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The incidence of the European Union Emissions Trading System and the role of revenue recycling: Empirical evidence from combined industry- and household-level data

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## Discussion Papers

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Opinions expressed in this paper are those of the author(s) and do not necessarily reflect views of the institute.

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# The Incidence of the European Union Emissions Trading System and the Role of Revenue Recycling

Empirical evidence from combined industry- and household-level data

Martin Beznoska<sup>1</sup>, Johanna Cludius<sup>2</sup>, Viktor Steiner<sup>3</sup>

**Abstract:** We calculate the expected incidence of the European Union Emissions Trading System (EU-ETS) using industry and household-level data. By combining data on direct CO<sub>2</sub> emissions by production sector from the German Environmental Account with the German Input-Output Accounts, we calculate the CO<sub>2</sub> intensity of each sector covered by the EU-ETS. We focus on the impact of price increases in the electricity sector, both directly in the form of higher electricity bills for consumers and indirectly through products that use electricity as an input to production. Taking into account behavioral effects derived from an estimated consumer-demand system, we provide incidence calculations on the basis of the German Income and Expenditure Survey for the year 2008 data updated to 2013. We confirm the ex-ante expected regressive effect, which is, however, both rather small in magnitude and can be offset and even more than offset by revenue recycling, in particular the reduction of social security contributions on labor income.

**Keywords:** European Union Emissions Trading System, Tax Incidence, Revenue Recycling, Almost Ideal Demand System

**JEL Classification:** D12, H23, Q52

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## 1 Introduction

In order to reach its goal of reducing emissions by 20% below 1990 levels until 2020 the European Union has introduced its Emissions Trading System (EU-ETS) in 2005 (European Union 2003). Since the price of permits increases the cost of production for emissions-intensive industries, such as electricity generation or the manufacture of glass and paper, consumer prices are likely to rise as a consequence. While this is indeed desirable, since it induces a shift away from polluting goods to less energy-intensive ones, concerns have been raised as to whether those price increases might predominantly hurt low-income households, since they spend a larger fraction of their income on emissions-intensive products than high-income households. While this effect has been confirmed in the literature, researchers have noted the possibility to alleviate potential adverse distributional effects by way of revenue recycling.

Although the effects of a carbon tax are often comparable to those of an emissions trading system, as a cornerstone of European environmental policy, the EU-ETS merits special analysis. We are not aware of any study to date explicitly modeling the impact of the EU-ETS on households in a European member state using real world data. As the EU-ETS is due to enter its third phase in 2013, such an analysis seems of considerable policy relevance, as this will be the first phase during which a large amount of emission permits will be auctioned rather than given out for free: This will offer European governments the opportunity to alleviate unwanted distributional effects by way of revenue recycling.<sup>1</sup>

This paper contributes to the empirical evaluation of the expected distributional effects of the EU-ETS by combining industry and household-level data for Germany. We focus on the impact of price increases in the electricity sector, both directly in the form of higher electricity bills for consumers and indirectly through a whole range of products that use electricity as an input in production. For our analysis, we combine industry- and household-level data in order to calculate the expected distributional effect of the EU-ETS on German households, as described in the next section. Our simulation results confirm the ex-ante expected regressive effect of the EU-ETS on private households. However, this effect is rather small in magnitude even in simulations that do not take into account adjustments in demand for consumer goods

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<sup>1</sup> During this third phase, for the first time, a substantial share of emissions permits is auctioned: more than 50% as compared to only 4% during the second trading period (2008-2012) (European Commission 2010a; European Commission 2010b).

induced by relative price changes. We find that, on average, the financial burden of the EU-ETS, as measured by the compensating variation, is about 0.8 percent of total nondurable consumption. This burden varies between 1.1 percent in the lowest decile and 0.7 percent in the highest decile of the consumption distribution which we use to approximate lifetime income. Furthermore, we show that the small regressive effects of the EU-ETS can be offset, and even more than offset, by revenue recycling, in particular the reduction of social security contributions on labor income.

## **2 Previous Literature**

While economic literature has traditionally focused on the efficiency side of environmental taxation and regulation, there are a number of studies that estimate the incidence of various environmental policies on the distribution of household incomes. Although none of these studies looks explicitly at the EU-ETS, a brief review of the main results of these studies seems a useful background for our own analysis (a more detailed review of the relevant older literature, mainly restricted to studies for the U.S., is provided by Parry et al. 2005).

Metcalf (1999) who models a revenue-neutral green tax reform in the U.S. finds that while the burden of the environmental tax is distributed regressively, the whole reform is much less so and can even be rendered progressive by targeting low-income families. In their analysis of a 15% decrease in carbon emissions by way of an emissions trading system in the U.S., Dinan and Rogers (2002) compare both efficiency and equity effects of a system where those permits are given out for free to one where they are auctioned and the revenue returned either as a cut to corporate taxes, payroll taxes or as lump-sum transfers. They come to the conclusion that unless the government auctions most of the permits, and returns them in equal lump-sum transfers, this policy is highly regressive and note the trade-off between using revenues to increase efficiency of the tax system and using them to alleviate regressivity. Burtraw et al. (2009) model a hypothetical emissions trading system in the U.S. with a price of \$21 per ton of carbon in 2015 and find that returning revenue in the form of per capita lump-sum transfers to households, especially if these are taxable, makes the policy progressive. The same is true if revenues are returned as an expansion of the personal income tax credit. A reduction of the income tax and

payroll tax, albeit favored for efficiency reasons, exacerbates the regressivity of an emissions trading system.

Researchers have also taken into account behavioral changes of private households to check whether this approach significantly alters conclusions derived in a static analysis. Parry (2004) uses an analytical model that allows for behavioral change of households and abatement by firms, assuming a flat-rate own-price elasticity for electricity of -0.25. He compares grandfathered emissions permits for different pollutants with emission taxes, technology mandates and input taxes and finds that grandfathered permits are highly regressive as the scarcity rents created accrue to shareholders, who are typically high-income households and because the government has no revenue with which to alleviate the regressive effect of the tax in isolation. He finds, however, that the windfall profits to firms erode the higher the abatement (i.e. the tighter the cap or stricter the standard), because substitution away from the polluting products becomes more pronounced and the abatement by firms more costly. If an emissions tax is used or permits are auctioned and the revenue recycled proportionally, the policy looks much less regressive. If revenue is recycled in a progressive manner (as equal lump-sum transfers) the policy becomes progressive for CO<sub>2</sub> and N<sub>2</sub>O. Brännlund and Nordström (2004) incorporate the labor-leisure choice of a household in its budget constraint and estimate a demand model where a household's consumption of nondurables and labor-leisure choice are interacting. They consider a doubling of the Swedish CO<sub>2</sub> tax, where revenue is returned in form of a lower VAT or a subsidy to public transport. First, they calculate demand elasticities for motor fuel, public transport, electricity, heating and other goods and find that those are very similar across income groups. Next, they use these elasticities as an input to their simulation model, where they assume that costs are fully passed forward to consumers. They find that the reform is regressive, but point out that regional differences are more important than differences in income. Examining the distributional effects of an increase in the gasoline tax by way of a demand system using expenditure survey data, West and Williams III (2004) find that it is regressive if behavioral change is left unaccounted for. If an incidence measure is used that takes into account substitution away from gasoline, they find that the tax is much less regressive, as low-income households have a much higher demand elasticity of gasoline than high-income households. This effect is especially pronounced for large price increases. Furthermore, they find that returning the

revenue as a cut to income taxes makes the gasoline tax increase much less regressive and has the additional benefit of reducing the deadweight loss on the labor market. Lump-sum transfers, while less efficient than a reduction in the income tax, make the reform even progressive.

In their recent study of a domestic emissions trading system in Canada, Araar, Dissou and Duclos (2011) combine a general equilibrium model with stochastic dominance analysis to assess its impact on welfare and inequality under three different policy instruments: an output-based allocation of permits, revenue recycling in the form of lower payroll taxes and revenue recycling in the form of lower consumption taxes. While they find that inequality increases under all three scenarios as compared to the base case, they report rather modest effects, which are significant for the output-based allocation and reduction in payroll taxes and insignificant for the reduction in consumption taxes.

