Policy Papers

Compensating households from carbon
tax regressivity and fuel Poverty : a
microsimulation study

Audrey Berry

PP 2017-08

www.faere.fr

Compensating households from carbon tax regressivity and fuel poverty: a microsimulation study

Audrey Berry*

*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

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

Abstract

For households, taxing carbon raises the cost of the energy they use to heat their home and to travel. This paper studies the distributional impacts of the recently introduced French carbon tax and the design of compensation measures. Using a microsimulation model built on a representative sample of the French population from 2012, I simulate for each household the taxes levied on its consumption of energy for housing and transport. Without recycling, the carbon tax is regressive and increases fuel poverty. However, I show how compensation measures can offset these impacts. A flat cash transfer offsets tax regressivity by redistributing <60% of households' contribution. This result falls to 17% when the transfer is targeted at low-income households. Furthermore, I find that targeting the cash transfer reduces fuel poverty by up to 50% below its pre-tax level with a 30.50€/tCO2 carbon tax. These results demonstrate compensating households is achievable at reasonable cost relative to carbon tax revenues. Carbon taxation even constitutes an opportunity to finance ambitious policies to fight fuel poverty.

Highlights

- I quantify the distributional impacts of carbon taxation with microsimulation.
- Without recycling, the carbon tax is regressive and increases fuel poverty.
- Different designs of cash transfers are compared to protect households.
- Regressivity is offset by redistributing <60% of households' contribution.
- Targeting the recycling at low-income reduces fuel poverty far below pre-tax level.

Keywords

Carbon tax; Distributional impacts; Fuel poverty; Revenue recycling; Microsimulation

Acknowledgements

1. Introduction

France committed to reduce its greenhouse gas emissions by 40% in 2030 compared to 1990 levels. To achieve this objective, the government introduced a carbon tax in 2014. It takes the form of a carbon component directly integrated into existing taxes on energy consumption. The amount of carbon tax is proportional to CO_2 emissions in order to internalize the environmental externalities of consuming energy. In France, the carbon tax affects all energies – including network gas, heating oil, diesel and gasoline – except electricity, which is already covered by the European carbon market (EU ETS). The trajectory of the carbon tax progressively increased from 7€/tCO_2 in 2014 to 30.5 €/tCO_2 in 2017, and the law on energy transition (2015) plans the carbon tax to reach 56 €/tCO_2 in 2020 and 100 €/tCO_2 in 2030[1] to meet our climate objectives.

This paper aims to explore the distributional impacts of the recently introduced French carbon tax. In the long-term, the carbon tax should lead to a decrease in households' energy spending, but during the transition to a low-carbon economy, its consequence for households is to raise travel cost and heating cost. Taxing carbon increases the cost of fossil fuels, which firms are likely to pass through to consumers in the form of higher prices. There follows a decline in purchasing power that is likely to affect households in their daily life. Moreover the burden it places on households' budget increases with lower incomes and as households are constrained in their behaviour (Simon and Thao Khamsing, 2016). One can think of households living in poorly insulated housing, or those who have no alternative to car use. Because they may not have the capacity to adjust their energy consumption, part of the population is likely to face difficulties to meet their energy needs. This phenomenon - called fuel poverty – is gathering 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). The number of households in fuel poverty rose by 17% in France between 2006 and 2013. It is now affecting more than 20% of households according to the French National Observatory on Fuel Poverty (ONPE, 2016). In this context, it is essential to ensure that the carbon tax will not exacerbate further the issue of fuel poverty. This study seeks to quantify the distributional impacts of the carbon tax and to design compensation measures that restore social equity across households.

---

[1] For comparison, in 2016, about 19 countries had implemented or scheduled for implementation a carbon tax (World Bank 2016). Their amount varied between US$137/tCO2e (€118/tCO2) for Sweden to less than US$1/tCO2e (€0.9/tCO2) for Mexico.

In order to smooth the transition to a low-carbon society, the energy transition law is complemented with social objectives aiming at fighting against fuel poverty and ensuring the right for all households to access energy without excessive cost relative to their financial resources. The French government committed to reduce fuel poverty by 15% in 2020 compared to 2015 level, as well as to eliminate all energy-inefficient housing by 2025[2]. To support low-income households, the French government has already implemented a set of measures. Some curative measures are proposed to help the fuel poor pay their energy bills. In 2016, three million low-income households benefited from social tariffs on electricity and gas. The government is currently testing an "energy check" to replace social tariffs. It corresponds to a financial support sent to households for the payment of their energy spending. It is conditional on income, and four million households are expected to be eligible by 2018. In addition, shutting down energy access has been forbidden during the winter period in case of bill arrears. The government also proposes preventive measures, which focus on improving housing conditions in terms of energy efficiency. The program "Habiter Mieux" provides financial support to low-income homeowners willing to renovate their home. Yet those measures are limited in scale and they do not directly tackle the impacts introduced by the carbon tax. Addressing the social consequences of taxing energy is essential to ensure the social acceptability of an ambitious carbon tax, as planned by current laws.

The aim 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. Secondly I look at how to compensate households for these impacts. I discuss the design of compensation measures and I evaluate how much recycling it requires. To do so, I developed a microsimulation model built to evaluate fiscal policies affecting energy taxes in France, which include the carbon tax. It simulates the impact of the carbon tax at the individual household level and enables an accurate assessment of its distributional consequences. The model is built on the most recent data available in France (2012) that contains detailed information on energy consumption both for housing and transport. The model is static, and if it fails to account for general equilibrium consequences, it offers a good approximation of the short-term impacts of a given policy. Another contribution is to analyse the link between fuel poverty and carbon taxation. On the one hand, because it increases the cost of using carbon-intense energy, the carbon tax weights heavily on

---

[2] Energy-inefficient housing corresponds to housing consuming more than 330 kWh/m^2/year. They are classified F or G under the French energy performance scale.

households' budget and threatens part of the population to fall in fuel poverty. On the other hand, the revenue generated by the carbon tax provides the opportunity to finance ambitious public policies aiming at fighting against fuel poverty. As such this study sheds new light on the carbon tax as an opportunity to respond to the issue of fuel poverty.

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 main results and related discussion. The fourth section summarizes findings and provides policy recommendations.

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 allows assessing the aggregate and distributive impacts of reforms on energy taxation and compensation measures already implemented or under review. In particular this model allows analysing the distributional effects of carbon taxation and the vulnerability of households to the transition toward a low-carbon society. The model is based on the most recent data on energy consumption available in France, a survey of 5405 households - Phebus 2013 – which includes detailed information about each household, their housing characteristics and their energy consumption both for housing and transport in 2012. For the purpose of this paper, the baseline scenario corresponds to the energy tax system in 2012. Then I simulate counterfactual scenarios corresponding to introducing a carbon tax, and I measure the average impact on household energy spending as well as the distribution of impacts across society.

It is the only known microsimulation model based on the survey Phebus at the time of writing. Compared to existing microsimulation models applied to energy in France, this model integrates direct information on energy consumption in volume - without deriving volumes from energy spending. It includes both energy for domestic use and traveling - without matching of distinct databases. It is based on the most recent data, especially data on transport - compared to the latest survey on transport ENTD which dates back to 2008.

