Distributional effects of carbon pricing when considering household heterogeneity: An EASI application for Austria*

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Abstract

This paper studies the distributional impacts of a carbon tax in Austria and explores compensating measures to mitigate negative side effects. We extend previous studies by focussing on household heterogeneity, i.e. how housing attributes and socio-demographics govern a household's vulnerability to energy price increases. We apply the EASI demand system, which captures non-linear Engel curves and heterogeneous preferences; both crucial to estimate energy consumption. By simulating stylized, separate price increases we identify how seemingly overall similar welfare effects differ, depending on the energy good taxed, the region a household lives in, year of construction and household composition. These impact channels, with the severity of impacts differing according to various household characteristics are also reflected by the carbon tax scenario and reveal the importance of targeted support schemes. Although, each of the tested transfer schemes is able to enhance equality and cushion negative welfare effects, transfer schemes focussing on household size or on particular vulnerable population segments show the strongest effects in terms of equality, proportionality of the tax burden and welfare. Consequently, in order to yield a socially fair energy or carbon tax regime, taking household heterogeneity into account is essential.

Keywords: demand system, energy consumption, carbon taxation

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1 Introduction

The Austrian government aims to become climate-neutral by 2040 (Österreich Bundeskanzleramt (2020)). A core lever in meeting this ambitious target is the restructuring of the current tax system, based on ecological components. Although carbon taxes have the advantages of an easy implementation, low administrative costs and the ability to create incentives for emission reduction, they are among the least used climate policy instruments (Carattini et al. (2018); Barrage (2020)). The reason for this low penetration is due to the fact, that carbon pricing has a potentially distortionary and regressive character (Kirchner et al. (2019); Reaños and Wölfing (2018); Renner et al. (2018)). In order to ensure political feasibility as well as social acceptability, policy makers have to consider the following criteria when designing energy and carbon taxes (Andersson (2019); Klenert et al. (2017)): they should be effective and at the same time socially fair. Numerous studies underscore the necessity of compensating measures to mitigate negative effects (Renner et al. (2018); Reaños and Wölfing (2018); Beck et al. (2015)); however, these studies do not take household heterogeneity, in other words housing attributes and social-demographics, into account and thus ignore the large variety of a household's vulnerability towards carbon taxation. Consequently, they draw mainly on lump-sum transfers or flat transfer as a support scheme instead of target based policy action capturing the multifaceted nature of vulnerability.

In order to shed light on the role of household heterogeneity and how it steers a household's vulnerability, we investigate the distributional effects of carbon taxation in Austria at a high level of resolution. We choose Austria as a case study region, since it is a wealthy, industrialised EU member state, with ambitious climate targets and its intention to implement a green tax reform including carbon pricing by 2022. In line with the literature we use microsimulation based on household expenditure and consumption data to investigate the distributive impacts of energy price increase. The carbon tax scenario leads to price increases in the three main energy sources (motor fuels, electricity and heating) and the impacts thereof on household energy consumption, equality and welfare are studied. Methodologically. we employ the Exact Affine Stone Index (EASI) demand system enabling us to include socio-economics and socio-demographics of households. By doing so, we show how household characteristics influence a household's vulnerability towards carbon pricing and how these impacts differ across the examined energy goods. Moreover these results inform the development of target based governmental transfers, which are able to consider the revealed types of vulnerability. The evaluation draws on various measures, in other words the compensating variation, Gini-index and Suit-index, in order to cover a broad spectrum of inequality and welfare.

Most studies analysing distributional effects of energy price increases focus on specific parts of household energy consumption: either fuels (ex.: Berry (2018) and Tiezzi (2005)) or electricity & heating (ex.: Kirchner et al. (2019) and Reaños and Wölfing (2018)). Only a few exceptions (Renner et al. (2018), Renner et al. (2019)) cover all spheres of households energy consumption, but focus on developing countries. Carbon pricing targets all spheres of energy consumption, in other words motor fuel, different types of heating fuels and electricity, while distributional impacts will differ between these goods. Pertinent studies highlight that in industrialised countries, a price increase in motor fuels mainly affects middle-income class households (Tiezzi (2005); Berry (2018)), while a price increase in electricity and heating affects poor households the most and shows a high regressive nature (Kirchner et al. (2019); Reaños and Wölfing (2018)). Consequently in order to understand the effects of a carbon tax, a separate investigation of price increases for each of the energy goods identifying the main and maybe diametral impact channels, is a prerequisite.

Studies analysing energy or carbon price increase find regressive behaviour with a noteworthy difference between the more affluent and the extremly poor (Reaños and Wölfing (2018), Renner et al. (2018)), but do not analyse in more depth the nature of effects such as region, household characteristics or housing attributes. For the example of an increase in food prices, Moro and Sckokai (2000) have already highlighted that household characteristics significantly influence welfare effects and that the inclusion of different household types reveals additional, interesting results. Still, household heterogeneity is barely taken into account for when studying energy price increases. This lack in heterogeneity consideration is also visible in the discussion of support schemes and compensating measures to offset regressive effects. Berry (2018) highlights this shortcoming by focussing on the extremely poor and concludes that governmental transfers based on criteria other than income are cost-effective and reduce fuel poverty. Carl and Fedor (2016) state that 36 % (10.1 billion US dollar) of worldwide carbon tax revenues earned go back to corporates or taxpayers in the form of tax cuts or direct transfers. They argue that from a distributional perspective a flat cash transfer does not compensate all household types in a fair way. Naturally, the impacts of carbon pricing differ between households due to their carbon dependency. In particular, short term switching costs towards cheaper renewable solutions depend strongly on the living conditions of a household. Examples are dwelling conditions, the heating system, the area they live in or energy inefficient equipment. This calls for the inclusion of housing attributes and socio-demographics of households in analysing the distributional impacts of carbon taxation and the effectiveness of compensating schemes to offset negative effects.