Further studies have been carried out for European countries. Baker and Köhler (1998) who study the effect of excise duties used to cut emissions by 10% in eleven EU member states, find that this policy is weakly regressive if revenues are used to reduce employers' taxes, but becomes strongly progressive if revenues are distributed lump-sum. Modeling a hypothetical CO<sub>2</sub> tax of €20/tCO<sub>2</sub> for Ireland, Callan et al. (2008) also find that the initial effect is regressive, but that households across the income distribution can be made better off, if revenues are partly passed back to them. They implement different forms of recycling the revenue, such as an increase in social security payments, an increase in the personal tax credit, or a reduction of the tax rate and note that the increase in social security payments is the most progressive of the options. In their study of the Danish CO<sub>2</sub> tax Wier et al. (2005) find that it is regressive (especially its direct component) and even more so than other Danish levies, such as the value added tax (VAT). They note the importance of family size and regional differences. Bach et al. (2001) carry out a broad-based analysis of the German environmental fiscal reform of 1999, which increased taxes on fossil fuels and electricity and in turn lowered social security contributions (SSC). As part of a larger fiscal reform, income tax and child benefits were also adjusted. Overall, they find only moderate effects. When taken in isolation, the introduction of the environmental tax is regressive, looking at the whole reform package, most households are better off than before the reform. Interestingly, there exist a number of studies for European countries (Labandeira and Labeaga 1999 for Spain; Tiezzi



2005 and Martini 2009 for Italy; Symons et al. 2002 for five European countries), which find that carbon taxes in those countries are not necessarily regressive, even before revenue is returned to households.

### 3 Data and Empirical Methodology

We obtain direct CO<sub>2</sub> emissions by production sector from the German Environmental Accounts (Statistisches Bundesamt 2010b). Combining this information with the German Input-Output Accounts (Statistisches Bundesamt 2010a), we are able to calculate the CO<sub>2</sub> intensity of each sector covered by the EU-ETS and predict the percentage price increase for all sectors following an assumed average carbon price of €25 during Phase 3 of the EU-ETS, both directly incurred by installations covered by the EU-ETS and indirectly by sectors using CO<sub>2</sub> intensive goods as an input to production.

In light of low EUA prices, the German government has revised price forecasts down to €10 per carbon permit in 2013 (Dow Jones 2012). The European Commission, however, is considering several short-term measures to strengthen the carbon price, both through proposing at set-aside for carbon permits (IETA 2012) or delaying auctions for Phase 3 permits. In particular, it is currently discussing delaying auctions of up to 1.2 billion permits. If those permits were to be removed on a permanent basis as part of a wider reform of the EU-ETS, this could see EUA prices being pushed back above €20 (Point Carbon 2012).

Both data sets reflect emissions and industry structures for the year 2007. The production sectors are then aggregated into 25 groups of consumption goods, such as electricity, food and beverages, and clothing. We calculate the emissions intensity ( $e_i$ ) of a sector by dividing total direct CO<sub>2</sub> emissions ( $E_i$ ) by the total value of production ( $Y_i$ ). Multiplying emissions intensity with the price of CO<sub>2</sub> permits ( $p_{EUA}$ ), gives us the direct percentage price increase in each sector ( $\Delta p_i^d$ ). Using the matrix of Leontief coefficients ( $C$ ) allows us to estimate the total percentage price increase in each sector ( $\Delta p_i$ ), both directly induced by the price on CO<sub>2</sub> and indirectly through price increases in sectors that provide inputs to production (Equations (1)-(3)):

$$(1) \quad e_i = \frac{E_i}{Y_i} \quad \text{Emissions intensity of sector } i$$

$$(2) \quad \Delta p_i^d = e_i \times p_{EUA} \quad \text{Direct effect of EUA price in sector } i$$

$$(3) \quad \Delta p_i = \Delta p_i^d \times C \quad \text{Total effect of EUA price in sector } i$$

Consistent with the literature, we assume perfectly elastic supply in the long-run and hence 100% cost pass-through to consumers. After translating percentage price increases in the production sectors  $i$  into price increases for consumption goods  $j$  (see below), the burden incurred by households through the introduction of a carbon price can be calculated. The burden to household  $h$  of a price increase for product  $j$  ( $B_j^h$ ) consists of the total price increase for good  $j$  ( $\Delta p_j$ ) multiplied by the initial consumption level ( $q_j^{h0}$ ) minus the reduction of consumption ( $\Delta q_j^h = q_j^{h0} - q_j^{h1}$ ) evaluated at initial prices ( $p_j^0$ ), and summed over all goods consumed by this household.

$$(4) \quad B^h = \sum_{j=1}^K \Delta p_j q_j^{h0} - \sum_{j=1}^K p_j^0 \Delta q_j^h$$

In a first step, we abstract from behavioral change ( $\Delta q_j^h = 0$ ) and estimate the “first-round” effects of the EU-ETS on German households under the assumption of a permit price of €25 by calculating the percentage increase in expenditure necessary to retain the consumption level of all 25 groups of consumption goods. Abstracting from behavioral change and expressing the burden as a share of the household’s expenditure budget ( $y^{h0}$ ) in the base period yields:

$$(5) \quad \frac{B^h}{y^{h0}} = \sum_{j=1}^K \frac{\Delta p_j}{p_j^0} s_j^{h0}$$

where  $s_j^{h0}$  are the initial budget shares the household spends on products that increase in price. Thus, the first-round distributional burden of the price increases induced by the EU-ETS as a share of household income depends on the price increase and the initial budget share spent on products that increase in price. The calculation of first-round effects takes into account both the direct effect on household expenditures incurred through a higher price for electricity and the indirect effect through consumption of products that use electricity as an input to the production process, but does not account for substitution and income effects induced by changes in the relative prices of consumption goods.

This analysis is based on the German Income and Expenditure Survey (EVS) (Statistisches Bundesamt 2011). The EVS is an administrative data source and contains detailed information on income sources and expenditure patterns of households, as well as information on other household characteristics, such as social status and age of the household members. The Survey is published every five years and households are observed one quarter reporting individual income and household level expenditures. Currently, the most recent available survey is for the year 2008.

Table I shows average household expenditures and incomes sorted by equivalent expenditure decile for the households included in the EVS. Following, e.g., Poterba (1991) and Metcalf (1999), we sort households by the level of their expenditures on nondurables which seems to be a better proxy of a household's longer-term income situation than current income. To account for differences in household composition we calculate equivalent expenditures using the new OECD equivalence scale.<sup>2</sup> Average expenditures and incomes reported in Table I are obtained by using the EVS population weighting factors adjusted by the equivalence scale.

**Table I Average monthly expenditure and income (in €) by equivalent expenditure deciles**

Equivalent expenditure decile	Average expenditure	Average net income	Average electricity expenditure
1	924	1,300	60
2	1,271	1,807	68
3	1,508	2,209	69
4	1,736	2,592	70
5	1,945	2,877	73
6	2,153	3,152	75
7	2,414	3,527	78
8	2,709	3,890	80
9	3,202	4,527	85
10	5,149	5,729	94
Average	2,287	3,139	75

Source: German Income and Expenditure Survey (EVS) 2008; own calculations.

<sup>2</sup> The new OECD scale weights the first adult by 1 every additional adult in the household by 0.5 and children by 0.3.