Microsimulation is particularly relevant to the analysis of the distributional impacts of public policies and tax reforms (Merz, 1991), (Spadaro, 2007), (Bourguignon and Spadaro, 2006). The main advantages are to include the use of nationally representative data, the ability to

incorporate a wide range of behaviours and the ability to overcome aggregation biases[3]. However it does not consider interactions between households. For such purpose, agent-based models would be better suited. Moreover most microsimulation models do not consider general equilibrium consequences because it requires too much data and computational power, though this can be approached by coupling a microsimulation model with a computable general equilibrium model. For these reasons, when it is static, microsimulation modelling is best suited to evaluate the short-term impacts of a given policy.

Designing the microsimulation model requires the five following elements:

- a database containing a sample of representative households - with the relevant variables for the problem under study;
- a modelling of the energy tax system – to derive households' energy spending;
- a modelling of households' behaviour - to incorporate behavioural responses;
- the indicators to measure the distributional impacts;
- the scenario to be analysed.

2.1. The database

The model is based on Phebus, a survey that was conducted in 2013 for the French government and that is representative of the French metropolitan main homes. 5405 households were interviewed about their energy consumption and the characteristics of their dwelling, including the energy performance. The objective of this survey is to inform public policies on households' energy consumption and housing renovation. The survey unit corresponds to a household. It also contains detailed information on the socio-demographic characteristics of each occupant and their energy habits. In the model, data is consolidated in a unique database for 2012, which corresponds to the counterfactual scenario. Then other databases are generated for each scenario that is evaluated in this study (see section 2.5).

This study deals with households using individual equipment for heating and water heating. They represent 80,7% of French households. For these households, the energy spending is known in the survey. The 19,3% other households use collective equipment and they are excluded from

---

[3] The aggregation bias means that non-linear relationship at the individual level cannot be estimated at the aggregate level. In regard with environmental taxes, (Rausch and Schwarz, 2016) demonstrated that failing to incorporate household heterogeneity can affect the incidence of a carbon tax. Applied on US data, they found a significant bias, which mainly affects the sources side of income, but also the uses side of income.

the study. Their energy spending is not perfectly identifiable from the other expenses of the house because it is included in their collective building charges. This explains why they show lower individual energy spending than other households. As a result, it is more difficult to identify which household is fuel poor. Households using collective equipment relate mostly to apartments, among which renters are overrepresented. This must be kept in mind when interpreting results.

2.2. The energy tax system

2.2.1. Modelling the carbon tax

In the model, the carbon tax is applied in addition to existing taxes on energy. Its structure is inspired by actual implementation rules, but it slightly differs from the French legislation, where the carbon tax is introduced as part of existing energy taxes – called TIC (Taxe Intérieure de Consommation). In the model, the carbon tax and TIC are modelled separately. The carbon tax corresponds to an excise duty applied on the volume of energy consumed. It is expressed per ton of CO_2. The carbon tax rate applied on each type of energy is function of its carbon content[4] (see Table 1). Though the carbon content of electricity is not null, there is no carbon tax applied on electricity, as it is out of scope in current French law[5]. The carbon tax rates are derived for each type of energy as such:

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

In 2012, a carbon component at 30.5 €/tCO2 would have represented between 8% and 15% of energy prices before taxes. The highest share of carbon tax falls on network gas. Similarly it would have represented between 5% and 12% of energy prices after taxes. Gasoline and diesel are the energy bearing the highest level of pre-existing taxes, so that their share of carbon component in energy prices after taxes are the lowest (5,3% and 6,5% respectively).

---

[4] Carbon contents correspond to direct emissions for production (upstream) and combustion in France. They are detailed in Appendix A and available online at: http://23dd.fr/images/stories/Documents/PV/Ademe_Metro_Chapitre_2_Energie.pdf

[5] Electricity is subject to a carbon price through the European carbon market, but the price per ton 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 share in the price of kWh is negligible – about 0,003c€/kWh, that is 0,02% of the consumer price in 2012.

	Carbon content	Carbon tax rate	Share of carbon tax
	tCO2	Carbon tax = 30.5€/tCO2	Compared to 2012 energy prices
1 ton of heating oil	3.483	106.23 €/ton	9.3%
1 MWh of network gas	0.000238	7.3 €/MWh	12.4%
1 litre of diesel	0.00297	0.091 €/l	6.5%
1 litre of gasoline	0.00282	0.086 €/l	5.3%
1 litre of LPG	0.00187	0.057 €/l	6.5%

Table 1: Carbon content and carbon tax rate according to the type of energy

2.2.2. Modelling energy spending (energy tax system in France)

In the microsimulation model, energy spendings are estimated for each household taking account of the types of energy they use, their consumption levels and the types of contracts and options they subscribed. Prices per kWh, litre or ton as well as subscription costs are expressed before taxes. The type of energy and type of contract are supposed to remain unchanged in the different scenarios (level of power subscribed, type of contract, type of energy for heating, type of fuel for traveling). Volumes consumed, taxes and prices before taxes are taken at their 2012 level. The model simulates the different taxes that apply to energy consumption according to the 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). Carbon taxation is introduced as described in the previous section. Then a VAT rate – Value Added Tax - is applied on the cost associated to consumption and a reduced VAT rate is applied on the subscription cost. The modelling of energy spending is presented below for each type of energy.

Electricity / Network gas

$Energy\ spending\ (including\ all\ taxes)$
$$= Subscription\ cost\ [type\ of\ contract] \times (1 + reduced\ VAT)$$
$$+ Volume\ consumed\ \times (cost\ per\ kWh\ + TIC^* + carbon\ tax\ ) \times (1 + normal\ VAT)$$

Gasoline / Diesel / LPG / Heating fuel / Wood

$Energy\ spending\ (including\ all\ taxes)$
$$= Volume\ consumed \times (cost\ per\ litre\ or\ ton\ + TIC^* + carbon\ tax)$$
$$\times (1 + normal\ VAT\ )$$

TIC = TICGN / TICPE / TCFE - carbon tax

8

2.3.   Households behaviour

Changes in behaviour following the introduction of the carbon tax are modelled individually for each household in the sample. In this paper, behavioural responses are modelled with the price elasticity of demand. It measures the responsiveness of the volume of energy consumed to a change in energy price, other things being equal. In other words, it represents the percentage change in energy consumed in response to a one per cent change in energy price. The formula for the price elasticity of demand is:

$$price\ elasticity\ of\ demand = \frac{\Delta volume/volume}{\Delta price/price}$$

Values of price elasticity of demand used are estimated from the survey Budget des Familles 2011 based on Engel curves (see Appendix B for more details). They correspond to short-term elasticity. They account for a decrease in consumption, while the stock of households' equipment remains the same. The hypothesis is that in the short-term households cannot replace their heating system, or their vehicle. Price elasticities are differentiated by type of energy and by decile of income.

