivity/regressivity of a tax more precisely by looking at its deviation from proportionality. The Suits Index of the carbon tax is − 0.149, a negative value that confirms the regressivity of the tax. Regressivity is similar for transport energy and domestic energy – the corresponding Suits Indices are − 0.148 and − 0.150 respectively. This result differs from most studies, which generally find regressivity to be significantly lower on transport energy because car use is less in low-income households. This can be explained by a change in household travel practices, with increasing car dependency among low-income households.

The above results correspond to the impact the carbon tax would have on household budgets without behavioural responses, in other words without changes in consumption practices. The advantage of this scenario is that it provides an initial picture of the distributional impacts. It is, however, an unsatisfactory picture, one that lacks realism, since changes in prices are known to generate changes in consumption. The aim of the carbon tax is to send households a price signal to reduce their consumption of carbon-intensive energy. If low-income households reduce their consumption more than high-income households, one might expect the carbon tax to become less regressive. However, this situation could reflect an unwanted restriction in energy consumption, a possibility that will be discussed in the next section on fuel poverty. In this study, the price elasticity of energy demand for low-income households is about 30% higher for housing and 30% lower for mobility (see Appendix B). Yet results show that accounting for behavioural responses – in terms of the price elasticity of energy demand – does not change the level of regressivity. The impact on the Suits Index is negligible: it decreases the regressivity of the carbon tax by less than 2%. Looking at a more extreme scenario, assuming that the price elasticity of energy demand is − 1 for the poorest 50% of households and 0 for the richest 50% of households, regressivity would be reduced by only 15% (the Suits index moves from −0.149 to −0.127). This implausible scenario maintains a high level of regressivity. These results are in line with existing studies, which find the carbon tax to be regressive in developed countries (Parry et al., 2005; Fullerton, 2008; Sterner, 2007) and more particularly in France (Nichèle and Robin, 1995; Ruiz and Trannoy, 2008; Berri et al., 2014; Clerc and Marcus, 2009; Bureau, 2011; CGDD, 2016).

Fig. 2 shows the impact of the carbon tax on households in terms of residential location.[9] Households living in the suburbs and isolated towns devote a larger share of their income to the carbon tax than households living in urban centres, especially in the transport sector. However, the explanation is not the same in the two cases: expenditure on carbon tax in suburban households is very high relative to the general population. In households living in isolated towns, on the other hand, spending on the carbon tax is close to the population average, and it is because their incomes are low that the carbon tax is proportionally so high. Moreover, having a low income exacerbates the situation. The impact of the carbon tax on transport fuels on households living in the suburbs and belonging to the first three income deciles is 1.7 times greater than it is for the average household (Fig. 2). These results confirm the importance of accounting for residential location when evaluating the impact of the carbon tax on households (Lemaître and Kleinpeter, 2009; Nicolas et al., 2012).

### 3.4. The impact of the carbon tax on fuel poverty

In this study, households are said to be in fuel poverty if they are identified by at least one of the following two indicators used by ONPE: the 10% ratio and/or the BRDE indicator (see subsection 2.4.2). A

[9] The Phebus survey provides information about where households live, which is divided into three categories in this study: households living in urban hubs, the suburbs or isolated towns. The three categories are derived from the nine modalities of the CATAEU2010 variable – municipality type – in INSEE's (French National Institute of Statistics) urban zoning classification.

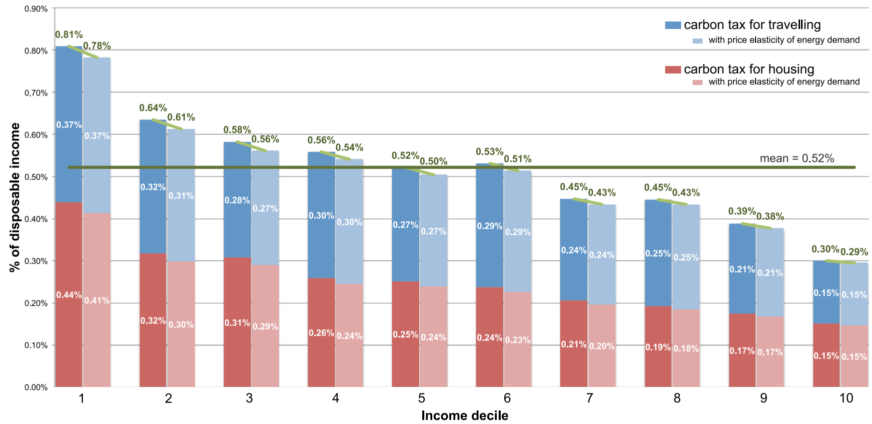


**Fig. 1.** Carbon tax as a share of households' disposable income, by income decile (€30.50/t$CO_2$).

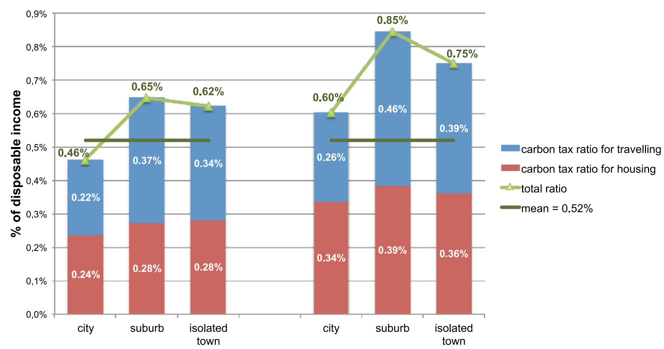


**Fig. 2.** Carbon tax as a share of households' disposable income, by residential location (€30.50/t$CO_2$).

carbon tax of €30.5/t$CO_2$ would cost a fuel-poor household an average of €93 a year for domestic energy. This cost is higher than the average impact in all income deciles, except for the 10th. Households that were already facing energy difficulties are thus expected to be among the most affected by the carbon tax. By computing the two indicators before and after implementation of the carbon tax, I find that the share of households in fuel poverty is expected to increase by 6.4% (Fig. 3). This means that 200,000 additional households would fall into fuel poverty as a result of the carbon tax. If the level of regressivity depends not on the level of the tax, but only on the distribution of energy expenditure across the population, the analysis for fuel poverty is different. Fuel poverty is defined by reference to a threshold, so that the higher the carbon tax rate, the more households cross the fuel poverty threshold. With a carbon tax of €100/t$CO_2$, for example, fuel poverty would increase by 25.1%, putting a further 780,000 households into fuel poverty.