Since our incidence analysis refers to 2013, when the EU-ETS is due to enter its third phase, we update information on total consumption and household income as well as the consumption patterns from the EVS 2008 to 2013. For this purpose, we pool EVS data for the years 1998, 2003 and 2008 and run regressions on a number of household characteristics, and total expenditures interacted with time trends. Using estimated regression coefficients and holding household composition constant at the 2008 level we project consumptions patterns for 2013.<sup>3</sup>

In a second step, we account for behavioral change and estimate the “second-round” effects of the EU-ETS using elasticities from an empirical demand system of nondurables estimated on pooled EVS data for the years 1993, 1998, 2003 and 2008. In addition to electricity, which accounts for more than half of the emissions covered by the EU-ETS, we explicitly model the demand for mobility as we expect airlines covered by the EU-ETS since 2012 to pass on the cost of carbon to consumers, and housing, as a good closely related to electricity, and a composite of other nondurables. As in West and Williams (2004) and a couple of other related studies, we use the “Almost Ideal Demand System” of Deaton and Muellbauer (1980a) to model consumer behavior.<sup>4</sup> The budget share equations derived from the AIDS are given by

$$(6) \quad s_j^h = \alpha_j^h + \sum_k \gamma_{jk} \log p_k^h + \beta_j \log \left( \frac{y^h}{P^h} \right), \quad j, k = \text{commodities}; h = 1, \dots,$$

where  $s_j^h$  is the expenditure share of commodity group  $j$ ,  $p_j^h$  is the household specific price of commodity group  $j$ ,  $y^h$  is the household budget, and  $P^h$  is a general price index (defined in Appendix B). The constant  $\alpha_j^h$  contains an overall constant  $\alpha_j$  and a set of household characteristics (see Appendix B for details).

Because of the adding-up restriction of the demand system implied by the household’s budget constraint, only three of the four share equations have to be estimated. The specification and estimation of this system of three equations on the

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<sup>3</sup> We also considered updating the industry-level data set to 2013. However, assumptions on the development of emissions and economic activity for all 72 sectors included in the German Input-Output Tables would have been necessary. As these two variables might well decouple to some extent during the next years, using 2007 data seemed to be favorable for consistency reasons.

<sup>4</sup> We have also estimated the QUAIDS (“Quadratic Almost Ideal Demand System”) suggested by Banks et al. (1997) which includes a quadratic term for total household expenditure. Since demand elasticities estimated from the QUAIDS differ little from the AIDS estimate, we only report the latter below. Estimation results for the QUAIDS are available from the authors upon request.

basis of pooled data from EVS surveys 1993, 1998, 2003 and 2008 are described in Appendix B.

Using the estimated parameters from the AIDS and the consumption patterns from the EVS 2008 as well as price and income information updated to 2013 we can simulate the change in household consumption induced by the changes in the prices for various consumer products due to the EU-ETS. This behavioral change is the second-round effect which we deduct from the first-round effect to get an overall measure of the incidence of the EU-ETS, i.e. its overall effect on the distribution of household incomes.

## 4 Results

### 4.1 Price Effects

Figure 1 shows percentage price increases for the 25 consumption groups. With an increase of 14% the effect is most pronounced for household consumption of electricity,<sup>5</sup> followed by the air travel sector, which is also expected to pass on the costs of compliance to consumers. To put this results into perspective, it should be noted that in 2007 already 20% of the electricity price consisted of environmental taxes, and a further 16% of the value added tax (VdEW Baden-Württemberg 2007). For all other sectors the price increase following the EU-ETS is in the range of inflation.<sup>6</sup>

There are two reasons for us to focus on price increases in the electricity sector, both directly in the form of higher electricity bills for consumers and indirectly through a whole range of products that use electricity as an input to production. First, the electricity sector is responsible for 65% of emissions under the EU-ETS. It is the only sector, which has to buy 100% of the permits from 2013 onwards. Other sectors, such as iron, steel, cement, lime and glass, are still granted free allocation on the basis that they might be susceptible to international competition and are not expected

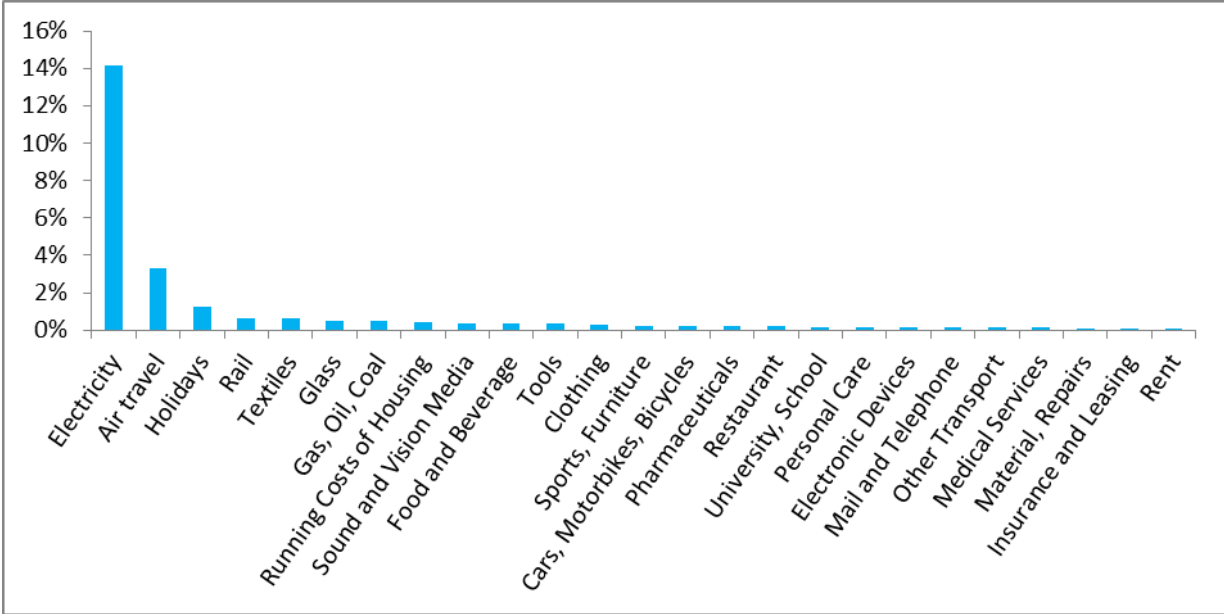
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<sup>5</sup> The price increase might in fact be even more pronounced as electricity prices are determined according to marginal plant (Matthes 2008), which, in Germany, is an emissions-intensive, coal-fired power plant. At the same time, the EU-ETS is expected to induce a shift away from emissions-intensive fuels, which might counteract this effect.

<sup>6</sup> A household's use of motor fuels and gas and oil for heating purposes are not covered by the EU-ETS but subject to alternative measures in the EU.

to be able to pass-through the full cost of carbon (European Commission 2010a).<sup>7</sup> A sensitivity analysis of this assumption is presented in Appendix A under the assumption that all sectors are able to pass on the cost of carbon to consumers.