2.4.   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. It starts with measuring the cost of the tax at the household level and then look at its distribution across society. Households are classified by some measure of economic well being, most often by income level. A tax will be said progressive 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 summarize distributional effects. They have the advantage to assess the overall effect of a tax in a single number. The Suits index of tax progressivity consists in measuring the deviation of a tax system from proportionality (Suits, 1977). It is the most widely used index in the literature on measuring the distributional effects of energy/transport taxation. With this approach, a progressive tax system is one in which the average tax to income ratio – the share of income paid in taxes - increases with income. The value of the Suits Index varies from +1 (extreme progressivity where the entire tax burden is

born 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 born by the poorest household). Its mathematical representation is:

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

with y_h the accumulated percent of total income of all households with an income lower or equal to household h and $T(y_h)$ the accumulated percent of total carbon tax of those same households.

2.4.2. Measuring fuel poverty

In France, the issue of fuel poverty was officially recognised in 2010, and the law defined a person in fuel poverty as: *experiencing particular difficulties in its housing to obtain the supply of energy necessary to satisfy its basic needs because of the inadequacy of its resources or its housing conditions*"[6]. This definition makes a connection between two causes of fuel poverty: low financial resources and poor energy performance.

The multidimensional nature of fuel poverty makes its measurement a difficult task and rouses debates about which indicator(s) should be used to evaluate fuel poverty. Yet, among policy makers, fuel poverty is usually measured with an energy to income ratio. It corresponds to households spending more than a certain share of their income on energy. In housing, the 10% ratio has been commonly used so far (Boardman 1991). Alternatively the threshold is sometimes taken at two times the median ratio to account for the evolution in energy prices. 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. It identifies households cumulating a high cost of energy and a low income. In this paper, I adopt the official indicators defined by the French National Observatory on Fuel Poverty. Three indicators are retained to quantify fuel poverty (ONPE, 2016). They correspond to the energy to income ratio, the low-income high-cost approach and a subjective indicator identifying households declaring feeling cold. This paper evaluates the impact of carbon taxation on the two first indicators defined by ONPE – the third indicator being declarative it cannot be assessed directly. The first indicator is the energy to income ratio. It identifies households spending more than 10% of their income on energy spending, among households belonging to the three lowest income deciles:

---

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

$$\frac{Energy\ spending}{Income} > 10\%$$

The second corresponds to the LIHC approach. It identifies households cumulating a high energy spending (per consumption unit[7] or per square meter) and a low income (after deducting the energy spending):

$$\frac{Energy\ spending}{Number\ of\ CU\ or\ m^2} > Median$$

$$\frac{Income - Energ\ spending}{Number\ of\ CU} < Poverty\ line$$

These indicators allow evaluating 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. Firstly there is no official indicator of fuel poverty in the transport sector in France. Secondly because of the high diversity in travel needs and unequal access to alternatives, a simple transposition of existing indicators in the domestic sector to the transport sector is not satisfactory (Berry et al., 2016). For these reasons, here the fuel poverty indicators will be restricted to the domestic sector.

2.5.   Scenarios

This study evaluates different scenarios describing the introduction of carbon taxation in France. Firstly it considers the carbon tax without behavioural responses and without recycling of the carbon tax revenue. The carbon tax is set at 30.5€/tCO2, which corresponds to the tax level implemented in 2017 in France. In a second step, price elasticity of demand is introduced so that households respond to rising energy prices by decreasing the volume of energy they consume. Values of price elasticity are differentiated per standard-of-living deciles for both housing and transport. In a third step, households receive monetary compensations. Different designs of compensations are tested that differ in size and eligibility. All scenarios are counterfactual situations of the year 2012, which corresponds to the reference year in the microsimulation model - before the carbon tax was introduced. All scenarios describe what would have happened if a carbon tax had been introduced in 2012.

---

[7]The size of the Consumption Unit (CU) of a household is based on the most widely used equivalence scale (the OECD scale): the first adult counts for 1, other persons aged 14 years old or older count for 0,5 each, and children under 14 years old count for 0,3 each. It is used to compare the standard of living of households of different composition.

2.5.1. Compensation measures

The revenue generated by the carbon tax offers the opportunity to compensate households for its negative impacts. Different designs of cash transfers are simulated and compared to support households. The first design corresponds to a flat cash transfer (flat transfer). The same amount is transferred to every household. Cash transfers can also be finely designed to account for the heterogeneity of the impact of the carbon tax, and in particular to allow horizontal redistribution between rich and poor, but also vertical redistribution between households with the same income level but different level of energy consumption (Cronin et al., 2017). To do so, the amount of transfer is adjusted to household composition (size-based transfer), residential location (geographic-based transfer) and income level (income-based transfer). The fifth design corresponds to a cash transfer targeted at low-income (targeted transfer). Only households belonging to the first three deciles of income are eligible to receive a flat transfer. Thus for each design of cash transfer, the amount of transfer received by a household is adjusted by a transfer multiplier. Transfer multipliers are summarised in table 2.

In this paper, I study two policy objectives: offsetting regressivity and offsetting additional fuel poverty. For each objective I evaluate the minimum cash transfer which:

- Makes the carbon tax become progressive, based on the Suits index of progressivity (see subsection 4.2.1),
- Brings back fuel poverty to its pre-tax rate, based on the indicators of fuel poverty (see subsection 4.2.2).

In the end, for each design and objective, a household receives the following cash transfer:

$$Cash\ transfer\ (household) = Minimum\ transfer \times Transfer\ multiplier\ (household)$$

Design of transfer	Transfer multipliers		
Flat	All population 1		
Size-based	1 CU* 1	1<CU<2 1.3	>2 CU 1.6
Geographic-based	City 1	Suburbs or Isolated town 1.4	
Income-based	Decile 1** 3	Decile 2 2	≥ Decile 3 1
Targeted	≤ Decile 3 1	≥ Decile 4 0	

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

Table 2: Transfer multipliers used to evaluate the amount of cash transfer received by each household

3. Results and discussion

3.1. The impact of the carbon tax on energy bills without behavioural response

A carbon tax set at 30.50€/tCO2 is estimated to increase annual energy spending of households by 195€ on average for housing and for travelling, among which 163€ is for the carbon tax and 32€ is for additional VAT (VAT applied on the amount of carbon tax). It represents almost 5% of households' energy spending in 2012, the reference year of the model, that is, before the introduction of the carbon tax. The mean impact is more important for travelling than for home purposes. Energy spending increases by 114€ for travelling (95€ for the carbon tax out of VAT) and by 82€ in the home (68€ for the carbon tax out of VAT). Yet the impact on energy spending varies a lot in the population. It depends on several factors: income, but also household composition, occupation status, heating type, residential location, etc. Almost one household in two is not affected by carbon tax in the domestic sector (those using electric heating), two in ten are not affected in the transport sector (those who do not use a thermal motor vehicle), and one in ten is not affected at all. On the opposite, one household in ten has its energy spending that increases by more than 250€/year either in the domestic sector or transport sector, and one in ten by more than 400€/year overall.

The average impact increases with income classes. The 10% poorest pay 130€ of carbon tax per household on average (including VAT). This is less than half what pay the 10% richest (274€/household) and two third what pays the average household in the population (195€/household).