As pictured in Fig. 3, at first glance, accounting for behavioural

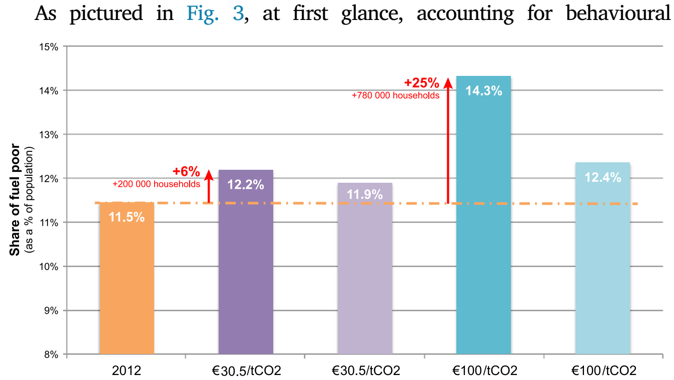


**Fig. 3.** The impact of the carbon tax on fuel poverty (€30.50/t$CO_2$ and €100/t$CO_2$).

responses can be expected to reduce the impact on fuel poverty. However, while the increase in prices resulting from the carbon tax should reduce consumption, it does not reduce the energy needs of households. Interpreting a fall in consumption is problematic, as it tells us nothing about the overall impact on the well-being of households. In the best case, a fall in energy consumption reflects the adoption of virtuous energy habits. But it could equally reflect deprivation of essential energy services. In particular for low-income households, carbon taxation could make some energy services unaffordable, with the result that households become unable to maintain adequate heating when no trade-off is available. This consequence is another form of fuel poverty, which is measured by the third indicator defined by ONPE (see subsection 2.4.2). In 2012, 14.3% of French households reported feeling cold.[10] This dimension of fuel poverty has important implications for compensatory measures. Taking behavioural responses into account could lead to the conclusion that only partial recycling is necessary to offset the increase in fuel poverty. Yet this does not hold if some households are not able to afford to consume energy and receive no compensation. For this reason, in the next section, compensatory measures will be evaluated without behavioural responses.

Table 4 shows the impact of the carbon tax on fuel poverty according to residential location and type of heating. Before the carbon tax, households living in isolated towns are overrepresented, with a rate of fuel poverty as high as 15.4%, compared with the average rate of 11.5%. Yet city-based households are more exposed to the risk of fuel poverty because of the carbon tax in both absolute and relative terms. 78% of households falling into fuel poverty because of the carbon tax actually live in the city. This represents almost 160,000 additional urban households at risk of fuel poverty. This can be explained by the fact that cities attract 66% of the population, but also that the energy used by urban households for heating is more carbon-intensive. The majority of urban households use network gas (35%) or collective energy (27%). In contrast, a greater proportion of heating in low-density areas comes from electricity and wood, types of energy not affected by the carbon tax. Though there is also greater use of heating oil in low-density areas (20% in the suburbs and 28% in isolated towns), the population concerned is relatively small. Only 23% of households pushed into fuel poverty by the carbon tax use heating oil, whereas 41% of the additional fuel-poor use collective energy and 36% network gas.

## 4. Compensating households for the negative impacts of the carbon tax

The revenue generated by the carbon tax offers the opportunity to

[10] For one of the following reasons: 1/ inadequate heating system, 2/ failure of the heating system, 3/ restriction of heating due to cost, 4/ poor insulation, 5/ power disconnection due to unpaid bills.

**Table 4**
Impact of the carbon tax on fuel poverty by residential location and type of heating.

| | No carbon tax | | Carbon tax = €30.5/$tCO_2$ (no behaviour) | | | |
|---|---|---|---|---|---|---|
| | **Number of fuel poor** | **Fuel poverty rate** | **Number of fuel poor** | **Fuel poverty rate** | **Additional fuel poor** | **% increase in fuel poverty** |
| Total population | 3 107 222 | 11.5% | 3 307 212 | 12.2% | 199 990 | 6.4% |
| City | 1 940 595 | 10.8% | 2 097 497 | 11.6% | 156 903 | 8.1% |
| Suburb | 855 283 | 12.1% | 889 800 | 12.6% | 34 517 | 4.0% |
| Isolated town | 311 344 | 15.4% | 319 915 | 15.8% | 8 571 | 2.8% |
| Electricity | 751 050 | 9.0% | 751 050 | 9.0% | 0 | 0.0% |
| Network gas | 801 913 | 10.7% | 874 151 | 11.6% | 72 238 | 9.0% |
| Heating oil | 514 199 | 17.0% | 559 314 | 18.4% | 45 115 | 8.8% |
| Wood | 153 371 | 7.0% | 153 371 | 7.0% | 0 | 0.0% |
| Collective energy | 745 808 | 14.6% | 828 446 | 16.2% | 82 638 | 11.1% |

compensate households for its negative impacts. In this study, a carbon tax set at €30.50/$tCO_2$ is expected to generate a total of €6.4 billion for the government. Because households contribute some two thirds of this total, they are estimated to generate €4.3 billion for the public purse (Table 5). It would be desirable for these revenues to be redistributed, at least in part, to compensate households. In Ireland, Callan et al. (2009) found that households could be made better-off without exhausting total carbon tax revenues, even if more than the tax revenue generated by households was recycled. In the next section, I will show that, in the French context, the regressivity of the carbon tax and additional fuel poverty can be corrected by recycling only part of the tax revenue generated by households. First however, I discuss a number of aspects relating to compensatory measures.

Households are generally compensated in two ways: by changes in existing redistributive instruments (income tax, social transfers, etc) or by the introduction of a new instrument (cash transfers, energy cheque, etc). The first option is simpler to implement and avoids the cost of implementing a new instrument. Social transfers mostly benefit low-income households, so increasing the levels would reduce regressivity. However, about a third of households in the first three income deciles would be left out, as they do not receive any existing social transfers (minimum welfare benefits, housing transfer or social benefits). The proportion of households left without support would be 25% in the first decile, 28% in the second decile and 48% in the third decile. This mechanism would therefore provide only partial compensation, which makes it an unsatisfactory solution.