**Figure 1 Percentage price increase for 25 groups of consumption goods**



**4.2 First-Round Effects**

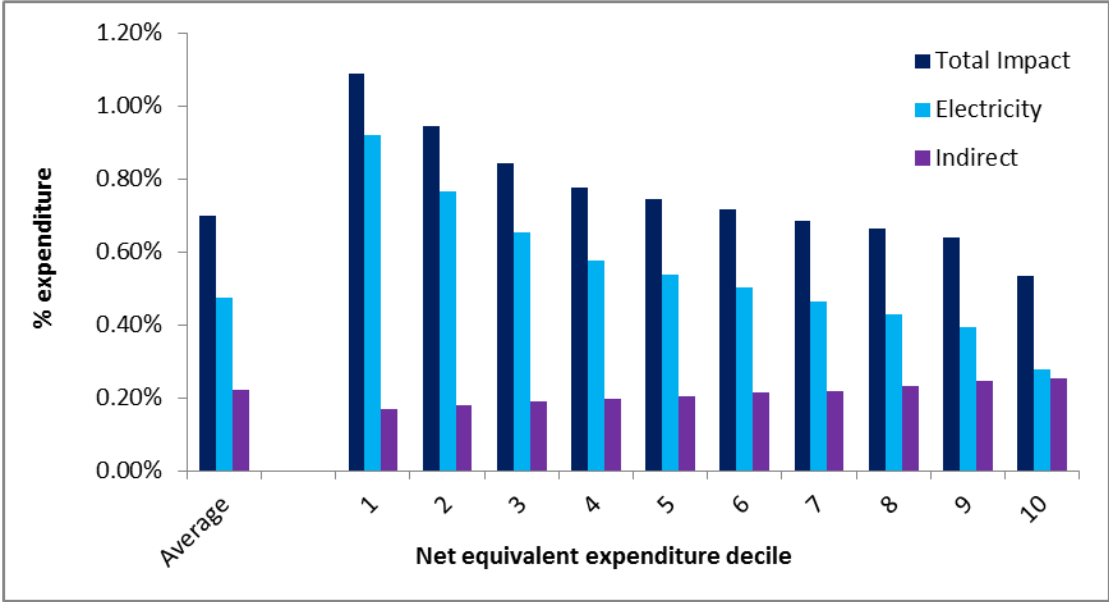
Figure 2 shows first-round effects, divided into the direct effect of the increase in the price of electricity and the indirect effect on other goods.<sup>8</sup> Without accounting for the adjustment of household budgets induced by the change in relative prices, estimated real total consumption expenditures on nondurables of private households would be reduced by about by about €6.3 billion. As can also be seen from Table II, the total impact of the EU-ETS on German households is clearly regressive. This result is driven by the regressive effect of direct electricity consumption, while the indirect effect is distributed progressively, a result that has previously been noted in the literature (Bull and Hassett, 1994; Casler and Rafiqui, 1993; Hassett, Mathur and

<sup>7</sup> This assumption is also consistent with the assumed revenue-neutrality of the policy: The full burden incurred by households induced by price increases due to the EU-ETS is recycled back to them. Otherwise one would have to infer how households were compensated for the burden imposed on them over and above the amount of revenue recycled.

<sup>8</sup> Note that the effect of air travel has been included in the “electricity” effect, as it also represents a direct effect and is too small in magnitude to display separately. Also note that we only consider consumption of nondurables here so that the effect of the price increase will be less than revenues from the EU-ETS which are expected to amount to €7.5 billion.

Metcalf, 2009). Affecting less than 1.1% of household expenditure for all deciles, the overall effect is fairly moderate.

**Figure 2 First-round effects of the EU-ETS on German households, as % of household expenditure**

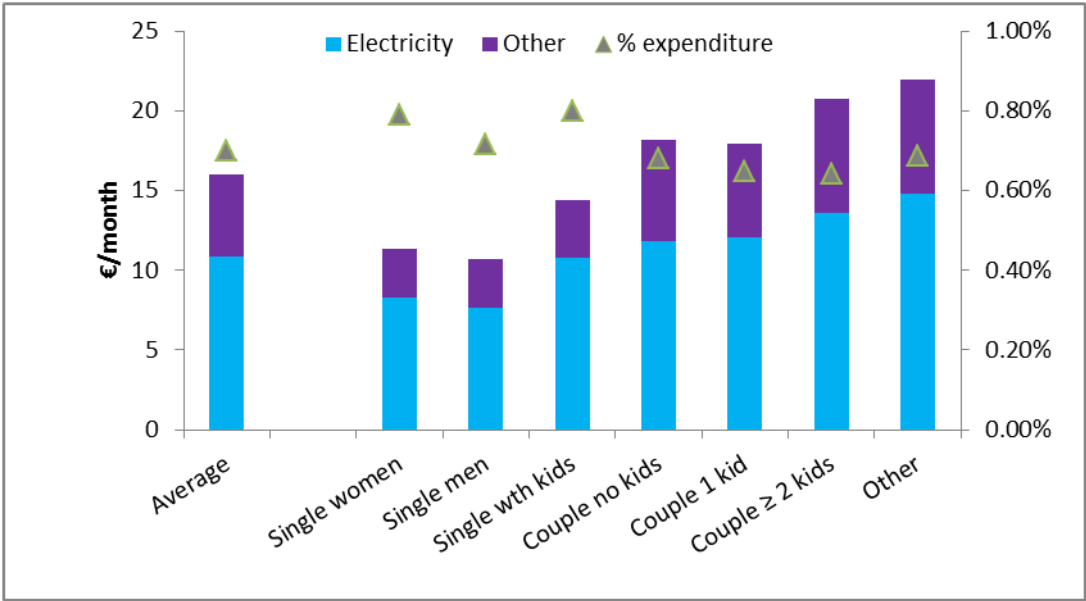


**Table II First-round effects of the EU-ETS on German households, as % of household expenditure**

Net equivalent expenditure decile	Total Impact	Electricity	Indirect
1	1.09%	0.92%	0.17%
2	0.95%	0.77%	0.18%
3	0.84%	0.65%	0.19%
4	0.78%	0.58%	0.20%
5	0.74%	0.54%	0.21%
6	0.72%	0.50%	0.21%
7	0.68%	0.46%	0.22%
8	0.66%	0.43%	0.23%
9	0.64%	0.39%	0.25%
10	0.53%	0.28%	0.25%
Average	0.70%	0.48%	0.22%

Figure 3 further illustrates this result by calculating impacts in monetary terms for different household types. On average, German households face additional costs of €16/month. Looking at the share of expenditure affected, we see that the effect is roughly proportional for all household types, although somewhat larger for single women and singles with kids.

**Figure 3 Monetary impact of EU-ETS on selected household types**



This analysis of first-round effects implicitly assumes price elasticities of zero for all consumption goods affected, it is best suited for a short-run view and small price changes and can serve as an upper bound to the estimation of the impact. In the next section we check to what extent our conclusions change if we allow for adjustments of household consumption to price increases of consumer goods, We confirm that results on regressivity hold even after accounting for behavioral change by calculating a demand system (below).

**4.3 Second-Round Effects**

As described in Section 3, we account for behavioral response of consumers to price changes induced by the EU-ETS (“second-round” effects) using estimated price and budget elasticities. The derivation of these elasticities from the estimated AIDS is described in Appendix C. In the first panel of Table III compensated price elasticities for the four commodity groups listed at the top of the table are reported, while the



second panel contains uncompensated price elasticities, and the bottom row shows the budget elasticities for the four commodity groups.

**Table III Estimated Demand Elasticities**

	Electricity	Mobility	Housing	Composite good
	<b>Compensated Price Elasticities</b>			
Electricity price	-0.65 [-0.75; -0.55]	-0.02 [-0.05; 0.01]	-0.02 [-0.03; -0.01]	0.05
Mobility price	-0.04 [-0.10; 0.03]	-0.53 [-0.59; -0.48]	-0.17 [-0.19; -0.16]	0.18
Housing price	-0.21 [-0.34; -0.08]	-0.89 [-0.98; -0.80]	-0.65 [-0.71; -0.59]	0.53
Composite good price	0.90 [0.75; 1.05]	1.44 [1.34; 1.54]	0.84 [0.78; 0.90]	-0.76
	<b>Uncompensated Price Elasticities</b>			
Electricity price	-0.67 [-0.77; -0.57]	-0.05 [-0.08; -0.02]	-0.04 [-0.06; -0.03]	0.01
Mobility price	-0.07 [-0.13; -0.00]	-0.61 [-0.66; -0.55]	-0.22 [-0.24; -0.20]	0.09
Housing price	-0.37 [-0.50; -0.24]	-1.27 [-1.36; -1.17]	-0.88 [-0.94; -0.82]	0.10
Composite good price	0.65 [0.50; 0.79]	0.84 [0.74; 0.93]	0.46 [0.40; 0.52]	-1.43
	<b>Budget Elasticities</b>			
	0.46 [0.44; 0.48]	1.09 [1.07; 1.11]	0.68 [0.67; 0.69]	1.22

Note: 95%-confidence bands are given in parenthesis below point estimates of elasticities. Standard errors are calculated using the delta method. For the composite good no s.e. of elasticities can be calculated, as they are derived from the adding-up condition.