3.2. The carbon tax is regressive

To account for differences in standards of living, the impact of the carbon tax is analysed in terms of tax to income ratio: it corresponds to the amount of carbon tax paid (out of VAT) as a share of households' disposable income. Low-income households clearly bear the highest burden of the tax, with a tax to income ratio of 0.77% on average for the 10% poorest households, against 0.23% for the 10% wealthiest (Figure 1). It means that the 10% poorest are 2.4 times more impacted than the 10% wealthiest, and 1.5 times more impacted than the average household (0.52%). Low-income households are the most affected by the carbon tax both on housing energy (which represents 0.36% of their income) and on transport energy (0.42%). The tax burden then decreases progressively with income in the domestic sector. This

is less clear in the transport sector, where middle-class households remain highly impacted - deciles 3 to 6 show similar tax to income ratio – compared to the richest households. It means their fuel consumption increases at the same pace as their income, which can be explained by driving longer distances, by changes in the modal share towards cars and by owning bigger vehicles.
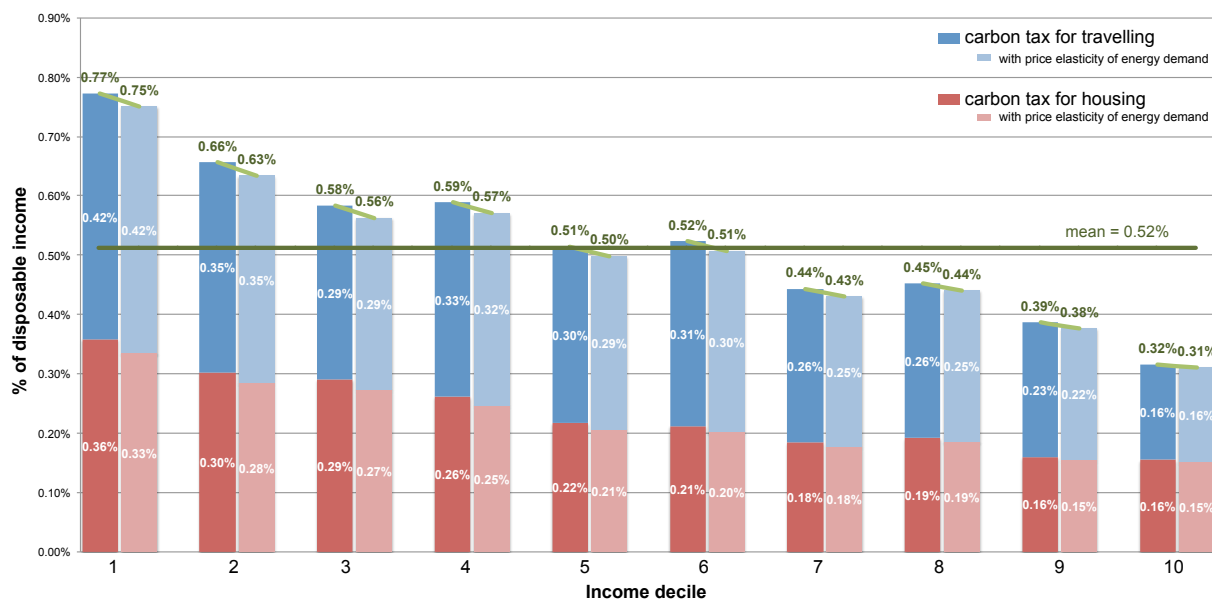

Figure 1: Carbon tax as a share of households' disposable income, according to income decile (30.50€/tCO_2)

The Suits Index measures more precisely the progressivity/regressivity of a tax by looking at its deviation from proportionality. The Suits Index of the carbon tax equals -0.146. Such negative value confirms the regressivity of the carbon tax. Regressivity is more pronounced for transport energy than for domestic energy - the corresponding Suits Index are -0.159 and -0.127 respectively. This result differs from most studies that generally find regressivity to be lower on transport energy because of lower car use among low-income household. This can be partly explained by the perimeter of the study, which excludes households using collective equipment – of which urban households are more numerous so that they are more likely to use public transport rather than car – but this may also reflect an evolution in households travel practices – with a higher car dependency among low income households.

Previous results correspond to the impact the carbon tax would have on households' budget, other things being equal. Net of tax energy prices, other taxes affecting energy (VAT and TIC) and volumes of energy consumed by households are kept constant. Such scenario has the

advantage to offer a first picture of distributional impacts. However it is not satisfying; it lacks realism since changes in prices are known to generate changes in consumption. The carbon tax aims at sending a price-signal for households to decrease their consumption of carbon-intense energy. However, accounting for behavioural responses - in terms of price elasticity of energy demand - does not change the main result in terms of regressivity. The way households adjust their consumption of energy to higher energy prices modifies their profile of spending on carbon tax. In particular if low-income households reduce more their consumption compared with high-income households, we can expect the regressivity of the carbon tax to decrease. However such situation could reflect unwanted restriction in energy consumption that will be discussed in the next section on fuel poverty. In this study, price elasticity of energy demand of low-income households is about 30% higher for housing and 30% lower for travelling (see Appendix B). The impact on the Suits Index is negligible: it decreases regressivity of the carbon tax by less than 2%. Looking at a more extreme scenario, assuming the price elasticity of energy demand equals -1 for the 50% poorest households (a x% increase in energy prices leads to a x% decrease in the volume of energy consumed) and 0 for the 50% richest households (they do not reduce their consumption at all), it would decrease regressivity by only 16% (the Suits index moves from -0.146 to -0.123). This implausible scenario keeps a high level of regressivity.

These results are in line with existing studies, which find the carbon tax to be regressive among developed countries (Sterner, 2007). In France, most studies based on micro data that focused on estimating the impact of rising taxes on energy (or on carbon) found that low-income households would be the most impacted (Nichèle and Robin, 1995), (Clerc and Marcus, 2009), (Ruiz and Trannoy, 2008), (Bureau, 2011), (Clerc and Marcus, 2009) and (Simon and Thao Khamsing, 2016).

It is worth noting that carbon taxes generally appear far less regressive when permanent income is used, than when annual income is used (Poterba, 1991), (Hassett et al., 2011). Permanent income corresponds to expected long-term average income. In France, using total consumption as a proxy for permanent income, (Bureau and Marical, 2011) found households devoting the highest share of their budget on transport energy were not the poorest but middle-class households. In this study, due to data limitation, regressivity is measured using annual income.

3.3.   The carbon tax increases fuel poverty

The rate of fuel poverty is estimated for different scenarios of carbon tax. In this study, households are said in fuel poverty if they are identified by at least one of the two following

indicators officially used by ONPE. The first indicator identifies households spending more than 10% of their income on energy. The second indicator identifies households cumulating a high spending per consumption unit or per square meter (higher than the median) and a low standard of living after energy spending (lower than the poverty line). A carbon tax at 30.5€/tCO2 would increase the share of households in fuel poverty by 6% compared with a counterfactual scenario without carbon taxation (figure 2). This means 140 000 additional households would fall in fuel poverty. If the level of regressivity does not depend on the level of the tax, but only on the distribution of energy spending in the population, the analysis is different for fuel poverty. Fuel poverty is defined by reference to a threshold, so that the higher the level of the carbon tax, the higher the number of households crossing the fuel poverty threshold. Looking at a carbon tax set at 100€/tCO2, it would increase fuel poverty by 17%, meaning 420 000 additional households would fall in fuel poverty.