Methodologically, in order to analyse this multifaceted issue, we employ the EASI demand system (Lewbel and Pendakur (2009)), which is able to to take household heterogeneity into account and capture high order Engel curves. The latter is of particular relevance for energy goods, which show a high degree of non-linearity (Reaños and Wölfing (2018)) and would lead to biased estimation results. Analysing distributional impacts of price increases trace back to Deaton and Muellbauer (1980) and the almost ideal demand system (AIDS); still one of the most applied approaches. However, AIDS and its quadratic version QUAIDS are only able to consider linear or quadratic Engel curves and are hence only suitable when clustering all energy goods in one category. Reaños and Wölfing (2018) underscored the flexibly of the EASI system, also in comparison to QUAIDS, by applying it to study energy price increases in Germany. To the best of our knowledge, the full potential of the EASI demand system to take household heterogeneity into account has, so far, still not been utilised. This is also noted by Reaños and Wölfing (2018) who call for the exploration of specific vulnerable subgroups within the population.

This paper aims to address the above mentioned issues and contributes to the literature twofold: first, we employ the EASI demand system with special consideration of housing attributes and socio-demographics of households to study energy and carbon price increases. This enables the identification of vulnerable household types based on their housing and socio-economic characteristics. Moreover, we explore how the vulnerability differs across energy goods. The vulnerability assessment draws on attributes describing the carbon dependency of a household such as area of residence, the energy source of the heating system, household size or car ownership. Second, the estimation results with the identified vulnerabilities inform the design of several cash-transfer schemes aiming to capture household heterogeneity. The political debate mainly neglects the multifaceted nature of compensating policies. For example, Ireland applies the "National Fuel Allowance Scheme", which is a weekly cash payment in the colder portion of the year to low-and fixed-income households (it amounts to about EUR 20) (Convery et al. (2013)). In Switzerland households receive a flat cash transfer of EUR 80.49 (CHF 87 in 2020) per insured person called the "Ökobonus", which is distributed through the country's mandatory basic health insurance system (The Swiss Confederation (2020)). We aim to go beyond flat- and income-based transfer and to design, as suggested by Berry (2018), target-based cash-transfers which take household heterogeneity into account. These transfer schemes are then evaluated by means of various criteria such as the Gini and Suits indices as well as the respective costs.

The paper is structured as follows: Section 2 describes the EASI demand system as well as the welfare and inequality measures used. In section 3 an overview is provided of the consumer and price data and the commodity grouping for the demand system. The following section illustrates the simulation results and the identification of vulnerable population segments. Section 5 lays out the results of policy simulation for the two scenarios, separate price increase and the carbon tax scenario. Subsequently, Subsection 5.3 evaluates various types of governmental transfers aiming to mitigate the negative effects of the price increase related to the carbon tax. Section 6 summarises and discusses our findings, while Section 7 draws the main conclusions for future climate policy and research.

2 Methodology

2.1 The EASI demand system

The EASI demand system is the most significant and recently developed method for demand system analysis (Reaños and Wölfing (2018)). The model focuses on heterogeneous preferences in household consumption and how consumption is affected by different price shocks. It is an advancement of the almost ideal (Deaton and Muellbauer (1980)) and quadratic almost ideal (Banks et al. (1997)) demand system and, as with its predecessors, the expenditure shares are linear in parameters given real expenditures. In contrast to other demand systems the EASI demand system can have any rank and the Engel curves can have any shape over real expenditures (Lewbel and Pendakur (2009)). The possibility of non-linear engel curves is important to avoid biased estimates for the distributional effects. Two additional advantages of the EASI model are first, different socio-demographics for different household types can be included and second, the error term equals random utility parameters to take unobserved preference heterogeneity into account. In this section a short overview of the model is presented, for further details, we refer the reader to Lewbel and Pendakur (2009).

In a typical demand system analysis, a cost function is specified and after using Shepard's Lemma the Hicksian demands are obtained. As a next step one would obtain the Marshallian demand by solving indirect utility and substituting this into the Hicksian demand function. For the EASI demand system a cost function is constructed that contains a simple expression for the indirect utility (u) called implicit utility function (y). After replacing indirect utility u by the implicit utility function, the so-termed implicit Marshallian demand function is obtained. The parametric EASI cost function for empirical work has the following form:

$$C(p,u,z,\epsilon) = u + p' \left[\sum_{r=0}^{R} b_r u^r + Cz + Dzu \right] + \frac{1}{2} \sum_{l=0}^{L} z_l p' A_l p + \frac{1}{2} p' Bpu + p'\epsilon. \tag{2.1}$$

The cost function depends on the log prices p, the indirect utility u, some household characteristics z and on ϵ which equals random utility parameters and represents unobserved preference heterogeneity. In addition, b, A, B, C and D are parameters to be estimated.

By using Shepard's lemma the Hicksian budget shares can be obtained which are represented by:

$$w = \sum_{r=0}^{R} b_r u^r + Cz + Dzu + \sum_{l=0}^{L} z_l A_l p + Bpu + \epsilon \tag{2.2}$$

As a last step the indirect utility function u has to be replaced by the implicit utility function y which is defined as:

$$y = \frac{x - p'w + \sum_{l=0}^{L} z_l p' Ap/2}{1 - p' Bp/2} \tag{2.3}$$

It can be seen that y only depends on the observable variable x, which is the log real expenditure, the log prices p, the household characteristics z and the log Stones index $p'w$. Finally, after replacing the indirect utility function the budget shares take the following form:

$$w = \sum_{r=0}^{R} b_r y^r + Cz + Dzy + \sum_{l=0}^{L} z_l A_l p + Bpy + \epsilon \tag{2.4}$$

In addition, y is a function dependent on variables that arise on the left hand side of equation 2.4 and so the demand system becomes non linear. Therefore, the system can be estimated by using non linear GMM or iterative linear three stage least square (3SLS). The latter option is used for this analysis.