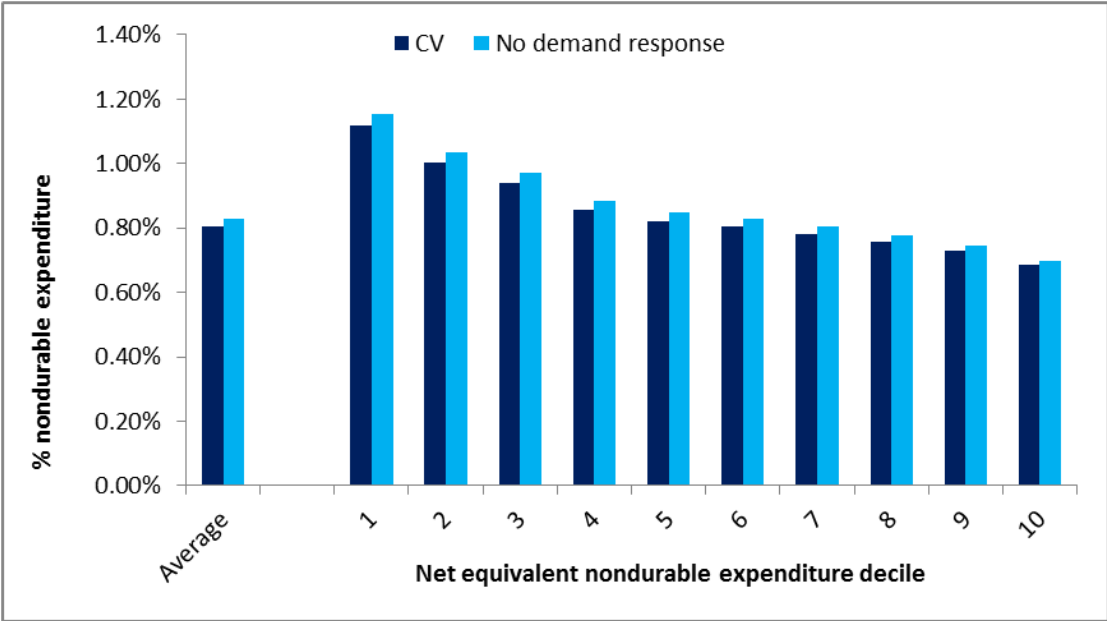
With the exception of the own price effect for housing, all estimated price effects are smaller than one in absolute value and significantly different from zero (see Table 2A in Appendix B for estimation results). Estimated budget elasticities imply that electricity and housing are inferior goods, while expenditures on mobility and the composite durables good are luxury goods. Due to the relatively small budget shares of electricity and mobility, the compensated and uncompensated own-price elasticities of these goods differ little. In contrast, because of the relatively large budget

elasticity and its large budget share, the estimated compensated price elasticity of the composite good is only about half of the uncompensated elasticity. As the estimated cross-price elasticities reported in Table III show, mobility and housing are complements to electricity, while the composite good is a substitute for electricity with relatively large elasticities. This holds for both compensated and uncompensated cross-price elasticities.

Using the uncompensated price elasticities in Table III, we can calculate the second-round effects of the EU-ETS on household incomes. Taking into account second-round effects, consumption expenditures would be reduced to about €5.9 billion, a reduction of about 6 percent as compared to the first-round effect.

Another way to account for second-round effects is to calculate compensating variations as a welfare measure of a tax change and compare this to the first-round tax burden. Using the estimated compensated price elasticities in Table III and information on observed prices and quantities, the compensating variation for each household can be calculated as described in Appendix C. Assuming that each household is given the same welfare weight, a welfare measure can be obtained by simply summing the compensating variations over all households. The sum of compensating variations is €6.12 billion which yields a deadweight loss of the EU-ETS of €0.22 billion or 3.7%.<sup>9</sup>

**Figure 4 Welfare effects, as percentage of nondurable consumption**



<sup>9</sup> Of course, accounting for the reduction of external costs (emissions), which is the aim of the EU-ETS, this deadweight loss would most likely be turned into a welfare gain.

In addition to average effects, Figure 4 shows welfare effects relative to nondurable consumption by expenditure decile. The effects measured by compensating variations do not differ substantially from the ones estimated without accounting for demand responses. The average tax burden of the EU-ETS is only reduced by 2.7% due to substitution effects, and the effect clearly remains regressive when adjustments in households' budget shares are taken into account.

As the second-round effects of the analyzed policy change differ little from the simpler analysis of first-round effects, we will conduct our analysis of the impact of revenue recycling on the basis of the first-round effects.

### **4.3 Role of Revenue Recycling**

In this section, we analyze the effects of the EU-ETS on household welfare if the revenue obtained by the German government through the auctioning of emissions allowances is returned to households via lump-sum rebates and, alternatively, as a reduction in social security contributions (SSC). At a carbon price of €25, the estimated yearly revenue is €7.5 billion, equivalent to the amount of permits the electricity sector requires times a carbon price of €25. With this amount the social security contributions rate could be reduced by 0.8 percentage points or provide a lump-sum transfer of €94 per person in the household.<sup>10</sup> As a point of comparison, as a result of the environmental fiscal reform, the German government generated revenues of roughly €17 billion per year (€9 billion from households directly and another €8 billion from industry) and was able to reduce SSC by 1.6 percentage points (Deutscher Bundestag 1999).

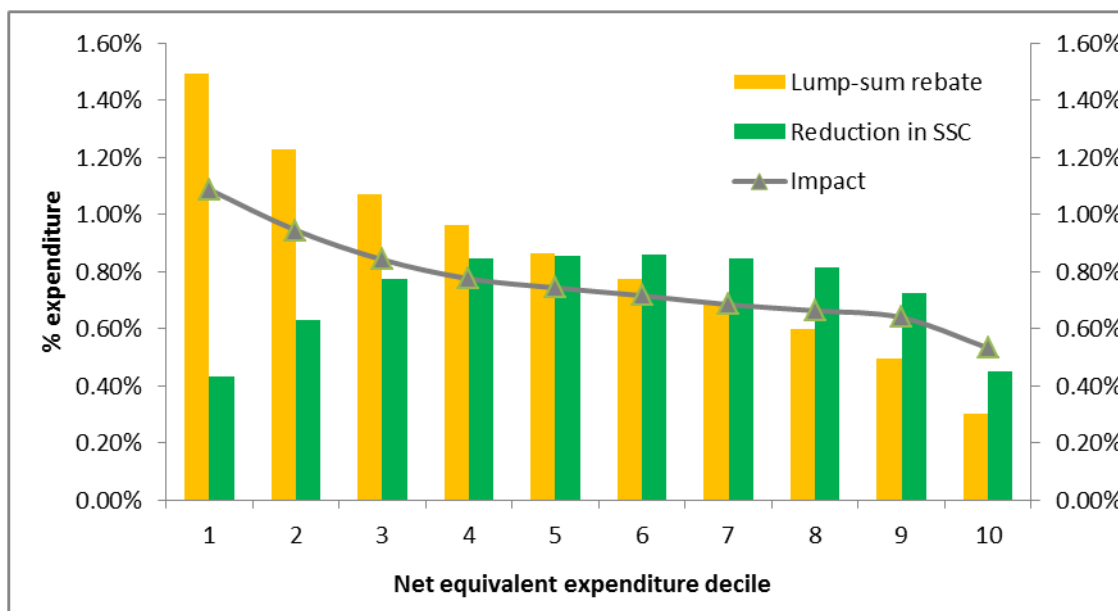
Figure 5 shows the impact the EU-ETS has on German households if all of the revenue is recycled back (i) as lump-sum rebates (ii) as a cut in the rate of social security contributions. Both measures reduce the impact of the reform on German households significantly, but while the lump-sum rebate makes the EU-ETS progressive, a reduction in social security contributions retains the regressivity of the policy. Table IV shows the impacts as a percentage of household expenditure along the equivalent expenditure deciles. In case revenues are fed back as lump-sum

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<sup>10</sup> The case for targeted revenue recycling schemes rather than revenues being absorbed by the general budget can be made on the basis that it is likely to increase public support for the policy in question (see, for example, Kallbekken, Kroll and Cherry, 2011, who derive this result in their experiments).

rebates, lower income deciles gain from the EU-ETS, while for a reduction in social security contributions high income deciles gain.