Accounting for behavioural responses reduces the impact on fuel poverty. However interpreting a decrease in consumption raises concerns, as it does not tell us about the overall impact on households' well-being. In the best case, a decrease in energy consumption translates the adoption of virtuous energy habits. But it could also translate a deprivation in essential energy services. In particular for low-income households, carbon taxation could make some energy services no longer affordable, so that households suffer from cold 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 section 2.4.2). In 2012, 18% of households declared feeling cold at home in France.
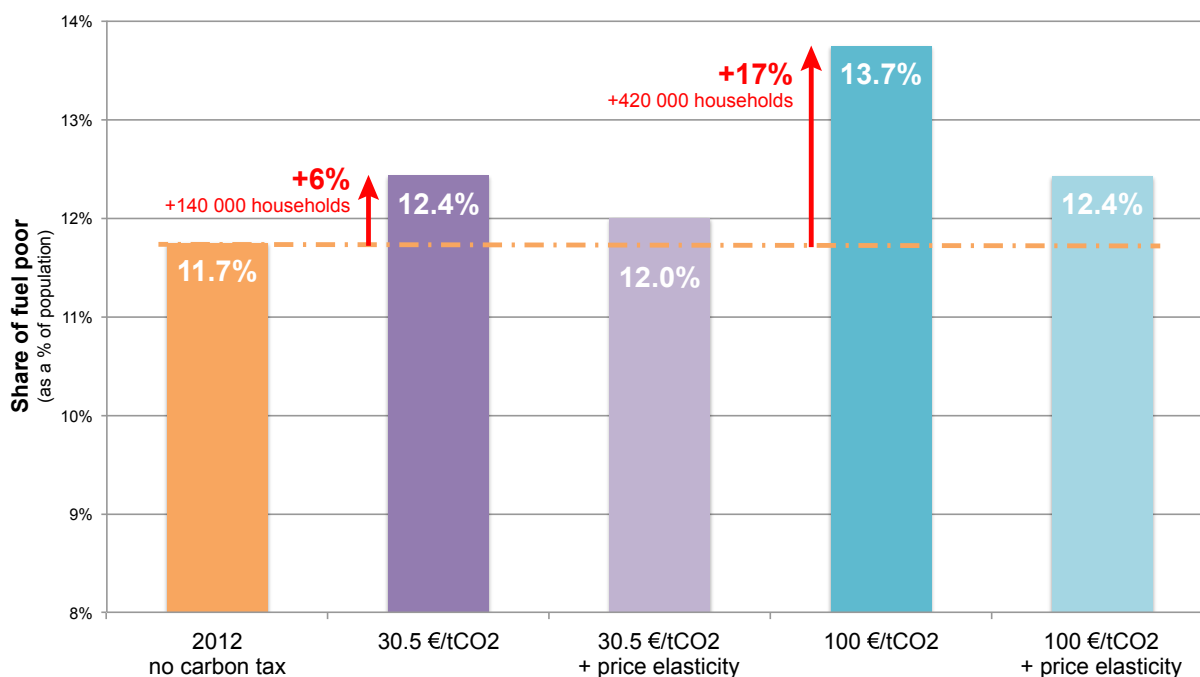
Figure 2: The impact of the carbon tax on fuel poverty (30.50€/tCO$_2$ and 100€/tCO$_2$)

3.4. Households living in low-density areas are more affected by the carbon tax for travelling, but they are less likely to fall in fuel poverty

Households living in low-density areas are equally affected by the carbon tax on domestic energy use, but they are more affected on transport energy use. Figure 3 shows the share of disposable income spent on paying the carbon tax according to households' residential location. The survey Phebus provides information about where households live, which is summarised into three modalities in this study: households living in urban poles, suburbs or isolated towns[8]. Households living in the suburbs and isolated towns devote a larger share of their income to paying the carbon tax for transport compared to households living in an urban pole. However, the explanation is not the same in either case: households living in the suburbs have a very high carbon tax spending relative to the population, which contributes to increase their income share. Households living in isolated towns, on the other hand, have a carbon spending close to the population. It is the weakness of their income that makes the carbon tax weight in their income.

---

[8] The three modalities are derived from the nine modalities of the variable CATAEU2010: type of municipality in the urban zoning of INSEE (the French National Institute of Statistics).

Moreover having a low-income worsens the situation. Households living in the suburbs and belonging to the first three deciles of income are 1.6 times more impacted by the carbon tax on transport energy use than the average household (they devote 0.46% and 0.29% of their income respectively). Households living in an urban pole have the best situation; they cumulate a relatively low-carbon tax spending and low share of income. These results confirm the importance of accounting for households' residential location when evaluating the impact of the carbon tax on transport energy use, households living in low density areas being more impacted than those living in the city (Lemaître and Kleinpeter, 2009), (Nicolas et al., 2012).

With regard to fuel poverty, before the carbon tax, households living in isolated towns are overrepresented, with a rate of fuel poverty reaching 15.7% - compared to the average rate of 11.7%. Yet households living in the city are those more likely to fall in fuel poverty because of the carbon tax. Cities gather 60% of the population but 73% of the households falling in fuel poverty because of a carbon tax at 30.5€/tCO2. This represents 100 000 additional urban households that could fall in fuel poverty. This result derives from the fact that urban households are more numerous to heat their home with carbon-intense energy. They are 55% to use network gas or heating oil in the city, whereas this figure falls to 37% in low-density areas. If the share of electric heating is similar - slightly more than one third - the difference mainly comes from a greater use of wood heating in low-density areas. Moreover this result is reinforced by the fact that 75% of households falling in fuel poverty because of the carbon tax use network gas (25% use heating oil), and households using network gas are 84% to live in the city. Thus, households living in the city are more likely to fall in fuel poverty because of the carbon tax on domestic energy.
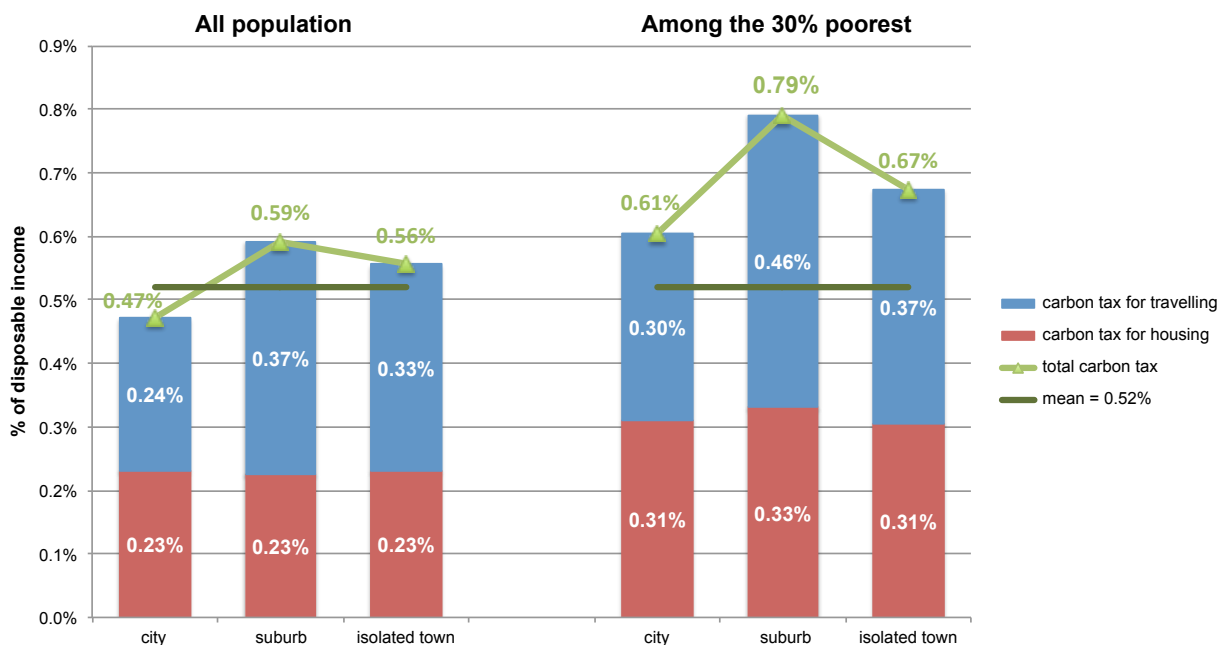
Figure 3: Carbon tax as a share of households' disposable income, according to residential location (30.50€/tCO$_2$)