The second option offers the opportunity to design a measure tailored for our purpose. Cash transfers can be carefully designed to reflect the heterogeneity of the impact of the carbon tax and to limit the number of losers. However, the design should not be too complex. It should rely on available data and simple criteria in order to limit management costs and maintain transparency. Moreover the compensation should not interfere with the role of the carbon tax as a price signal. This means that it should not be indexed directly, or indirectly, on energy expenditure, so that the incentive on households to adjust their energy consumption is maintained. In this study, households are compensated with cash transfers. I assess two compensation goals: the first is to offset the regressivity of the carbon tax, the second to reduce fuel poverty. For each objective, I simulate different designs of cash transfers and discuss their cost relative to carbon tax revenues.

**Table 5**
Transfer multipliers used to evaluate the amount of cash transfer received by each household.

| **Design of transfer** | **Transfer multipliers** | | | |
|---|---|---|---|---|
| Flat | All population | | | |
| | 1 | | | |
| Size-based | 1 CU* | 1 < CU < 2 | ≥ 2 CU | |
| | 1 | 1.3 | 1.6 | |
| Geographic-based | City | | Suburbs or Isolated town | |
| | 1 | | 1.4 | |
| Climatic-based | Paris | H1 | H2 | H3 |
| | 1 | 1.8 | 1.6 | 1.3 |
| Income-based | Decile** 1 and 2 | Decile 3 and 4 | ≥ Decile 5 | |
| | 3 | 2 | 1 | |
| Targeted | ≤ Decile 3 | | ≥ Decile 4 | |
| | 1 | | 0 | |

* CU = Consumption Unit.
** Decile of standards of living.

## 4.1. The design of cash transfers

Six different designs of cash transfer to support households are simulated and compared. The first corresponds to a flat cash transfer (flat transfer), in which the same amount is transferred to every household. The next four types of are finely tailored to account for the heterogeneity of the impact of the carbon tax, in particular to allow horizontal redistribution between rich and poor, but also vertical redistribution between households with the same income level but different levels of energy consumption (Cronin et al., 2017). The transfer amount is therefore adjusted to household composition (size-based transfer), residential location (geography-based transfer), climate zone (climate-based transfer), and income level (income-based transfer). The sixth design corresponds to a cash transfer targeted at low-income households (targeted transfer). Only households belonging to the first three deciles of income are eligible to receive a flat transfer. Thus for each design, the amount of cash transfer received by a household is adjusted by a transfer multiplier. The transfer multipliers are summarised in Table 5. In the end, for each design and objective, a household receives the following cash transfer:

$$\textit{Cash transfer}\,(\textit{household}) = \textit{Minimum transfer} \quad \times \quad \textit{Transfer multiplier} \quad (\textit{household})$$

## 4.2. Offsetting regressivity

A first desirable policy objective would be to offset the regressivity of the carbon tax. To this end, I evaluate the minimum cash transfer that would make the carbon tax progressive, based on the Suits index of progressivity. Table 6 shows the results for the different scenarios. A flat cash transfer requires 59% of the carbon tax revenue generated from households to be recycled in order to make the carbon tax progressive. It equates to returning €93 to every household in the population. However, flat recycling is limited because it compensates all households as if they were the average.

Adjusting cash transfer to income level has the effect of reducing the overall cost of offsetting regressivity. In the design tested, it requires 33% of carbon tax revenue to be recycled. Although it also decreases the total number of winners, these winners remain concentrated at the bottom end of the income distribution (see Fig. C3 in Appendix C). Targeting the cash transfer at low-income households is found to be the cheapest option. In particular, if the first three income deciles are targeted, only 18% of carbon tax revenue needs to be recycled to make the carbon tax progressive.

On the other hand, adjusting for household composition, residential location or climate zone does not diminish the cost of offsetting regressivity. Though such designs appear justified in terms of equity, they do not change the results in terms of the cost of the measure and the proportion of winners. The reason for this is that, in these scenarios, the mean amount of cash

**Table 6**
Comparison of different designs to offset carbon tax regressivity (€30.5/$tCO_2$ carbon tax).

| Objective: offset regressivity | | | | | | | |
|---|---|---|---|---|---|---|---|
| Design of cash transfer | % of population eligible | Cost of the measure (billion €) | % of revenue recycled* | Mean cash transfer | Mean net transfer | % of winners** | Interquartile range*** |
| Flat | 100% | 2.52 | 59% | €93 | − €64 | 39% | €171 |
| Size-based | 100% | 2.50 | 59% | €92 | − €65 | 39% | €166 |
| Geographic-based | 100% | 2.52 | 59% | €93 | − €64 | 39% | €168 |
| Climatic-based | 100% | 2.45 | 57% | €90 | − €67 | 38% | €171 |
| Income-based | 100% | 1.39 | 33% | €51 | − €106 | 26% | €181 |
| Targeted at low-income | 30% | 0.75 | 18% | €93 | − €30 | 50% | €141 |

NB: Mean cash transfer, mean net transfer, % of winners and interquartile range are calculated among eligible population.

* The cost of the measure is compared to carbon tax revenue generated by households (which is about 2/3 of total carbon tax revenue).

** Winners correspond to households having a positive net transfer, i.e. receiving more cash transfer than they spend on carbon tax.

*** The interquartile range measures the difference of net transfer received by the 1st and 3rd quartile of income. A larger interquartile range reflects a distribution of net transfers that is more dispersed in the population.

transfer does not vary significantly between different income deciles, so that it is no more efficient in reducing regressivity than a flat cash transfer. However, it may be observed that adjusting for household composition or residential location slightly reduces the dispersal of the impact across households – it diminishes the interquartile range. Surprisingly this result does not hold for climate zone – the interquartile range remains the same – which suggests that impact of the carbon tax is not reduced for people living in warmer climates.

These findings indicate that losers are not identifiable by single characteristics but by combinations of characteristics. In consequence, while the question of how to adjust the design of cash transfers is relevant, the answer remains somewhat unclear. In particular, the benefits of adjusting the design of cash transfers may be somewhat limited compared with the administrative cost of implementing them.

Finally, it should also be noted that the proportion of recycling needed to correct for regressivity does not depend on the level of the carbon tax. It remains the same whatever the carbon tax rate is. This is because regressivity only depends on the initial structure of energy consumption. Furthermore, I find that incorporating behavioural responses into the model does not change the results, which is consistent with previous findings.

### 4.3. Reducing fuel poverty

A second desirable policy objective would be to reduce the impact of the carbon tax on fuel poverty. To see how this can be done, I evaluate the minimum cash transfer that brings fuel poverty back to its pre-tax rate, according to the fuel poverty indicators. I then look at how fuel poverty can be further reduced and discuss how the energy cheque,[11] a bill payment aid introduced by the government, is expected to perform compared with alternative scenarios.