**Figure 5 Impact of the EU-ETS and revenue recycling as percent of household expenditure**



**Table IV Impact of the EU-ETS after revenue recycling**

Net equivalent expenditure decile	Net impact after lump- sum rebate	Net impact after reduction in SSC	Gross impact
1	-0.41%	0.65%	1.09%
2	-0.28%	0.31%	0.95%
3	-0.23%	0.07%	0.84%
4	-0.19%	-0.07%	0.78%
5	-0.12%	-0.11%	0.74%
6	-0.06%	-0.14%	0.72%
7	-0.01%	-0.16%	0.68%
8	0.06%	-0.15%	0.66%
9	0.14%	-0.09%	0.64%
10	0.23%	0.08%	0.53%

This result hinges on the fact that social security contributions are deducted from work income. Therefore, a reduction in the rate of social security contributions does not benefit those households that do not have employment income. These

households are usually located in the lower deciles of the income distribution. At the same time, an upper threshold for social security payments exists, which implies that the impact is relatively smaller for those households earning more than this threshold, typically in the high income deciles. Finally, the self-employed do not contribute to the social security system and hence do not benefit from a reduction of contributions.

Table V displays inequality measures before the EU-ETS, for the gross impact without revenue recycling, and for the net impacts after a lump-sum rebate and a reduction in social security contributions respectively. Inequality is highest in the cases of no revenue recycling and can be reduced by both forms of revenue recycling. After recycling as lump-sum rebates, inequality is even reduced compared to the status quo. However, the changes are very small and not statistically significant.

**Table V      Inequality measures for the impact of the EU-ETS with revenue recycling (using equivalent weights)**

	Status quo (before EU-ETS)	Gross impact (no Revenue Recycling)	Net impact after lump-sum rebate	Net impact after SSC reduction
Gini	0.2612	0.2620	0.2602	0.2617
Theil	0.1233	0.1241	0.1224	0.1235
GE(1)	0.1134	0.1142	0.1123	0.1142
GE(2)	0.1628	0.1639	0.1616	0.1627

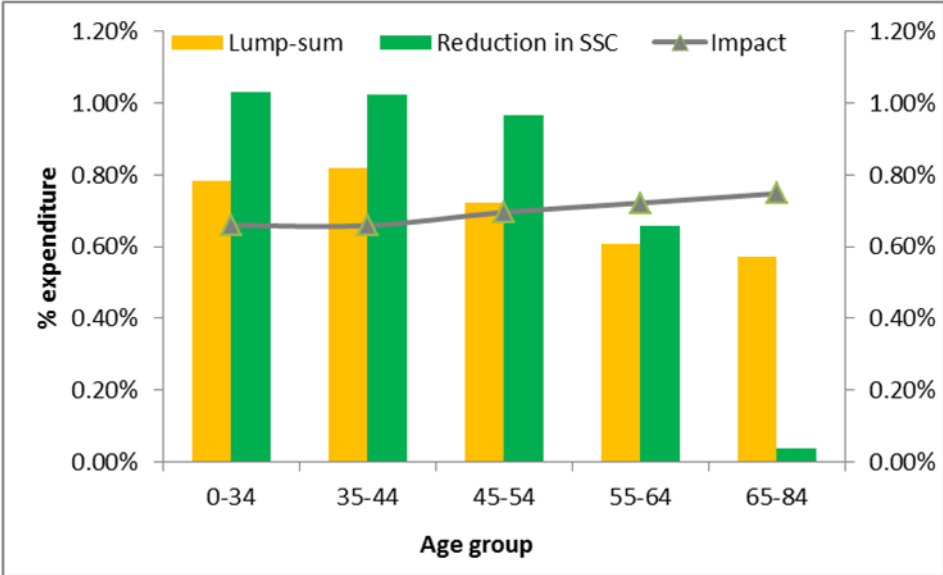
Although the recycling of revenue in the form of a reduced rate of social security contributions does not seem to alleviate the regressive nature of the EU-ETS as much as lump-sum rebates do, this form of revenue recycling may have the additional benefit of reducing existing distortions elsewhere in the taxation system. This trade-off between efficiency and equity considerations has previously been noted in the literature (Williams and Parry, 2010).<sup>11</sup>

Other dimensions exist, along which distributional effects of a policy can be assessed. As Figure 6 shows, older people in Germany are particularly impacted by the EU-ETS. They spend a relatively large share of their expenditure on goods affected by price increases through the EU-ETS and do not gain as much from

<sup>11</sup> On a different note, MacKenzie and Ohndorf (2012) suggest that that even if distortions in the taxation system are reduced through revenue recycling, costly rent-seeking behavior under instruments that generate revenues may outweigh this positive effect.

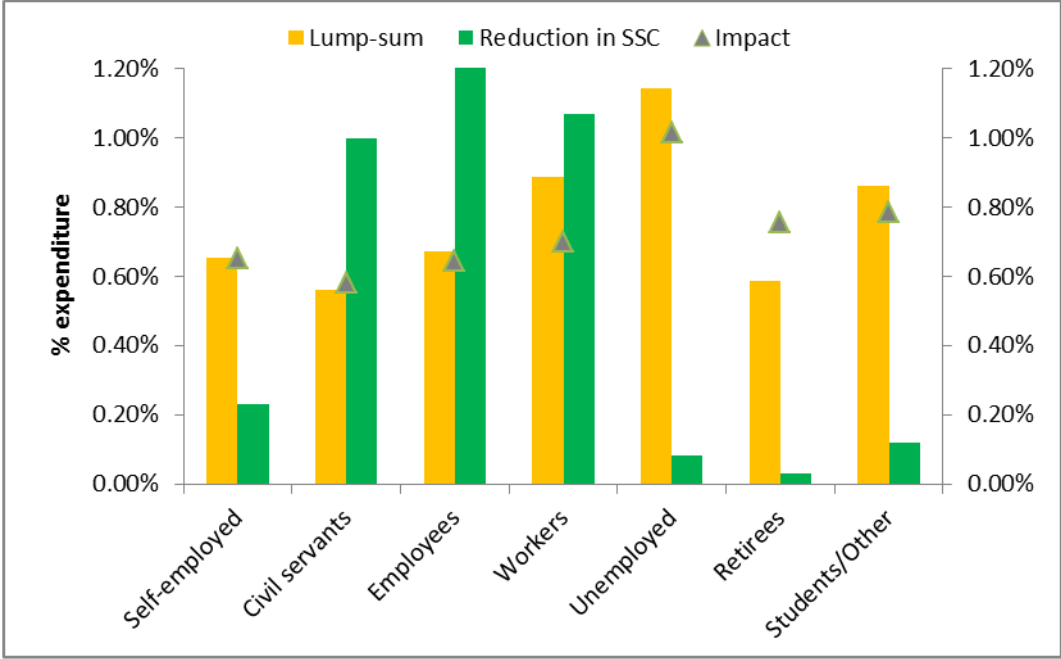
rebates. Especially if revenues are distributed as reductions to social security contributions, one can see the “pensioner effect,” i.e. as 65 is the official retirement age in Germany, most of those people do no longer contribute to the social security system and hence to do not benefit from the rate reduction. However, Parry et al. (2005) also note that indexed transfer payments, such as social security benefits, will adjust if the price of consumption goods increases as a reaction to emissions trading, however, further research is needed in order to assess if this compensates for a substantial amount of the price increase.