3.5. Compensating for the negative impacts could be achieved by recycling only part of the tax revenues

A carbon tax at 30.50€/tCO2 is estimated to generate 6.7b€ for the government, among which 4.4b€ are from households. It would be desirable for carbon tax revenues to be redistributed, at least in part, as compensation for households. The compensation could then contribute to lower energy bills and to accelerate the adoption of lower-carbon lifestyle (housing renovation, car replacement, etc.). In Ireland, Callan et al. (2009) found that making households better off could be achieved without exhausting the total carbon tax revenue. Yet they recycled more than what is generated by households. In the following, I will show that, in the French context, correcting for carbon tax regressivity and additional fuel poverty requires recycling only part of the revenue generated by households. Before that, some aspects relating to compensation measures are discussed.

Compensating households is generally achieved 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 check, 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 that increasing their amount would reduce regressivity. However, almost half

households belonging to the first three deciles of income would be left out as they do not benefit from any existing social transfer (minimum welfare benefits, housing transfer or any social benefits). The share of households that would be left without support reaches 30% among the first decile, 41% among the second decile and 53% among the third decile. Compensation would be partially ensured, which makes this solution unsatisfying.

The second option offers the opportunity to design a measure tailored for our purpose. Cash transfers can be finely designed to account for the heterogeneity of the impact of the carbon tax and to limit the number of losers. Yet the design should not be too complex. It should rely on available data and simple criteria in order to limit management costs and opacity. Moreover the compensation should not interfere with the price-signal of the carbon tax. As such it should not be indexed directly, or indirectly, on energy spending so that households continue to be incentivised to adjust their energy consumption. In this study, households are compensated with cash transfers. In the following, I evaluate two compensation objectives: the first aims at offsetting the carbon tax regressivity, the second aims at reducing fuel poverty. For each objective, I simulate different designs of cash transfers (see subsection 2.5.1) and I discuss their cost relative to carbon tax revenues.

A flat cash transfer requires recycling 58% of the carbon tax revenue generated from households to make the carbon tax become progressive - based on the Suits index of progressivity - and 29% of the revenue to compensate for additional fuel poverty – based on fuel poverty indicators in the domestic sector. Yet a flat recycling is limited because it only compensates households on average. Adjusting the cash transfer for income level has the effect to decrease the overall cost of compensating for the negative impacts of the carbon tax. It requires 37% of the carbon tax revenue to offset regressivity and 15% to offset additional fuel poverty. Though adjusting for household composition and residential location appears justified for equity purpose, it does not change results in terms of cost of the measure and share of winners. The mean amount of transfer for each decile of income does not vary significantly so that it does not reduce regressivity. Adjusting for household composition and residential location is actually found slightly less effective at offsetting additional fuel poverty. Targeting the cash transfer at low-income households is the cheapest option. It requires recycling only 17% of the carbon tax revenue to make the carbon tax progressive and 8% of the revenue to offset additional fuel poverty.

For all designs of cash transfers, offsetting regressivity is found more costly than offsetting additional fuel poverty. However the contrary does not hold: a recycling designed to offset

additional fuel poverty only partly offset regressivity. One reason is that fuel poverty only concerns the domestic sector in this study, whereas regressivity concerns both the domestic and transport sector.

It should also be noted that the share of recycling needed to correct for regressivity does not depend on the level of the carbon tax. It remains the same whatever the level of the tax. This is not true for fuel poverty; the share of recycling needed to offset additional fuel poverty differs with the level of carbon tax. This is because fuel poverty is measured relative to a threshold – more or less households will fall below the threshold depending on the level of the carbon tax - while regressivity only depends on the initial structure of energy consumption – which remain the same whatever the level of the carbon tax.

Accounting for behavioural responses does not change results for regressivity, but reduces the cost of fighting against additional poverty. This is consistent with previous results: the level of regressivity is almost not impacted by behavioural responses whereas the increase in fuel poverty is significantly reduced. Results are summarised in Figure 4 and Table 3.

Design of cash transfer	% of population eligible	Objective: offset regressivity				Objective: offset additional fuel poverty			
		Cost of the measure	% of revenue recycled*	Mean cash transfer	% of winners**	Cost of the measure	% of revenue recycled*	Mean cash transfer	% of winners**
Flat	100%	2 080 M€	58%	95 €	38%	1 029 M€	29%	47 €	19%
Size-based	100%	2 066 M€	58%	94 €	36%	1 104 M€	31%	50 €	19%
Geographic-based	100%	2 030 M€	57%	93 €	36%	1 192 M€	33%	54 €	22%
Income-based	100%	1 323 M€	37%	60 €	24%	524 M€	15%	24 €	13%
Targeted at low-income	30%	600 M€	17%	100 €	51%	282 M€	8%	47 €	30%

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

** Winners correspond to households receiving more cash transfer than they spend on carbon tax. It is calculated among households eligible to receive the cash transfer.