2.2 Elasticities

Households differ in their consumption decision according to socio-demographic and socio-economic characteristics, especially when price changes occur. These characteristics hence influence a household's vulnerability towards price changes. In order to shed light onto the question of how heterogeneity governs vulnerability, semi-elasticities with respect to household characteristics are analysed. The specification based on the EASI model is as follows:

$$\bigtriangledown_{z_l} w = c_l + d_l y + A_l p. \tag{2.5}$$

2.3 Welfare and inequality metrics

In order to quantify welfare effects, we use the parameter estimates of the demand system to determine the compensating variation (CV). It measures the amount of compensation a household needs to attain the initial utility level u^0 after a price change, relative to total household expenditures, which makes this particular welfare measure ideal for analysing the impact of price increases and corresponding compensation measures. CV is frequently used to study distributional effects of changing energy prices (ex.: Schulte and Heindl (2017)) and is defined as follows (Hicks (1946)):

$$CV = e(p_0, u_0) - e(p_1, u_0) = C(p_0, u, z, \epsilon) - C(p_1, u, z, \epsilon). \tag{2.6}$$

The Gini index is a measure of statistical dispersion intended to represent the income inequality or wealth across the population and is a common measure for changes in equality. A value of zero represents total equality while a value of 1 indicates total inequality. The coefficient is defined as the area between the hypothetical line of total equality and the Lorenz curve, which plots the cumulative percentages of total income against the cumulative population (Gini (1912)).

$$G = S/(S + T) \tag{2.7}$$

where S is the area between the hypothetical line of equality and the Lorenz curve and T is the area between the Lorenz curve and the axes.

The last inequality and welfare measure used is the Suits-index which measures the distribution of the tax burden across the income deciles (Suits (1977)). This index is very useful, especially, for the investigation of different transfer schemes, and is defined as follows:

$$S = 1 - (1/500) \int_0^{100} T(Y)\, dy \simeq 1 - (1/500) \sum_{i=0}^{i=n} [T(Y_i) + T(Y_{i-1})][Y_i - Y_{i-1}] \tag{2.8}$$

where Y and $T(Y)$ are the cumulative percentage of total income and the corresponding cumulative percentage of tax burden. The Suits-index takes values between -1 (extreme regressivity) to 1 (extreme progressivity). A value of 0 corresponds to a proportional distribution of the tax burden.

The usage of three different welfare and inequality measures allows us to shed light on different aspects of tax fairness and equity.

3 Data

3.1 Expenditure and price data

Expenditure and income data are drawn from the Austrian Household Budget Survey (HBS) provided by Statistics Austria. It is a nationally representative survey and comprises detailed expenditure data as well as socio-demographic information on around 7,000 households per wave. We used data from the HBS of the years 2004/2005, 2009/2010 and 2014/2015. Surveys prior to 2004/2005 are not comparable in terms of expenditure categories and socio-demographics. Our estimation is based on a pooled cross-section data set of 22,096 households. Household data is matched with monthly consumer price indices at a state level[1] for the years 2004, 2005, 2009, 2010, 2014 and 2015, published by Statistics Austria. The goods classification matches exactly those of HBS (both are classified in COICOP). Although price indices do not give actual prices in monetary units, they are commonly used in demand systems, since they measure precisely the evolution of prices for the goods categories under investigation (Reaños and Wölfing (2018)).

3.2 Commodity groups

We start the analysis with a demand system comprising eight commodity groups: motor fuels, electricity, heating, housing, food, non-durables, durables and others. This aggregation follows the literature and enables the identification of interactions between energy consumption and other consumption on a differentiated level. A key contribution is the separate representation of a household's main energy consumption categories motor fuels, electricity and heating. Therein heating comprises the subcategories natural gas, heating oil, biomass, coal, district heating and alternative heating such as heat pumps. We follow Reaños and Wölfing (2018) and match to each subcategory expenditure the corresponding energy price. Note that heating a dwelling with electricity is very atypical in Austria; only 10% of Austrian households use electricity based heating systems (see table A.1). Housing subsumes maintenance and repair, operating costs rent and rent equivalent for homeowners. Food comprises food and beverages consumed at home, while hotels and restaurants are subcategories of non-durables. The latter

[1] In Austria prices do not differ across provinces

comprises public and private services such as communication, education and health. Durable goods are long-term investments due to their high transaction costs and subsume among others, mobility (except fuels), household appliances, clothes and leisure. "Others" subsumes the remaining expenditure categories such as financial activities, personal hygiene and insurance as well as social security and other services. Table A.3 reports the respective average expenditure share.

3.3 Household types and socio-demographic characteristics

The specified EASI demand system allows for the consideration of household preferences and hence for taking heterogeneous preferences into account; an aspect neglected in many studies (Pashardes et al. (2014), Renner et al. (2018), Berry (2018)). Thus, we include socio-demographic variables, which allow differentiation of the consumption behaviour of different groups in society. On the one hand we follow Schulte and Heindl (2017) and include household types distinguished by the number of children and adults living in the house. The resulting household types are as follows: single household without children (S0), single household with children (S1), couples without children (C0), couples with children (C1) (see Table A.2 for details). On the other hand we include additional socio-demographics and housing attributes such as the household composition, built year and primary energy source of the heating system. The selection of variables draws on pertinent studies analysing energy and fuel poverty. It is well known that households which spend a relatively large share of their income (i.e. over 10% classifies as energy poor) on heating live in poorly insulated buildings, are numbered to the lowest income quartile or can not afford efficient heating systems (EU-Energy-Poverty-Observatory (2019)). Table A.1 reports some descriptive variables used in the analysis.

4 Estimation Results

4.1 Elasticities

In order to study the impacts of household characteristics and heterogeneous preferences on budget shares we focus on elasticities, which are - as pointed out by Reaños and Wölfing (2018) - easier to comprehend and more intuitive compared to the parameter estimates of the demand system. Table 1 reports the semi-elasticities of the socio-demographic and socio economic variables, while for completeness, Table A.4 in the appendix reports the parameter estimates of the three energy goods and statistics of the demand system.[2] All coefficients presented are significant at the 1% level and so is

[2] The parameters of the other consumer goods are available on request to the author

the Wald test of their joint significance.