The different designs of cash transfer are now compared in terms of their effectiveness in reducing fuel poverty. According to the fuel poverty indicators used in this study – which are derived from the official French indicators – one must be in the first 3 income deciles in order to be identified as fuel poor. Thus any cash transfer that goes to a household in the 4th to 10th income deciles is pointless in combating fuel poverty. In what follows, cash transfers are all targeted at the poorest 30% of households.[12] The five previous designs are tested: flat, size-based, income-based, geography-based and climate-based. In addition, a sixth design is introduced, derived from the energy cheque implemented in France. The amount of the cash transfer is adjusted to account for three sizes of household and three levels

**Table 7**
Transfer multipliers for the energy check.

| Transfer multplier | 1 CU | 1 < CU < 2 | 2 + CU |
|---|---|---|---|
| Decile 1 (< 10 720€) | 3 | 3.9 | 4.8 |
| Decile 2 (between 10 720–13 600€) | 2 | 2.6 | 3.2 |
| Decile 3 (between 13 600–15 660€) | 1 | 1.3 | 1.6 |

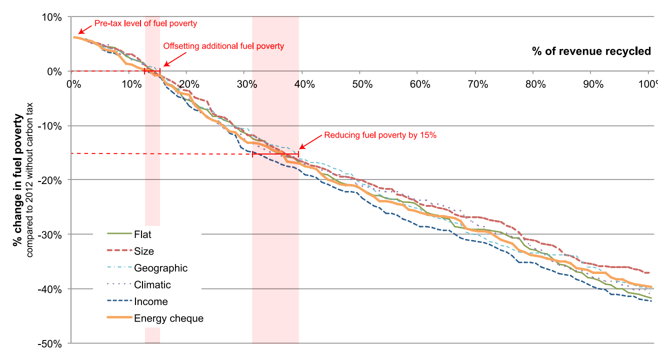


**Fig. 4.** Change in fuel poverty for different designs of targeted cash transfers (€30.50/$tCO_2$).

of income. The transfer multipliers, reported in Table 7, correspond to the official coefficients used for the energy cheque. It should be noted that there is one difference from the official energy cheque: I expand the target to include all households in the first three income deciles – the poorest 30% of households – whereas only the poorest 15% of households are eligible for the official energy cheque (about 3.8 million households).

Fig. 4 shows the percentage change in fuel poverty for each scenario compared with the baseline scenario without carbon tax. A flat transfer targeted at the poorest 30% of households could reduce fuel poverty by up to 42% below its pre-tax level with a €30.5/$tCO_2$ carbon tax. Adjusting the transfer to income level is the most efficient design tested and could on average reduce fuel poverty by an additional 1.7% points. Adjusting the transfer to household composition is on average slightly more expensive. This scenario favours large households which tend to spend more on domestic energy, but disadvantages single-person households, which are numerous and overrepresented among the fuel poor. Adjusting for residential location or climate zone does not change the results much. The former favours households living in low-density areas, which are overrepresented among the fuel poor, but this is to the detriment of the urban fuel poor, who represent the largest proportion of those in fuel poverty. Adjusting for climate confirms the previous findings, that living in a milder climate does not provide protection from fuel poverty.

Redistributing carbon tax revenues entirely to fuel poor households may appear unfair, since there are other worthwhile goals to pursue. A minimum

[11] In 2018, the government introduced an “energy cheque” to replace preexisting social tariffs targeted at poor households. It corresponds to a financial support sent to households for the payment of their energy expenditure.

[12] The income distribution relates to disposable income before the cash transfers.

**Table 8**
Comparison of different designs to reduce fuel poverty by 15% below pre-tax level (€30.5/t$CO_2$ carbon tax).

| Objective: reduce fuel poverty by 15% | | | | | | | |
|---|---|---|---|---|---|---|---|
| Design of cash transfer | % of population eligible | Cost of the measure (billion €) | % of revenue recycled* | Mean cash transfer | Mean net transfer | % of winners** | Interquartile range*** |
| Flat | 30% | 1.50 | 35% | €186 | €63 | 77% | €141 |
| Size-based | 30% | 1.59 | 37% | €196 | €73 | 80% | €122 |
| Geographic-based | 30% | 1.64 | 39% | €203 | €81 | 80% | €148 |
| Climatic-based | 30% | 1.47 | 34% | €181 | €59 | 76% | €139 |
| Income-based | 30% | 1.37 | 32% | €170 | €47 | 69% | €184 |
| Energy check | 30% | 1.57 | 37% | €195 | €72 | 73% | €176 |

* The cost of the measure is compared to carbon tax revenue generated by households (which is about 2/3 of total carbon tax revenue).
** Winners correspond to households having a positive net transfer, i.e. receiving more cash transfer than they spend on carbon tax.
*** The interquartile range measures the difference of net transfer received by the 1st and 3rd quartile of income. A larger interquartile range reflects a distribution of net transfers that is more dispersed in the population.

**Table 9**
Budget implications of a package including a carbon tax and the energy check.

| **Description** | **Budget* (million €)** | **% of total carbon tax revenues** |
|---|---|---|
| Carbon tax, 30.50€/t$CO_2$ | 6 388 | 100% |
| Of which on households | 4 259 | 67% |
| Energy check, restricted to the first 3 income deciles | − 1 573 | − 25% |
| Carbon tax + Energy check | 4 815 | 75% |

* In 2012, government revenues were 286 billion € and GDP was 2032 billion €. The carbon tax revenues would be 2.2% of government revenues and 0.3% of GDP.

objective could be to bring fuel poverty back down to its pre-tax level. In this case, a flat cash transfer would require the recycling of 14% of the carbon tax revenue generated from households, which would mean giving €74 to every household in the first three income deciles. Fig. 4 shows that the results are similar for all scenarios. Turning to a more ambitious objective, derived from the Energy Transition Act, I assess how a 15% reduction in fuel poverty in 2012 compared with its pre-tax level – before the introduction of the carbon tax – could be achieved.[13] Table 8 shows the results for the different scenarios. Depending on the scenario, achieving this objective would require recycling between 32% and 39% of the carbon tax revenue generated from households, the cheapest option being the income-based scenario (Table 8 and Fig. 4). These scenarios would entail giving back an average between €170 and €203 to households belonging to the poorest 30%.