**Figure 6 Impact of the EU-ETS and revenue recycling on different age groups, as % of household expenditure**



Finally, looking at the impact the EU-ETS has on people of different social status, Figure 7 shows that a reduction in social security contributions favours civil servants, employees, and workers. If revenues are returned in a lump-sum fashion nearly all groups are, on average, compensated for the impact caused by higher prices, except for the retirees, who again, seem to be particularly disadvantaged.

**Figure 7 Impact of the EU-ETS and revenue recycling on people of different social status, as % of household expenditure**



**5 Conclusion**

The potentially adverse distributional effects of pollution control policies in general and the European Union Emissions Trading System (EU-ETS) in particular have received increasing attention during the past years. The ability to address those concerns will be material in shaping climate policy in the long-run.

We confirm the ex-ante expected regressive effect the EU-ETS has on households. This result holds also if behavioral change on the household part is considered. However, the initial regressive effect is both rather small in magnitude and can be offset and even more than offset by revenue recycling. This result puts into perspective concerns about adverse distributional effects of the EU-ETS and should be taken into account when assessing the different options for revenue recycling of auctioning revenues from the EU-ETS.

In December 2010 the German government passed a law setting up a new Energy and Climate Fund (Deutscher Bundestag 2010), which will receive most of the proceeds generated through the EU-ETS auctions and will be used to finance national energy efficiency and renewable energy projects and international climate protection measures in accordance with the German Energy Concept (BMWI and

BMU, 2010). In contrast to proposals for other countries (see, e.g., Metcalf, Marthur and Hassett 2010 for the U.S., and Hatfield-Dodds et al. 2011 for Australia), the German government has not formulated plans to use EU-ETS revenues to compensate low-income households. Using the revenue for clean energy and climate protection measures, as is envisaged by the German government, does not directly impact the income of households. Whether the benefits of such a policy accrue to low- and high-income households alike is a point of disagreement (see Fullerton, 2008, for an overview of the possible effects).<sup>12</sup> However, if those spending programs were targeted directly at low income households, e.g. via energy efficiency schemes, the initial regressive effect could also be offset. While using the auctioning revenue to fund climate protection measures seems reasonable, some of the revenue could indeed be used to offset adverse distributional effects and to improve the efficiency of the taxation system, thereby not only reaping additional benefits, but also making the policy more attractive to the public as a whole.

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<sup>12</sup> Furthermore, as Cremer, Gahvari and Ladoux (2003) point out, in order to fully assess implications of a more specific plan to recycle revenue for the income distribution among households, it is crucial to take account of the pre-existing distortions in the taxation system.



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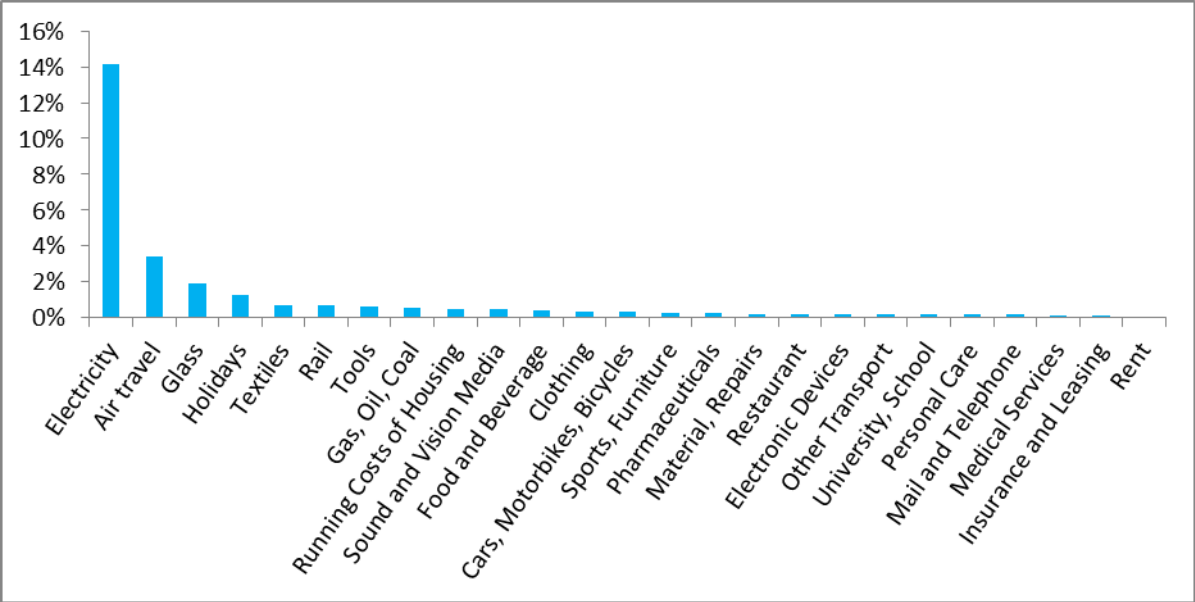
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**Appendix A: Sensitivity Analysis**

For this sensitivity analysis, we assume that all sectors covered by the EU-ETS pass the full cost of carbon forward to consumers (and not just electricity and aviation sectors). The literature, in accordance with economic theory, assumes that the allocation methodology is indeed irrelevant for the rate of cost pass-through. Even if emissions permits are given out for free, they represent assets that could be sold if they would not have to be held to cover an installation’s emissions. A firm is expected to add the opportunity cost of the forgone alternative use (i.e. selling of permits) to its production costs (Sijm, Neuhoff and Chen, 2006).

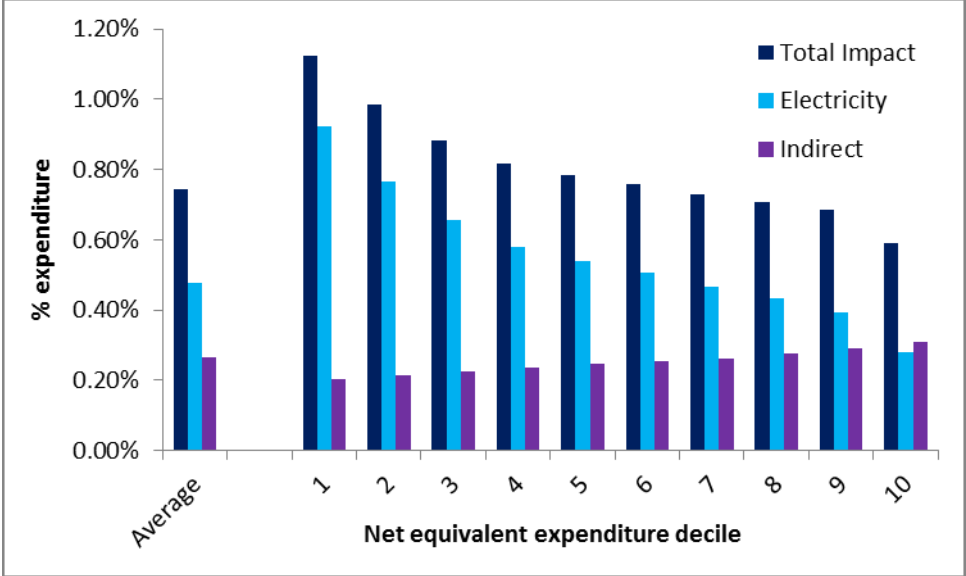
**Figure A1 Sensitivity analysis of price increase in 25 consumer goods (assumption: all ETS sectors pass costs forward to consumers)**



As Figure A1 shows, the price increase for electricity is still by far the largest, also in this sensitivity scenario. Therefore, conclusions regarding the impact of the EU-ETS on consumers remain very similar to the above analysis. As Figure A2 and Table A1 show the overall effect is now larger, while the regressive nature of the total effect and the progressive nature of the indirect effect remain. However, in this setting, where only part of the burden imposed on households is obtained by the government in the form of auctioning revenue, companies are expected to generate considerable windfall profits. Parry (2004) who approximates the impact of those windfall profits on the income distribution by looking at share holdings across income deciles,

concludes that in such a setting emissions permits that are given out for free are especially regressive.