Findings show, that the budget share of motor fuels increases with car-ownership and falls if households live in urban areas or include people of higher age groups (over 55 years of age). The difference between urban and rural areas is also highlighted by the positive impact of wood as prime energy source. The latter can be interpreted as a proxy for rural areas, since only 2.2% of the urban households use wood for heating. The budget share of electricity increases with living size, number of household members and housing type. Regarding the latter, we find that households living in detached houses have a higher budget share of electricity than those in other housing types. Semi-elasticities highlight the strong impact of household composition on electricity expenses. For instance, a couple with children has a 23% higher budget share for heating than a single household. In addition, the ownership of a house has a similar effect on the budget share to being a couple with children. The elasticities also show that households that live in dwellings built after 2000 tend to spend less on all three energy goods.

Our findings underscore that the primary energy source has the strongest influence on the budget share of heating. In particular, households using oil, coal, gas and district heating spend more on heating than those using renewable energy sources (reference group). As in the case of the other energy commodities, rising income weakens this strong influence (see table A.4). Semi-elasticities highlight the strong influence of housing attributes, in particular ownership and living size. For instance, owning a house implies a 40% higher budget share. Attributes that lead significantly to falling budget shares are living in an urban area and dwellings that were built after 1980.

The estimation results reveal that heterogeneity matters and that the impacts of energy price increases depend on socio-economic as well as socio-demographic characteristics which vary, and are even diametral, across energy goods. Thus, in order to take a closer look on this issue, we derive, in addition to the composite-based grouping, household types capturing multiple characteristics and attributes having a high influence on energy prices (as identified above). This illustrative selection of three distinct household types represent different levels of vulnerability and allows a higher level of resolution of distributional impacts. While two of the examples of household types "house-owning couple without children living in rural areas" (from here on Elderly couple rural, V1) and "family living in a rural area and car-owning" (Family rural, V2) show high vulnerability regarding energy price increases, the household type "single household in urban areas" (Urban single, V3) is among the

	Motor fuels	Electricity	Heating
Couple without Children	0.0004	0.0033	0.0002
	(0.0017)	(0.0010)	(0.0013)
Single with Children	-0.0026	0.0049	0.0010
	(0.0025)	(0.0015)	(0.0019)
Couple with Children	0.0009	0.0061	-0.0008
	(0.0018)	(0.0011)	(0.0014)
Electricity	0.0070	0.0018	0.0089
	(0.0025)	(0.0014)	(0.0019)
Gas	0.0052	-0.0093	0.0283
	(0.0024)	(0.0013)	(0.0018)
Heating oil	0.0055	-0.0087	0.0374
	(0.0024)	(0.0013)	(0.0018)
Wood	0.0104	-0.0053	0.0145
	(0.0024)	(0.0013)	(0.0018)
Coal	0.0098	-0.0029	0.0273
	(0.0031)	(0.0017)	(0.0024)
District heating	0.0047	-0.0089	0.0294
	(0.0024)	(0.0013)	(0.0018)
1945-1980	0.0005	-0.0005	0.0000
	(0.0009)	(0.0005)	(0.0007)
1980-2000	-0.0003	-0.0006	-0.0028
	(0.0010)	(0.0006)	(0.0008)
After 2000	-0.0029	-0.0038	-0.0055
	(0.0013)	(0.0007)	(0.0010)
Ownership Flat	-0.0040	0.0011	-0.0004
	(0.0013)	(0.0007)	(0.0010)
Ownership House	-0.0011	0.0059	0.0105
	(0.0017)	(0.0010)	(0.0013)
Age over 55	-0.0082	0.0016	0.0018
	(0.0014)	(0.0008)	(0.0010)
Car	0.0313	0.0002	-0.0001
	(0.0018)	(0.0011)	(0.0014)
Urban	-0.0091	-0.0011	-0.0043
	(0.0015)	(0.0009)	(0.0012)
Living size	-0.0001	0.0001	0.0001
	(0.0000)	(0.0000)	(0.0000)

Note: The standard errors are represented in brackets; Only significant effects are presented. Full set of parameters are available from the authors upon request.

Table 1: Semi-Elasticities of the socio demographic and socio-economic characteristics

	Elderly couple rural (V1)	Family rural (V2)	Urban single (V3)
Children		x	
Urban area			x
Ownership	x		
Tenant			x
Age > 55	x		
Car		x	
% in population	21.2%	8.3%	16.1%

Table 2: Attributes of the three vulnerability-based household types

less affected groups. Table 2 gives an overview on the attributes. We use this selection of examples to underscore how welfare effects differ based on a household's characteristics, these types; however, are not representative of the most vulnerable ones in Austria.

5 Policy Simulation

In order to evaluate the distributional impacts of an energy price increase and to investigate compensating measures aiming to mitigate negative side effects, we adopt a stepwise approach. First, in a stylised simulation we study separate price changes of 20% for all fossil-based energy sources and compare the magnitude and shape thereof. We chose a 20% price increase to make our results comparable to other studies (Kirchner et al. (2019), Reaños and Wölfing (2018) and Renner et al. (2019)). Based on the estimation results, we expect the distributional impacts to differ across the energy goods regarding socio-demographics, providing a deeper understanding of distributional impacts.

Second, we simulate a carbon tax scenario where prices of all energy goods increase according to their carbon content. The modelling of this scenario aligns itself to Berry (2018) and affects all carbon based energy sources (gas, oil, coal, motor fuel and electricity). The carbon tax rate is modelled on top of current energy prices and follows Kirchner et al. (2019) who assume a EUR 120 /tCO_2 for Austria. On the one hand this tax rate is politically feasible, similar to the tax rate in Sweden (Carl and Fedor (2016)) and on the other hand, it allows a comparison of results with Kirchner et al. (2019) who apply a more aggregated macro-economic perspective. The carbon tax is equivalent to price increases of between 12% and 69%. As expected coal and heating oil show the highest price increases (details are reported in Table 3). The derived price increases are consistent with Berry (2018) and Kirchner et al. (2019) regarding magnitude and direction.