Finally, Table 9 shows the effects on the government budget of the sixth design, inspired by the energy cheque. A carbon tax set at €30.5/t$CO_2$ is expected to generate €6.4 billion of which €4.3 billion come from households.[14] Achieving a 15% reduction in fuel poverty with energy cheques would cost €1.6 billion, which corresponds to recycling 25% of total carbon tax revenues. Households would receive an average cash transfer of €195 per household per year, with the actual amounts of the cash transfer ranging from €76 to €365. Overall, this package (carbon tax + energy cheque) would bring a net amount of €4.8 billion to the public purse. A 15% reduction in fuel poverty, which would also compensate for regressivity, can therefore be achieved with a relatively limited share of total carbon tax revenues.

## 5. Conclusions and policy implications

Prior work has documented the distributional effects of taxing carbon/energy and the effectiveness of redistributing revenues to households through offset schemes. However, these studies have focused on offsetting the regressivity of the tax and neglect the many losers in the poorest populations. In particular, they have not addressed the issue of fuel poverty. In this study, I explored the extent to which taxing carbon could amplify fuel poverty or, conversely, provide an opportunity to combat it.

I confirmed that, without revenue recycling, the carbon tax is regressive, but more importantly I showed that it seriously exacerbates fuel poverty. This finding highlights the fact that the question of fuel poverty cannot be separated from ecological issues. I then showed that substantial decreases in fuel poverty – far below the pre-tax level – can be achieved by targeting revenue recycling at low-income households. I therefore demonstrate that, though the carbon tax could increase fuel poverty, it does not need to. In addition, I demonstrate that it is possible to compensate households by only recycling some carbon tax revenues, leaving the remaining revenues available to pursue other purposes. Finally, the results show that adjusting the design of cash transfers to criteria other than level of income does not diminish the cost of compensating households. The benefits of fine-tuning the design of cash transfers may therefore be fairly limited.

However some limitations need to be noted. First, the results relate to a counterfactual scenario for 2012, before the implementation of the carbon tax. To evaluate the actual impact of the French carbon tax, future work should therefore include the modelling of changes in population characteristics – such as income, volume of energy consumed, socio-demographic variables – in subsequent years. Second, although monetary support can help low-income households meet their energy needs in the short term, there are some situations it cannot resolve, such as when fuel poverty is caused by poor insulation or inefficient heating. Future work should consider modelling other types of redistribution to households. In particular, incentives to retrofit dwellings and to replace heating systems might be a more promising strategy for achieving a lasting reduction in fuel poverty. Third, although the hypotheses in this study are standard for short-term analyses, they do not take into account macroeconomic effects, such as how the cost of the carbon tax is split between producers and consumers of energy, or the impact of the carbon tax on revenue factors. Future work could thus entail coupling the microsimulation model with a general equilibrium model in order to evaluate the longer term distributional impacts of the carbon tax.

Despite these limitations, this study raises policy implications that are timely and relevant. The results stress the importance of redistributing some carbon tax revenues to households. In France, no redistribution of carbon tax revenues to households has so far been implemented,[15] which raises questions of social justice and acceptability, particularly given the recent acceleration in the trajectory of the carbon tax. At the very least, this study shows that carbon tax revenues could be used to correct the inequities it generates.

[13] The Energy Transition Act sets the target of reducing fuel poverty by 15% by 2020 compared with its 2015 level.

[14] Two-thirds of total carbon tax revenue come from households and one-third from businesses.

[15] The energy cheque, as implemented in 2018 in France, aims to replace pre-existing social energy tariffs targeted at the poorest rather than to compensate for the additional cost due to the carbon tax.

Most notably, this is the first study to my knowledge to investigate the interaction between carbon taxation and fuel poverty. It provides compelling evidence that the question of fuel poverty cannot be ignored in the quest for a fair energy transition. The results show that allocating a portion of carbon tax revenues to low-income households would help to reduce fuel poverty. In particular, in France, it would contribute to the achievement of the targets set by the Energy Transition Act. This study therefore demonstrates that taxing carbon actually provides an opportunity to fund ambitious policies to combat fuel poverty.

**Acknowledgements**

I would like to thank Céline Guivarch for her constructive feedback and encouragement, Franck Nadaud for his help on methodological aspects, as well as Cyril Bourgeois, Frédéric Ghersi, Diane Aubert and anonym referees from FAERE and Energy Policy for sharing their comments on the manuscript. I am also very grateful to conference participants at FAEE, AFSE, FAERE, ISEFI, IAEE and FSR. Financial support from the French agency ADEME (Agence de l'Environnement et de la Maitrise de l'Energie, France) and from Chaire Modélisation prospective (France) is gratefully acknowledged.

## Appendix A. The French energy tax system

This section presents the different taxes that apply to energy consumption in France. The French energy taxation system belongs to indirect taxation. Energy suppliers are in charge of collecting the taxes paid by energy consumers and transferring it to the State. There are two types of indirect taxation in the energy sector: ad valorem taxes and excise duties. Ad valorem taxes are collected on the value of a product. They are proportional to the price. One example is VAT. Excise duties are collected on a quantity, rather than a value. One example is a carbon tax based on the carbon content. Excise duties are generally used to discourage people from consuming products embedding negative externalities – such as climate change is case of a carbon tax. French excise duties on energy are derived from the European directive 2003/96/CE, which defines the minimum amount of excise duties that have to be applied for each type of energy.

The microsimulation model simulates four taxes that are applied to energy according to the French legislation. Three taxes are excise duties. They are specific to a type of energy: TICPE for petrol products (in the model it relates to diesel, gasoline and heating oil), TICGN is for natural gas (it relates to network gas), and TCFE is for electricity. The excise duty on coal - TICC - is not modelled as it represents a very small share of the total energy consumed by households ($< 1\%$). The fourth tax that is modelled corresponds to VAT. It is an ad valorem tax and it is common to all types of energy.

The different energy taxes are further presented below.

*TIC: TICPE, TICGN and TICC (Taxe Intérieure de Consommation)*

TIC is an excise duty collected on the consumption of energy products. TICPE is for petrol products (essentially transport fuels and heating oil), TICGN for natural gas and TICC for coal. A fixed amount is applied to the quantity of energy consumed. In other words, TIC is added to the price of energy before VAT. In France, values of TIC are decided each year in the Finance Law. They are listed and accessible in the article 265 of Code des douanes. An extra amount can be added at the regional level for transport fuels. Each year regional councils deliberate on the value of the extra amount to apply – most of them choose to apply the largest extra amount authorised, currently set at €2.50 per hectolitre for gasoline and diesel. Part of this extra amount was introduced with Grenelle de l'Environnement (LF 2010, article 94) and is used to finance transport infrastructure projects relating to alternatives to car.