Table 3: Transfer multipliers for the fifth design of cash transfer, according to households' size and income
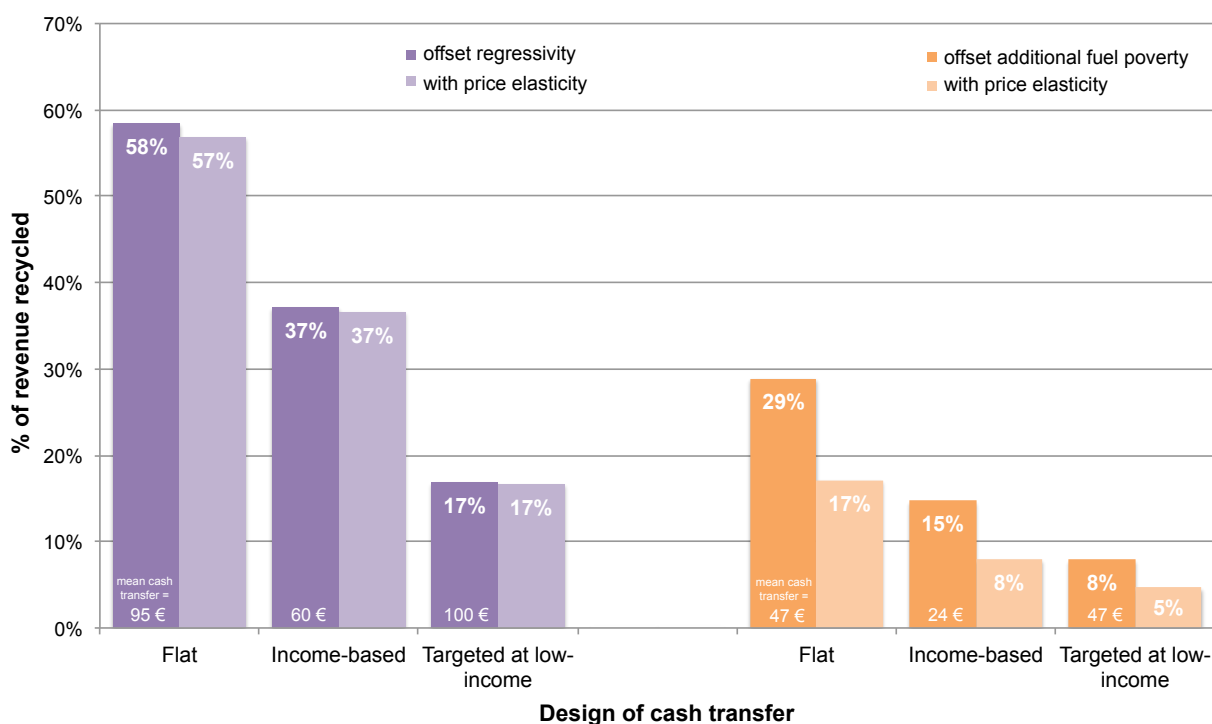

Figure 4: Share of carbon tax revenues required to support households for different objectives and designs of cash transfer (30.50€/tCO₂)

3.6. Targeting the recycling at low-income households reduces fuel poverty below its pre-tax level.

Different cash transfers are now compared in terms of their effectiveness to reduce fuel poverty. According to the indicators of fuel poverty used in this study – which are derived from the French official indicators - to be identified as fuel poor requires belonging to the first 3 income deciles. Thus any cash transfer that is given to a household belonging to the 4th to 10th income deciles is pointless to fight against fuel poverty. In the following, cash transfers are all targeted at the 30% poorest households. The four previous designs are tested: flat, size-based, income-based geographic-based. In addition, a fifth design is introduced that is derived from the energy check currently being tested in France. The amount of cash transfer differs according to three sizes of household and three sizes of income (see table 4). The transfer multipliers correspond to the official coefficients used for the energy check. It should be noted that there are two main differences with the official energy check. Firstly the paper evaluates cash transfers that provide complementary financial resources. They can be used to any expenditure item whereas the energy check can only be used to pay energy bills or to invest in housing renovation. Secondly I enlarged the target to include all households belonging to the first three deciles of income - the 30% poorest households - whereas only the 15% poorest households are expected to be eligible with the energy check (about 3.8 million households).

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

Table 4: Transfer multipliers for the fifth design of cash transfer, according to households' size and income

Figure 5 shows the percent change in fuel poverty compared to the counterfactual scenario without carbon taxation. A flat transfer targeted at the 30% poorest households could reduce fuel poverty up to 48% 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 reach a 55% reduction in fuel poverty. Adjusting the transfer to household composition or residential location is more expensive. In the first case, it favours large households who tend to spend more on domestic energy, but it disadvantages single-person households, which are numerous and overrepresented among the

fuel poor. In the second case, it favours households living in low-density areas, which are overrepresented among the fuel poor, but this is to the detriment of urban fuel poor, which remain the largest share of fuel poor. Similarly a carbon tax at 100€/tCO2 could reach a reduction in fuel poverty of 83% below pre-tax level.

The law on energy transition sets the objective to reduce fuel poverty by 15% by 2020 compared to 2015 levels. In this study, I evaluate a 15% reduction in fuel poverty in 2012 compared to its pre-tax level, that is before the introduction of the carbon tax. With the fifth design – inspired by the energy check - it requires recycling one third of the revenue generated by households with a 30.5€/tCO2 carbon tax. Table 5 shows the effects on the government budget of introducing this measure. The carbon tax generates 6.7 billion euros, of which 4.4 billion € come from households[9]. Achieving a 15% reduction in fuel poverty would cost 1.3 billion euros, which corresponds to recycling 20% of total carbon tax revenues. Households would receive an average cash transfer of 174€ per household per year, with actual amounts of cash transfer ranging between 69€ and 331€. Overall this measure would bring 5.3 billion € net to the government budget. It corresponds to recycling 20% of total carbon tax revenues. Therefore a 15% reduction in fuel poverty, which also compensates for regressivity, can be achieved with a relatively small share of total carbon tax revenues.

Description	Budget* (million €)	% of total carbon tax revenues
Carbon tax, 30.50€/tCO$_2$	6 652	100%
Of which on households	4 435	67%
Of which on households using individual equipment	3 560	54%
Adjusted cash transfer, restricted to the first 3 income deciles	(1 302)	-20%
Of which on households using individual equipment	(1 046)	-16%
Carbon tax + Adjusted cash transfer	5 349	80%

*In 2012, government revenues were 286 billion € and GDP was 2032 billion €. The carbon tax revenues would be 2.3% of government revenues and 0.33% of GDP.