For both scenarios, separate as well as carbon oriented price increase, the compensating variation (CV) is used to measure welfare effects. We study the CV for both household groupings, composite-

	Motor fuels	Electricity	Heating oil	Coal	Gas
Price increase	23.5%	12.1%	48.5%	68.5%	35.1%

Table 3: CO_2 content dependent price increase of the different energy goods

based and the examples of the vulnerability-based, in order to understand the implications of energy prices in more detail.

Third, we use the carbon tax scenario as a reference point to investigate different types of compensating measures. Again we use Berry (2018) as guidance and construct the different transfer schemes based on the distributional impacts of the carbon tax scenario. The different types of transfers will be evaluated by means of the welfare and equity indices. Note that all price scenarios are calculated based on the 2014/2015 wave.

5.1 Welfare impacts of separate energy price scenarios

Since, as indicated in the descriptives in Table A.1, half of Austrian households use fuel-based heating (51% use coal, gas or heating oil) and 80% own a car, we narrow the distributional analysis in this subsection to those users only. The distinction between users and non-users matters when studying separate price changes, as distributional impacts will be distorted when all observations are taken into account (Renner et al. (2017) provide a good overview of this issue). In our case the distortion is particularly pronounced for heating, where the true regressive effect is strongly attenuated (for comparison see Figure A.1 in the appendix). Figures 1 to 3 illustrate CV over expenditure deciles of the respective 20% price increase for both household groupings. Additionally, the overall effect for all households in Austria is indicated as a dashed line.

Figure 1 illustrates the inverse u-shaped behaviour of a price increase of fuels for the whole population (dashed line). We find that couples with children in the 3rd and 4th income decile are affected more strongly than the other composites. While, in the 3rd and 4th income decile a compensation of around 1.1% of their total expenditure would be required, single households with children in the same decile only require 0.8%. Couples with children live to a large extent in rural areas, while single households with and without children predominantly live in urban areas. The right panel in Figure 1 confirms the hypothesis. The vulnerability-based household type "Family rural" requires a compensation of 1.1 to 1.2% of the total expenditures; but the required compensation decreases with rising income. In comparison, "Urban single" requires a lower compensation (around 0.7%).

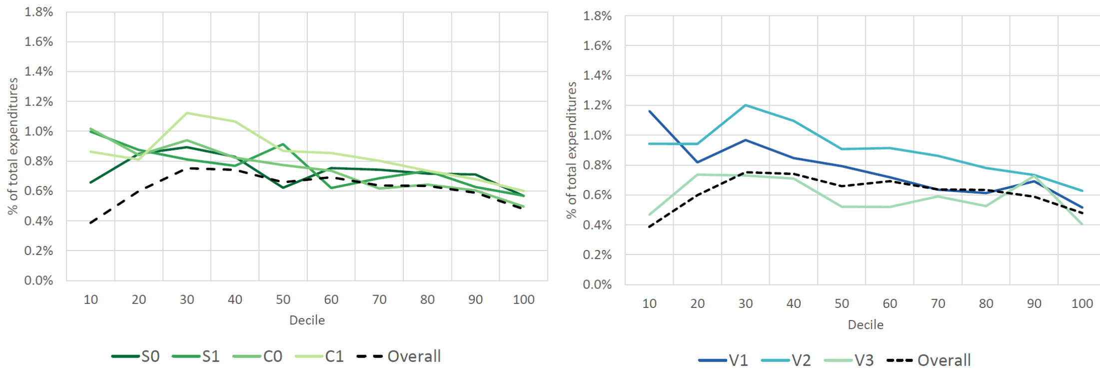

Figure 1: Effects [CV in%] of a 20% price increase in motor fuels across income deciles for the composite- and vulnerability-based household type

A price increase in electricity is clearly regressive, with a CV of 0.9% in the lowest income decile, decreasing with income to 0.3% in the highest decile. Figure 2 highlights that again couples with children are disproportionally more strongly affected, while the remaining composite-based groups show a similar pattern. Turning to vulnerability-based household types reveals a contrasting picture. "Urban single" are least affected, well below the overall average. "Family rural" and "Elderly couple rural", both in rural areas, are similarly affected and well above the overall average. Both household types underscore that in terms of electricity, price effects are more pronounced for households in rural areas.

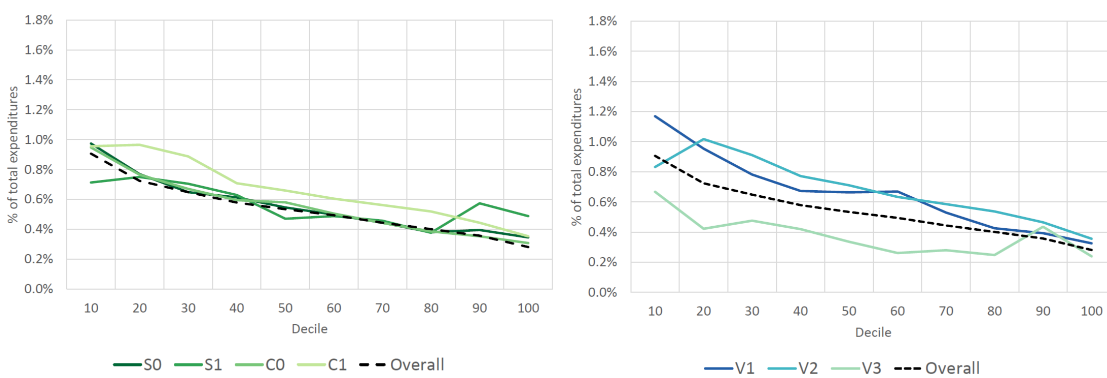

Figure 2: Effects [CV in%] of a 20% price increase in electricity across income deciles for the composite- and vulnerability-based household types