TIC have two main objectives. Firstly, they constitute a large source of governmental revenue. In particular, TICPE represents the fourth largest source of governmental revenue in France. Concretely, in 2012, revenues from TICPE amounted to 14 billion euros for the state - which represents 5% of governmental budget – and 11 billion euros for regional councils.[16] Overall revenues form TICPE represents 1,2% of GDP. Secondly, they act like a Pigouvian tax, that is a tax meant to internalise the social costs of consuming energy. Because TIC applies to fossil fuels - gas, fuel, coal and heating oil - they can be interpreted as accounting for their negative externalities, such as climate change, local pollution, noise and road damages in case of transport fuels. Yet TIC do not directly target environmental externalities like a carbon tax would, whose level is function of their carbon content.

*TCFE (Taxe sur la Consommation Finale d'Electricité)*

TCFE is an excise duty collected on the consumption of electricity. It is applied on the quantity of electricity consumed (amount of kWh). A fixed amount of tax is added to the price of electricity before VAT. TCFE is actually composed of three taxes: a national tax (CSPE) and two local taxes (TCCFE and TDCFE).

The national component CSPE (called TICFE since 2016) is used to finance public service obligations in electricity aimed at ensuring equality principles between electricity suppliers. More precisely, CSPE covers subsidies for renewable energies, equalisation of cost between territories, and social energy tariffs. Since 2016, it is not a contribution any longer but a tax that abounds the State budget.

The two local taxes are specific to each city and department respectively. Each year, local and departmental councils deliberate on the value of tax to apply - among a pre-defined range decided by the State. The exact value of TCFE then depends on one's residential location.

*VAT (Value Added Tax)*

VAT is an ad valorem tax collected on the value of energy consumed. It is applied on both the cost of energy and the amount of excise taxes. In France two rates of VAT affects energy. The normal rate of VAT applies on the cost of energy consumed. The reduced rate of VAT applies on the subscription cost for electricity and gas. The normal rate was 19.6% in 2012, and it has evolved to 20% since 2014. The reduced rate is 5.5%.

*Other energy taxes*

CTA (Contribution au Tarif d'Acheminement) is a tax that applies both on the consumption of electricity and natural gas. CTA is a percentage of the fixed portion of a tariff applying on transport and distribution network. It represents about 2% of a household annual bill. Because it not possible to model it directly and because it represents only a small part of a household energy expenditure, it is excluded from this study.

[16] https://www.performance-publique.budget.gouv.fr/sites/performance_publique/files/farandole/ressources/medias/documents/ressources/PLF2012/chiffres_cles.pdf.

Finally there are taxes for the energy consumed in collective equipment, but they are out of the perimeter of the study.

## Appendix B. Behavioural responses

The values of price elasticity of energy demand used in this study are estimated from the survey Budget des Familles 2011 based on Engel curves. This section introduces the Engel curve model and presents the estimation methods conducted in the pseudo-panel per deciles and per years. Then the values of price elasticity of energy demand are presented.

*General Engel curve model*

The estimates are based on the typical Working-Leser specification, which is to say on a set of categories of consumption. The curves are estimated in budget shares, which guarantees the additive property of equations without imposing estimation constraints in the system of equations. The general equation is written:

$$w_i = a_i + b_i \ln\left(\frac{X}{P}\right) + c_i \ln P_i + e_i \tag{1}$$

where ln (x/P) represents the total actual expenditure (in which P is the consumer price index) and lnPi the actual average price of the category considered. The deterministic term is a constant $a_i$ in the case of a cross-section and a linear trend in the case of a pseudo-panel: $a_{i0} + a_{i1}t$. The factors $a_i$ and $b_i$ reflect income elasticities and direct price elasticities relative to the budget shares. Thus they are not income elasticities and direct price elasticities relative to the total expenditure in the classical sense of the microeconomic theory of the consumer. These last two are functions of the estimated coefficients $a_i$ and $b_i$ and the budget shares $w_i$.

To calculate these elasticities, Engel curves are estimated using nominal expenditures. The expression of total expenditure is:

$$E_i = X.w_i = X(a_i + b_i \ln X + c_i \ln P_i)\ \forall\ i = 1, \ldots, p \tag{2}$$

Where Ei represents the total expenditure of category i.

The income and price elasticities are calculated from Eq. (2), using the following expressions: $e_{X.E_i} = \frac{\partial E_i}{\partial X} \times \frac{X}{E_i}$ for income elasticity and: $e_{E_i P_i} = \frac{\partial E_i}{\partial P_i} \times \frac{P_i}{E_i}$ for price elasticity.

In the end, income elasticity is:

$$e_{X.E_i} = \frac{\partial E_i}{\partial X} \times \frac{X}{E_i} = (w_i + b_i) \times \frac{1}{w_i} = 1 + \frac{b_i}{w_i}. \tag{3}$$

And price elasticity is:

$$e_{E_i P_i} = \frac{\partial E_i}{\partial P_i} \times \frac{P_i}{E_i} = \frac{X.c_i}{P_i} \times \frac{P_i}{X.w_i} = \frac{c_i}{w_i}. \tag{4}$$

The two expressions of income elasticities and price elasticities for each category of expenditures are then estimated from the observed data in the survey.

*Estimation in pseudo-panel*

Data is divided in seven different consumption categories. The seven categories are detailed below, with the codes COICOP INSEE of their components:

1. Food and Clothing (C1 + C3);
2. Domestic energy (C045);
3. Non-energy housing expenditure (C4-C045);
4. Fuels (C0721);
5. Transport services (C7-C0721);
6. Capital goods (everything else);
7. Services (C8-C12).

Capital goods appear as a residual position.

The consumption categories are aggregated per deciles of standards of living and per year. The weights of households correspond to the national weights in the survey. Thus the variables are averaged according to national weights per standards of living and per year. Two aspects motivate this choice: the need to take into account developments over time, and the need to work on the deciles of standards of living. With regard to price indices, they are calculated using the price indices of the corresponding categories and their budget shares in that category.

In addition, the problem of null values and discrete choice with truncation has been addressed using pseudo panel: there are no more null values. This approach was adopted in the context of prior work. Indeed, demand elasticities used in this study were estimated in a prior work, for which there was a double constraint: (1) estimate by deciles of living standards for the needs of a macro simulation model; (2) avoid value problems in a nomenclature compatible with the macro model.