**Figure A2 Sensitivity analysis of initial impact of EU-ETS as % of expenditure (assumption: all EU-ETS sectors pass costs forward to consumers)**



**Table A1 Sensitivity analysis of initial impact of EU-ETS as % of expenditure (assumption: all ETS sectors pass costs forward to consumers)**

Net equivalent expenditure decile	Total Impact	Electricity	Indirect
1	1.12%	0.92%	0.20%
2	0.98%	0.77%	0.22%
3	0.88%	0.65%	0.23%
4	0.82%	0.58%	0.24%
5	0.79%	0.54%	0.25%
6	0.76%	0.50%	0.25%
7	0.73%	0.47%	0.26%
8	0.71%	0.43%	0.28%
9	0.69%	0.39%	0.29%
10	0.59%	0.28%	0.31%
Average	0.75%	0.48%	0.27%

## Appendix B: Estimation of the AIDS

The estimation of the AIDS is complicated by the last term in equation (6) which is a nonlinear function of the prices for the various commodity groups. A convenient approximation is to use a simple approximation of this general price index, as suggested by Deaton and Muellbauer (1980a, p. 316), given by

$$(A1) \quad \log P^h \cong \sum_j s_j^h \log \left( \frac{p_j^h}{\bar{p}_j} \right),$$

where  $\bar{p}_j$  is the average price over all households to normalize the expression, and the other variables are defined as in the text below equation (6). Since  $s_j^h$  is endogenous in Equation (A1), we use the sample mean shares instead.

Inserting the price index of equation A1 into equation (6), the system of three share equations (leaving out the one for the composite good), is linear in the model parameters. Adding error terms to the three share equations to account for optimization error of households, estimation can be based on linear regression, with the following restrictions imposed:

$$(A2) \quad \sum_j \alpha_j = 1 \quad (A3) \quad \sum_j \gamma_{jk} = 0 \quad (A4) \quad \sum_j \beta_j = 0 \quad (A5) \quad \sum_k \gamma_{jk} = 0 \quad (A6) \quad \gamma_{jk} = \gamma_{kj}$$

where (A2) to (A4) are implied by the adding-up condition, (A5) implies homogeneity in prices, and (A6) the Slutsky symmetry condition. The adding-up condition implies that only  $n-1$  out of  $n$  equations can be estimated, while the parameters of the equation left out in the estimation can be derived from this condition.

The system of consumer demands, with the demand for the composite good derived from the adding-up condition, is estimated on pooled data from EVS surveys 1993, 1998, 2003 and 2008<sup>13</sup>. Administrative time-series price data from the Federal Statistical Office are merged to the micro data. To increase the price variation, the prices are weighted sums of the subgroup prices and shares. This approach was proposed by Lewbel (1989) and assumes Cobb-Douglas preferences within each commodity group. For the commodity group “housing”, we can exploit additional price variation between federal states in 2008 (not available for the earlier years). In the estimation we restrict the sample to households with positive expenditures in all

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<sup>13</sup> Note that the EVS 1993 is similarly defined as the other waves with the major difference that it reports yearly observations in contrast to quarterly ones in the other years. This is no problem here because we only model nondurable consumption which should be equally distributed over the year. We can control for quarterly differences that appear in the quarterly reported observations in the estimation.

categories resulting in 37,510 observations from the four waves. To account for heterogeneity among households, we control for age, gender, the level of education, and nationality, as well as for regional and time effects. Estimation results are reported in Table A2.

**Table A2 Estimation results for the AIDS system**

Dependent variables in shares of total budget:			
	Electricity	Mobility	Housing
	b/se	b/se	b/se
log(electricity price)	0.0105*** (0.0017)	-0.0034*** (0.0011)	-0.0187*** (0.0022)
log(mobility price)	-0.0034*** (0.0011)	0.0271*** (0.0019)	-0.0837*** (0.0031)
log(housing price)	-0.0187*** (0.0022)	-0.0837*** (0.0031)	0.0029 (0.0106)
log(other prices)	0.0117*** (0.0025)	0.0601*** (0.0034)	0.0996*** (0.0107)
log(budget)	-0.0181*** (0.0003)	0.0061*** (0.0007)	-0.1108*** (0.0015)
age	0.0006*** (0.0000)	-0.0017*** (0.0001)	0.0035*** (0.0002)
age squared	-0.0000*** (0.0000)	0.0000*** (0.0000)	-0.0000*** (0.0000)
German	0.0013 (0.0011)	-0.0007 (0.0025)	0.0025 (0.0049)
female	-0.0009*** (0.0002)	-0.0128*** (0.0006)	0.0075*** (0.0011)
medium education	0.0025*** (0.0003)	-0.0066*** (0.0006)	0.0006 (0.0012)
low education	0.0033*** (0.0005)	-0.0131*** (0.0011)	-0.0115*** (0.0022)
East Germany	-0.0046*** (0.0010)	0.0050** (0.0024)	-0.0379*** (0.0047)
medium agglomeration	0.0018*** (0.0004)	0.0007 (0.0010)	0.0079*** (0.0020)
low agglomeration	0.0067*** (0.0005)	0.0024* (0.0013)	0.0062** (0.0025)
constant	0.1325*** (0.0027)	0.1160*** (0.0063)	1.0035*** (0.0124)
$R^2$	0.13	0.16	0.22
Observations	37510		

**Source:** Own calculations using the EVS data (1993, 1998, 2003 and 2008), scientific-use-files provided by the Federal Statistical Office. Significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

## Appendix C: Elasticities and Compensating Variations

Given the estimated parameters from the demand system in Equation (A1), compensated and uncompensated price elasticities and budget elasticities can be derived from the system of share equations specified in (A1).

The compensated elasticity for good  $j$  with respect to a change in price  $k$  is given by

$$(A7) \quad \varepsilon_{jk}^c = -d_{jk} + \frac{\gamma_{jk}}{s_j} + s_k ,$$

where  $d_{jk}$  is the Kronecker delta, defined as 1 if  $j = k$  and 0 otherwise.

Uncompensated price elasticities are given by

$$(A8) \quad \varepsilon_{jk}^{uc} = -d_{jk} + \frac{\gamma_{jk}}{s_j} + \frac{\beta_j s_k}{s_j} ,$$

and budget elasticities by

$$(A9) \quad \eta_j = -1 + \frac{\beta_j}{s_j} .$$

Using estimated compensated price elasticities, compensating variations as a measure of the welfare loss of the price increase can be computed as:

$$(A10) \quad CV = e(p^1, u^0) - e(p^0, u^0) ,$$

where  $e(p, u)$  denotes the expenditure function, and

$$(A11) \quad e(p^0, u^0) = y .$$

A second-order approximation of the expenditure function evaluated at new prices and base period utility yields (see Deaton and Muellbauer, 1980b, p.174):

$$(A12) \quad e(p^1, u^0) \approx e(p^0, u^0) + \sum_j \frac{\partial e(p^0, u^0)}{\partial p_j^0} (p_j^1 - p_j^0) + \frac{1}{2} \sum_j \sum_k \frac{\partial^2 e(p^0, u^0)}{\partial p_j^0 \partial p_k^0} (p_j^1 - p_j^0)(p_k^1 - p_k^0) .$$

Rearranging this equation and plugging it into (A11) yields:

$$(A13) \quad CV \approx \sum_j p_j^0 q_j^0 \left( \frac{p_j^1 - p_j^0}{p_j^0} \right) + \frac{1}{2} \sum_j \sum_k p_j^0 q_j^0 \varepsilon_{jk}^c \left( \frac{p_j^1 - p_j^0}{p_j^0} \right) \left( \frac{p_k^1 - p_k^0}{p_k^0} \right) .$$

The first term represents the sum of initial expenditures on goods multiplied by the respective percentage price change, the second term is the second-order approximation of the compensated substitution effects. Thus the CV as a measure of welfare loss should be smaller than the tax burden neglecting the substitution effect of price increases.