Overall, a price increase in fossil-fuel based heating is regressive and appears to be less prevalent than an increase in electricity prices. However, taking household characteristics into account reveals a some-what different picture (Figure 3). Couples without children in lower income deciles, are disproportionally more harmed by rising prices in heating. Comparing medium-income households shows that single households with children are more strongly affected. The behaviour of vulnerability-based household types enhances clarity. Low-income "Elderly couple rural" is most vulnerable to price increases in fossil fuel-based heating. In the second income decile (CV of 1.6%) the required compensation is twice as high as the overall average. Descriptives reveal that the "Elderly couple rural" is more likely to use fossil-fuel based heating systems than other household types. Nonetheless they account for 8% of the Austrian population.

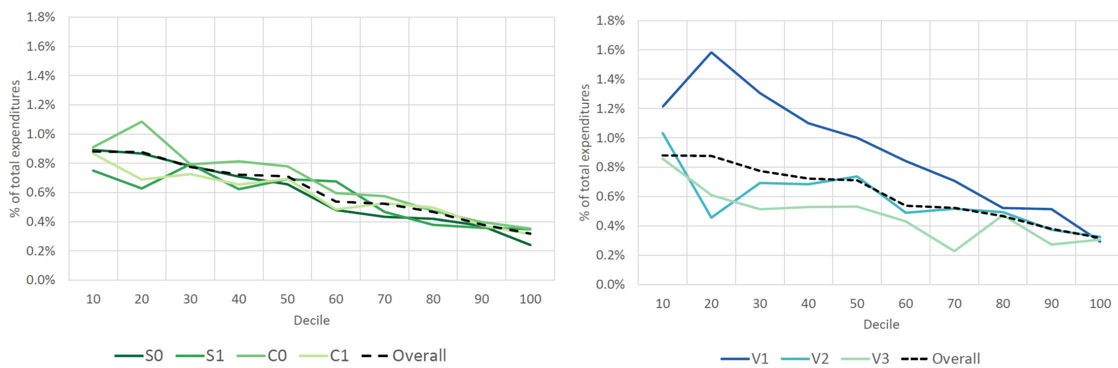

Figure 3: Effects [CV in%] of a 20% price increase in fossil based heating across income deciles for for the composite- and vulnerability-based household type

To summarise, studying a 20% price increase for each energy good separately reveals a complex picture of impacts. While electricity and heating show a regressive behaviour, motor fuels follow an inverse u-shape. Including household compositions and attributes underscores the diversity of effects and varying vulnerabilities a carbon-based taxation scheme would have. While elderly couples in lower-income deciles are severely affected by an increase in the price of heating, a young family needs more compensation to stem a price increment of electricity or motor fuels. Additionally, our results reveal differences in urban and rural regions; however depending on the energy goods in opposite directions.

5.2 Welfare impacts of the carbon tax scenario

In a similar vein, Figure 4 illustrates the distributional impact of the simulated carbon-oriented price increases, overall and for the respective household types. As expected, the CO_2 tax shows that low-income households (2.0%) are disproportionally more affected than affluent households (1.1%). Turning to the composite-based groupings reveals a similar pattern between the groups across income, except for singles households with children. The latter are under-proportionally affected in the lower income deciles, while the extremely affluent are over-proportionally affected. A similar pattern is observed by

"Urban single" of the vulnerability-based grouping. The "Elderly couple rural" is the most harmed, in particular in the lowest income quartile. The nature of the regressiveness of the "Elderly couple rural" mirrors their behaviour in the stylised example of an increase in the fossil-based heating price (of course, on a much higher magnitude). The analysis by means of different, heterogeneous groups underscores that households are affected by the CO_2 tax via different channels. For instance, the impacts for house owning elderly couples are rooted in the price increase in heating, while for single households price increases in electricity are the dominant factor (which are relatively small). Additionally, rural households are more strongly affected in price increases of motor fuel and heating.

In order to evaluate equity we apply the Gini index and the Suits index. While the Gini defines equality in a society based on income distribution, Suits measures the degree of regressiveness of a tax regime. As reported in Table 5, the carbon-oriented price scenario, without any compensating measures, enhances inequality and behaves regressive. The need for compensating measures, such as transfers, to mitigate these negative side effects is underscored by the importance of socio-demographics and household heterogeneity.

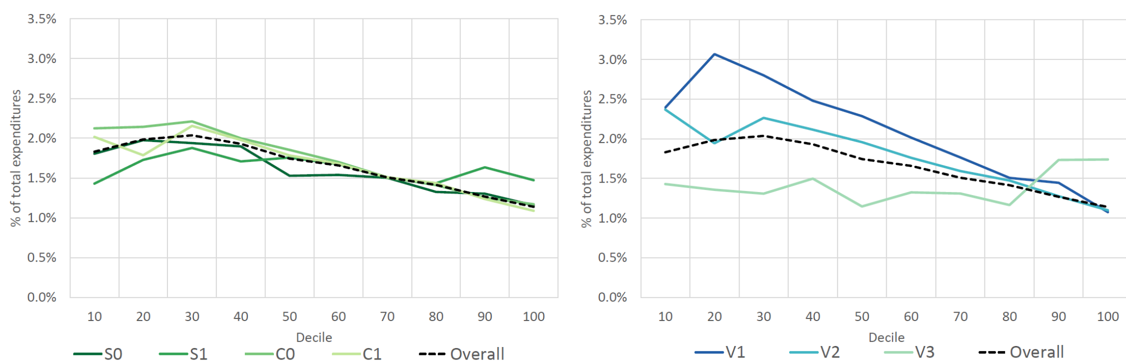

Figure 4: Effects [CV in %] of a CO_2 dependent price increase across income deciles for the composite- and vulnerability-based household types