*Results*

The estimated values of price elasticity of demand are summarised in Table C1. They correspond to short-term elasticity, so that they do not account for changes in households' stocks of equipment. The average price elasticity for energy demand is found higher in the home than for travelling. They are equal to −0.35 and −0.18 respectively. Price elasticities are further differentiated per deciles of standard of living to account for differences in price responsiveness according to one's standard of living. Responses are observed to decrease across deciles in the domestic sector from −0.46 (decile 1) to − 0.19 (decile 10). On the contrary they increase in the transport sector from − 0.02 (decile 1) to − 0.24 (decile 9), except for the tenth decile who shows a very low response. It is noteworthy the first and tenth deciles (-0.02 and −0.04 respectively) have a particularly small response in the transport sector. It could be explained by constrained situations and a lack of capacity to adapt their behaviours.

## Appendix C. Additional tables and figures

See Tables C1–C3 and Figs. C1–C3 here.

**Table C1**
Price elasticity of energy demand for housing and transport by income decile.
Source: Budget des Familles 2011 and authors' calculation.

| Deciles of living standards | Mean price elasticity of energy demand in the home | Mean price elasticity of energy demand for travelling |
|---|---|---|
| 1 | − 0.461 | − 0.016 |
| 2 | − 0.470 | − 0.149 |
| 3 | − 0.426 | − 0.236 |
| 4 | − 0.411 | − 0.146 |
| 5 | − 0.390 | − 0.217 |
| 6 | − 0.373 | − 0.261 |
| 7 | − 0.302 | − 0.277 |
| 8 | − 0.256 | − 0.288 |
| 9 | − 0.258 | − 0.238 |
| 10 | − 0.190 | − 0.039 |
| **Total** | **−0.354** | **−0.183** |

Interpretation: Following a 1% increase in energy prices, households will decrease their energy consumption by 0.35% in the home and by 0.18% for travelling.

**Table C2**
Comparison of modelled and declared households' energy expenditure by type of energy.

| | **2012 estimation sample** (5122 observations) | | | |
|---|---|---|---|---|
| | **Modelled spending** (€/year) | | **Declared spending** (€/year) | |
| | **Mean** | **Standard error** | **Mean** | **Standard error** |
| Electricity | 731.0 | 8.4 | 733.8 | 8.4 |
| Gas | 355.7 | 9.6 | 353.0 | 9.6 |
| Heating oil | 212.5 | 9.2 | 205.2 | 8.9 |
| Wood | 46.0 | 2.7 | 46.0 | 2.7 |
| Energy charges | 139.8 | 5.3 | 139.8 | 5.3 |
| Gasoline | 440.5 | 14.1 | 440.6 | 14.1 |
| Diesel | 969.1 | 20.3 | 968.8 | 20.3 |

**Table C3**
Descriptive statistics of the main variables used in this study.

| | **2012 estimation sample (annual data)** | |
|---|---|---|
| **Number of observations** | **5122** | |
| **Continuous variables** | **Mean** | **Standard Error** |
| Disposable income | €34170 | €323 |
| Domestic energy spending | €1557 | €14 |
| Domestic energy spending per UC | €1051 | €10 |
| Domestic energy spending per m2 | €18.5 | €0.2 |
| Domestic energy spending ratio | 5.7% | 0.1% |
| Fuel spending | €1414 | €24 |
| Fuel spending per UC | €874 | €15 |
| Fuel spending ratio | 4.4% | 0.1% |
| **Discrete variables** | **Share of total population** | |
| Owner | 58.2% | |
| Renter | 41.7% | |
| City | 66.5% | |
| Suburb | 26.1% | |
| Isolated town | 7.5% | |
| Collective equipment | 18.8% | |
| Single | 32.5% | |
| Single parent | 3.1% | |
| Couple | 31.8% | |
| Couple with children | 30.7% | |
| Worker | 52.8% | |
| Unemployed | 6.4% | |
| At home | 2.6% | |
| Retired | 31.5% | |
| Student | 2.1% | |

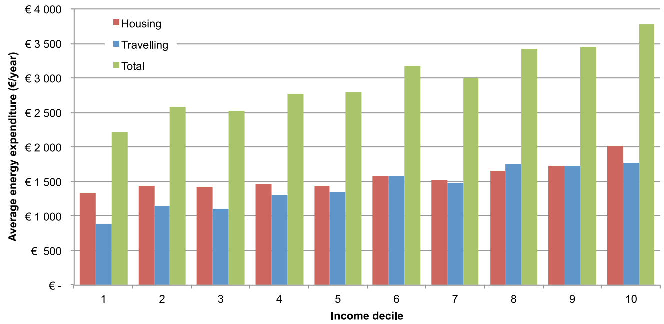


**Fig. C1.** Households' energy expenditure in 2012, by income decile (€/year).

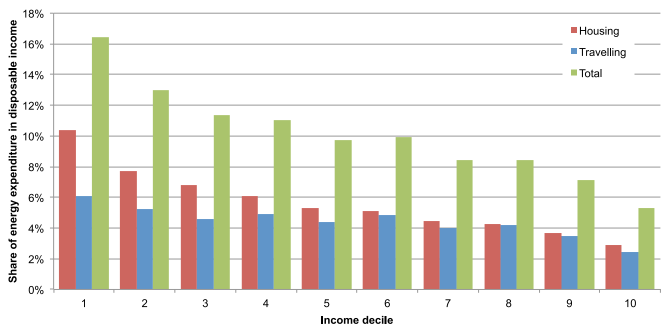


**Fig. C2.** Share of energy expenditure in disposable income in 2012, by income decile (€/year).

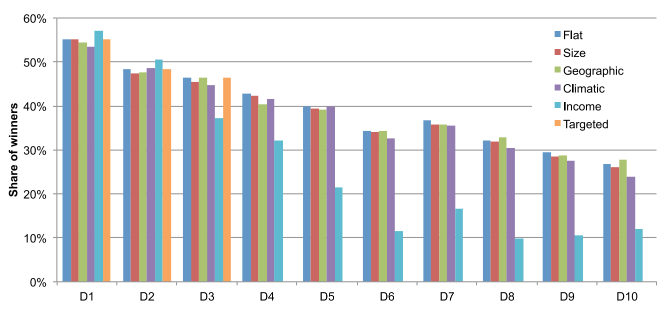


**Fig. C3.** Share of households receiving positive net transfer (cash transfer – carbon tax) for different scenarios of recycling, by income decile.