Tableau 5: Budget implications of a carbon tax and adjusted cash transfers

---

[9] Two-third of total carbon tax revenue come from household and one-third comes from firms.
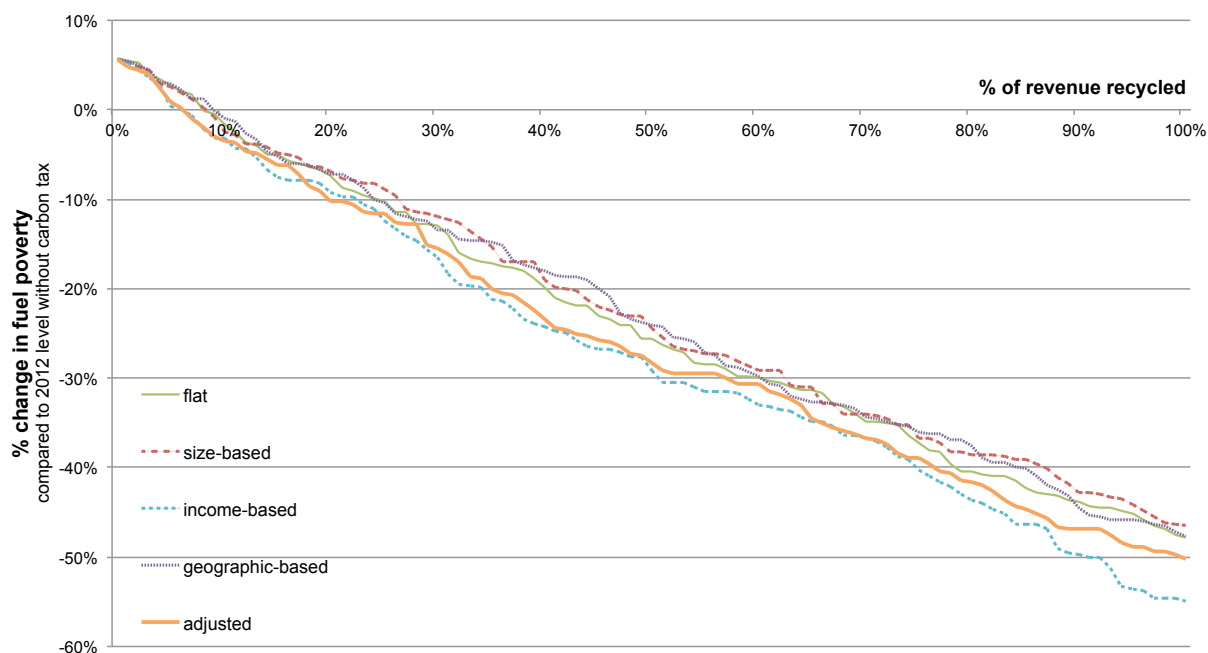
Figure 5: Change in fuel poverty for different designs of cash transfers (30.50€/tCO$_2$)

4. Conclusions and policy implications

In this paper, I explore the distributional impacts of taxing carbon on households' direct energy use for housing and transport in France with a microsimulation model. I quantify the regressivity of the carbon tax and the effect on fuel poverty. Without recycling, a 30.50€/tCO2 carbon tax increases fuel poverty by 6%, meaning 140 000 additional households could face difficulties to meet their energy needs for housing. Then I evaluate different designs of compensation measures to protect low-income households. I show that a partial recycling of carbon tax revenues - <60% of the revenues generated by households - is sufficient to offset carbon tax regressivity. I demonstrate targeting the recycling at low-income households reduces fuel poverty far below its pre-tax level – up to 50% with a 30.5€/tCO$_2$ carbon tax. Moreover, a 15% reduction in fuel poverty below pre-tax level – which also compensate for regressivity - could be achieved by recycling 20% of total carbon tax revenues. It corresponds to redistributing an average cash transfer of 175€ per year per household belonging to the 30% poorest households. These results demonstrate that compensating households is achievable at reasonable cost relative to total carbon tax revenues.

One contribution is to present a microsimulation model built for this purpose. The model is built on the most recent data available in France (Phebus 2012) that contains detailed information on energy consumption both for housing and transport. Another contribution is to analyse the link between fuel poverty and carbon taxation. If the carbon tax could increase fuel poverty, it needs not be. Carbon tax revenues constitute an opportunity to finance ambitious policies to fight fuel povertyMonetary support could help low-income households meet their energy needs during the transition to a low-carbon economy, before their get access to better housing conditions.

While addressing the short-term impacts of taxing carbon is essential, a more global analysis is needed to ensure the long-term acceptability of the carbon tax. Firstly the general equilibrium effects of the carbon tax impact the actual incidence of the carbon tax - how much of the carbon tax is passed through to consumers – and the evolution of the income distribution - which in turn affects regressivity and fuel poverty (Ghersi and Ricci, 2014). Secondly, other types of redistribution to households deserve to be considered. In particular, measures focusing on improving the energy efficiency of housing constitute a more promising strategy to reduce fuel poverty in a lasting way (Clinch and Healy, 2001). Further research is needed to articulate these two types of measures - providing monetary support and increasing energy performance. Finally the carbon tax revenue could be used to pursue other objectives, such as to reduce labour taxes. It is known to generally have positive effects on employment and growth, which in turn has positive effect on the distribution of income in the longer term (Combet et al., 2009). Further research is needed to find a balanced package in the use of the carbon tax revenues between different objectives and their relative impacts on households.

References

Berry, A., Jouffe, Y., Coulombel, N., Guivarch, C., 2016. Investigating fuel poverty in the transport sector: toward a composite indicator of vulnerability. Energy Res. Soc. 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, Special Section: Fuel Poverty Comes of Age: Commemorating 21 Years of Research and Policy 49, 76–82. doi:10.1016/j.enpol.2012.01.033

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

Bureau, D., Marical, F., 2011. Préservation de l'environnement, équité et accès aux services essentiels.

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.

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

Clerc, M., Marcus, V., 2009. Élasticités-prix des consommations énergétiques des ménages.

Clinch, J.P., Healy, J.D., 2001. Cost-benefit analysis of domestic energy efficiency. Energy Policy 29, 113–124.

Combet, E., Ghersi, F., Hourcade, J.C., 2009. Taxe carbone, une mesure socialement régressive? Vrais problèmes et faux débats.

Cronin, J.A., Fullerton, D., Sexton, S.E., 2017. Vertical and Horizontal Redistributions from a Carbon Tax and Rebate. National Bureau of Economic Research.

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

Fullerton, D., Metcalf, G.E., 2002. Tax incidence. Handb. Public Econ. 4, 1787–1872.

Ghersi, F., Ricci, O., 2014. A macro-micro outlook on fuel poverty in 2035 France. CIRED Work. Pap. 56.

Hassett, K.A., Mathur, A., Metcalf, G.E., 2011. The consumer burden of a carbon tax on gasoline. Fuel Taxes Poor Distrib. Eff. Gasol. Tax. Their Implic. Clim. Policy Thomas Sterner Ed Resour. Future Press.

Hills, J., 2012. Getting the measure of fuel poverty: final report of the Fuel Poverty Review [WWW Document]. URL http://sticerd.lse.ac.uk/case/ (accessed 4.22.14).

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.

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. doi: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 Urbaine février, 19–44.

ONPE, 2016. Chiffres-Clés de la précarité énergétique [WWW Document]. URL http://onpe.org/tableau_de_bord/tableau_de_bord_0 (accessed 2.28.17).

Poterba, J.M., 1991. Is the gasoline tax regressive?, in: Tax Policy and the Economy, Volume 5. 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. doi: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. Stat. 413, 21–46.

Simon, Thao Khamsing, 2016. L'impact, pour les ménages, d'une composante carbone dans le prix des énergies fossiles.

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. doi: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, Special Section: Transition Pathways to a Low Carbon Economy 52, 563–572. doi:10.1016/j.enpol.2012.10.009

5. 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[10]. 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

---

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

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 spending, it is excluded from this study.

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

6. 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:

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

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:

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

Where Ei represents the total expenditure of category i.

The income and price elasticities are calculated from equation (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:

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

And price elasticity is:

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

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.

Results

The estimated values of price elasticity of demand are summarised in Table 6. 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.

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 0.25% in the home and by 0.18% for travelling.

Source: Budget des Familles 2011 and authors' calculation

Table 6: Price elasticity of energy demand per decile of living standards