5.3 Evaluation of governmental transfers

Studying the carbon tax-oriented price scenario reveals that distributional impacts are highly diverse and go beyond income and household composition. Furthermore, although the joint effect seems similar for various groups, the impact channel differs and hence depends on the energy goods. Consequently, compensating measures aiming to increase equity and fairness of future energy taxation schemes have to take this diversity into account. In doing so, we use Berry (2018) as guidance and evaluate different transfer schemes covering a broad spectrum of aspects. Thereby, the carbon-oriented price scenario

Flat cash		**Target based**	
Transfer	Target	Transfer	Target
EUR 250 /a	All	EUR 430 /a	Elderly couple
		EUR 100 /a	Single urban
		EUR 260 /a	Family rural
		EUR 240 /a	Others
Geography-based		**Income based**	
Transfer	Target	Transfer	Target
EUR 140 /a	urban	EUR 130 /a	0 - 2nd decile
EUR 320 /a	rural	EUR 230 /a	2nd - 4th decile
Composition based		EUR 230 /a	4th - 6th decile
Transfer	Target	EUR 210 /a	6th - 8th decile
EUR 190 /a	Single without Children	EUR 150 /a	8th - 10th decile
EUR 230 /a	Single with Children		
EUR 280 /a	Couple without Children		
EUR 250 /a	Couple with Children		

Table 4: Transfer scheme used to evaluate the amount of cash transfer for each household in EUR/a

serves as a reference point. This scenario yields EUR 1.38 billion tax revenues, while the total amount of compensation (sum of CV over all households) required to gain the utility level prior to the energy taxation is EUR 2 billion.

According to Berry (2018), the design of governmental transfers should be based on simple criteria, encounter low management costs, ensure transparency and rely solely on available data. Based on the identified characteristics and attributes steering a household's vulnerability towards energy price increases, we test five different transfer schemes: (i) flat cash transfer, where every household receives the same amount of governmental transfer, (ii) geography based, where the amount differs between urban and rural areas, (iii) composition based, where the amount is based on the number of persons living in the household, (iv) target based, where the amount differs based on the actual impact, that is to say further defined groups and (v) an income-based transfer that divides households into income quintiles. The amount of compensation is designed such that for each subset of the respective transfer multiplier, CV averages 1%. Let us illustrate this mechanism using the example of the geography based transfer: the transfer required to reach a CV of 1% amounts to EUR 140 for households living in urban areas and EUR 320 for households living in rural areas respectively. Table 4 reports the amount of cash transfer for each scheme.

Figure 5 illustrates the welfare effects of the applied transfer schemes and, for comparison, the CO_2 tax scenario (as our reference point). We find that all transfer schemes are able to compensate for the regressive effects of the CO_2 tax scenario. Shape and direction of effects are similar in all schemes (except the income-based transfer): in the first quantile the effects are progressive, with extremely poor households being disproportionally less affected, while middle-income households are most harmed. Taking a closer look on the transfer schemes highlights that the effects of the flat and the geography-based transfers are nearly identical, where the CV of the extremely poor falls to -0.5% of total expenditure and hence these households are net-beneficiaries (overcompensation). Similarly, the effects of the composition-based and target-based transfers are alike, although the redistribution of transfers differs. While the redistribution in the composite-based scheme builds on the number of persons in the household, the target-based transfer differs based on a household's vulnerability, with the "Elderly couple rural" being most vulnerable. For both schemes, progressive effects are observed for the first income quantile, but without an overcompensation of the extremely poor, while middle-class households are hit hardest. The income-based transfer scheme is least effective in cushioning the negative welfare effects of the CO_2 tax scenario. Compared to the other transfer schemes, the behaviour is different: the first income decile is least affected while the second income decile is most harmed. All other income deciles are proportionally affected and, as intended, the CV hovers around 1%. In summary, when analysing welfare effects of transfer schemes, consideration of household attributes and socio-demographics, as in case of target or composite based transfer schemes, has a higher ability to mitigate the negative side effects of a CO_2 tax scenario. These schemes also come at lower costs, in other words amount of tax revenue used, compared to a flat or geography-based transfer.

Turning to equality and fairness reveals a similar picture. In comparison to a CO_2 tax scenario, all transfer schemes enhance equality, and thus the Gini coefficient is reduced. In terms of equality, the geography-based transfer is the most effective one with a reduction of 0.0038 points, whereas the flat cash transfer is, as expected, least effective (see Table 5). Additionally, the Suits index underscores all transfer schemes except the income based, cushioning the regressive nature of the CO_2 tax scenario; some even change it to a progressive tax scheme. This is particularly pronounced in the case of the geography based transfer. The Suits index also highlights that the composition based and the target based are positive as well as close to zero and hence indicate a proportional distribution of the tax burden.

The target-based transfer is among the most equitable ones, showing a high degree of proportion and ranges regarding costs below average. Still, welfare effects, in particular when analysing each vulnerable-household type separately, pinpoint different aspects of improvement. In order to enhance the understanding of the relevance of considering household heterogeneity in the design of a cash transfer realising an equal tax burden of 1%, Figure 6 plots the necessary amount for each vulnerable