## References


Beck, M., Rivers, N., Wigle, R., Yonezawa, H., 2015. Carbon tax and revenue recycling: impacts on households in British Columbia. Resour. Energy Econ. 41, 40–69. https://doi.org/10.1016/j.reseneeco.2015.04.005.

Berri, A., Vincent Lyk-Jensen, S., Mulalic, I., Zachariadis, T., 2014. Household transport consumption inequalities and redistributive effects of taxes: a repeated cross-sectional evaluation for France, Denmark and Cyprus. Transp. Policy 36, 206–216. https://doi.org/10.1016/j.tranpol.2014.08.007.

Berry, A., Jouffe, Y., Coulombel, N., Guivarch, C., 2016. Investigating fuel poverty in the transport sector: toward a composite indicator of vulnerability. Energy Res. Social. Sci. 18, 7–20.

Bourguignon, F., Spadaro, A., 2006. Microsimulation as a tool for evaluating redistribution policies. J. Econ. Inequal. 4, 77.

Bouzarovski, S., Petrova, S., Sarlamanov, R., 2012. Energy poverty policies in the EU: a critical perspective. energy policy. Energy Policy 49, 76–82. https://doi.org/10.1016/j.enpol.2012.01.033. (Special Section: Fuel Poverty Comes of Age: Commemorating 21 Years of Research and Policy).

Brännlund, R., Nordström, J., 2004. Carbon tax simulations using a household demand model. Eur. Econ. Rev. 48, 211–233.

Bureau, B., 2011. Distributional effects of a carbon tax on car fuels in France. Energy Econ. 33, 121–130. https://doi.org/10.1016/j.eneco.2010.07.011.

Callan, T., Lyons, S., Scott, S., Tol, R.S., Verde, S., 2009. The distributional implications of a carbon tax in Ireland. Energy Policy 37, 407–412.

CGDD, 2016. L'impact, pour les ménages, d'une composante carbone dans le prix des énergies fossiles. Point sur n°225.

Charlier, D., Risch, A., Salmon, C., 2016. Les indicateurs de la précarité énergétique en France. Rev. Fr. d'économie XXX 187–230.

Clerc, M., Marcus, V., 2009. Élasticités-prix des consommations énergétiques des ménages. INSEE Documents de travail.

Cronin, J.A., Fullerton, D., Sexton, 2017. Vertical and Horizontal Redistributions from a Carbon Tax and Rebate. NBER Working Paper. ⟨https://doi.org/10.3386/w23250⟩.

Derdevet, M., 2013. La précarité énergétique, un chantier européen prioritaire. Géoéconomie 66, 37–50.

Fullerton, D., 2008. Distributional Effects of Environmental and Energy Policy: An Introduction (Working Paper No. 14241). National Bureau of Economic Research. ⟨https://doi.org/10.3386/w14241⟩.

Fullerton, D., Metcalf, G.E., 2002. Tax incidence. Handbook of Public Economics 4. pp. 1787–1872.

Grainger, C.A., Kolstad, C.D., 2010. Who pays a price on carbon? Environ. Resour. Econ. 46, 359–376.

Guyet, R., 2014. La précarité énergétique en Europe : approche comparative. La Documentation française.

Hassett, K.A., Mathur, A., Metcalf, G.E., 2007. The Incidence of a US Carbon Tax: a Lifetime and Regional Analysis. National Bureau of Economic Research.

Hills, J., 2012. Getting the measure of fuel poverty: final report of the Fuel Poverty Review (Monograph).

Labandeira, X., Labeaga, J.M., Rodríguez, M., 2006. A Residential Energy Demand System for Spain. Energy J. 27. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol27-No2-6.

Legendre, B., Ricci, O., 2015. Measuring fuel poverty in France: which households are the most fuel vulnerable? Energy Econ. 49, 620–628.

Lemaître, E., Kleinpeter, M.-A., 2009. Dépenses de carburant automobile des ménages. CGDD, Etudes & documents.

Merz, J., 1991. Microsimulation: a survey of principles, developments and applications. Int. J. Forecast. 7, 77–104.
Nichèle, V., Robin, J.-M., 1995. Simulation of indirect tax reforms using pooled micro and macro French data. J. Public Econ. 56, 225–244. https://doi.org/10.1016/0047-2727(94)01425-N.
Nicolas, J.-P., Vanco, F., Verry, D., 2012. Mobilité quotidienne et vulnérabilité des ménages, daily trips and household vulnerability. Rev. d'Économie Régionale Urbain. février 19–44.
ONPE, 2016. Chiffres-Clés de la précarité énergétique.
Parry, I.W., Sigman, H., Walls, M., Williams III, R.C., 2005. The incidence of pollution control policies. NBER Working Paper. ⟨https://doi.org/10.3386/w11438⟩.
Poterba, J.M., 1991. Is the gasoline tax regressive? Tax Policy and the Economy. The MIT Press, pp. 145–164.
Rausch, S., Schwarz, G.A., 2016. Household heterogeneity, aggregation, and the distributional impacts of environmental taxes. J. Public Econ. 138, 43–57. https://doi.org/10.1016/j.jpubeco.2016.04.004.
Ruiz, N., Trannoy, A., 2008. Le caractère régressif des taxes indirectes: les enseignements d'un modèle de microsimulation. Econ. Et. Stat. 413, 21–46.
Spadaro, A., 2007. Microsimulation as a Tool for the Evaluation of Public Policies: Methods and Applications. Fundacion BBVA.
Sterner, T., 2007. Fuel taxes: an important instrument for climate policy. Energy Policy 35, 3194–3202. https://doi.org/10.1016/j.enpol.2006.10.025.
Suits, D.B., 1977. Measurement of tax progressivity. Am. Econ. Rev. 747–752.
Thomson, H., Snell, C., 2013. Quantifying the prevalence of fuel poverty across the European Union. Energy Policy 52, 563–572. https://doi.org/10.1016/j.enpol.2012.10.009. (Special Section: Transition Pathways to a Low Carbon Economy).
Wadud, Z., Graham, D.J., Noland, R.B., 2009. Modelling fuel demand for different socio-economic groups. Appl. Energy 86, 2740–2749.
West, S.E., Williams, R.C., 2004. Estimates from a consumer demand system: implications for the incidence of environmental taxes. J. Environ. Econ. Manag. 47, 535–558.