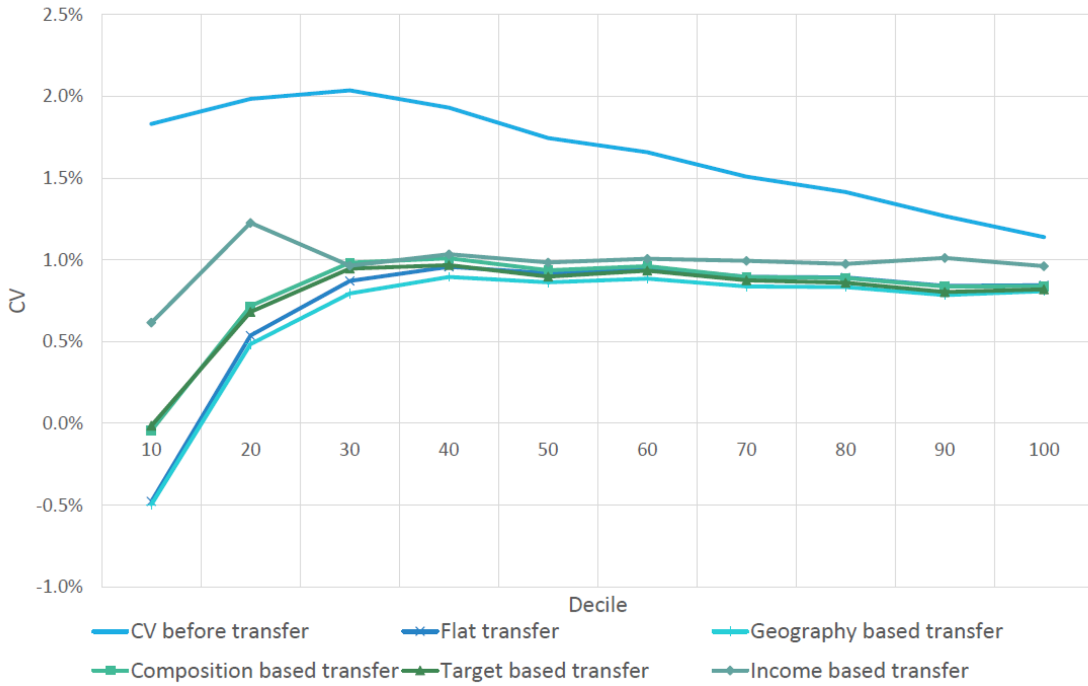

Figure 5: Effect [CV in%] of different transfer schemes across income deciles

	Gini-Index	Δ Gini-Index	Suits-Index	% of revenues
Carbon tax scenario	0.3136		-0.1743	
Flat cash transfer	0.3099	0.0037	0.0990	68.77%
Geography based transfer	0.3098	0.0038	0.5980	71.90%
Composition based transfer	0.3102	0.0034	0.0112	64.01%
Target based transfer	0.3102	0.0034	0.0172	65.30%
Income based transfer	0.3104	0.0032	-0.0177	51.91%

Table 5: Evaluation of different transfer schemes

household type in each income decile. As expected, the necessary amount not only differs across groups but also within a group between income deciles. For instance, in order to realise an equal tax burden, the ”Elderly couple rural” - the most vulnerable group with the highest cash transfer - would require EUR 400 in the mid-income levels, EUR 200 in low-income levels and only EUR 68 for the most affluent ones. Consequently, the uniform distribution of EUR 430 of compensation in the target-group based scenario overcompensates more than a third of households in this group; however, in contrast a transfer scheme solely based on income groups induces a similar level of inequality. The necessary compensation for the ”Elderly couple rural”, is on average more than three times as high the one for the ”Urban single” and hence an income-based transfer would over - as well as undercompensate different socio-demographics (see Figure 6). For instance, the income-based transfer is not able to compensate the two vulnerable household types, while the least affected one, the single household in an urban area, is to a large extent overcompensated.

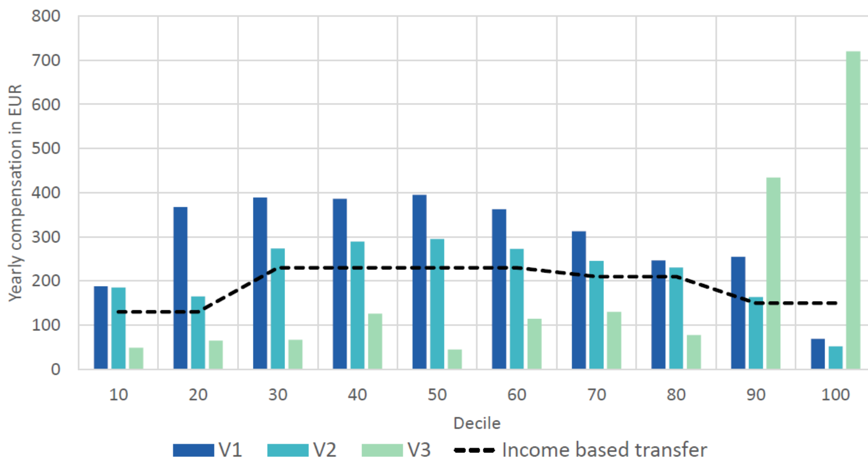

Figure 6: Necessary cash transfer [in EUR] for vulnerability based household types across income deciles compared to the cash transfer of the income based scheme [in EUR]

6 Discussion

The stylised separate price scenarios highlight the different channels of welfare effects; while electricity and fossil fuel-based heating are regressive, motor fuels show a u-shaped behaviour, with middle-income households being most harmed. The regressivity of price increases for electricity and heating corresponds to Reaños and Wölfing (2018) for Germany. The latter also uses a stylised increase of 20% for electricity and heating, but a price increase in motor fuels is not analysed. The u-shaped effects for motor fuels are consistent with Tiezzi (2005) and Labandeira et al. (2009); however, pertinent studies analysing distributional effects of energy price increases and comparing the different channels of effects are scarce and hence patterns and vulnerabilities are ignored.

At the first sight, the similar behaviour of electricity and heating price increases, differs strongly when taking household heterogeneity into account. Age, region and year of construction steer the effects of price increase in heating, while household composition drives the effects of electricity price increases. The u-shaped picture of motor fuels changes when distinguishing between urban and rural areas. Similarly, household composition is also a driving factor, with families in rural regions being most harmed. Our study also stresses the need for a user-based perspective, when analysing price increases in energy goods or fossil fuels. The distortion is particularly pronounced in the case of fossil fuel heating, where the full sample cushions the real regressivity of the price increase (see Figure A.1 in the Appendix). Consequently, ignoring the user-perspective means that the distributional effects will be underestimated when analysing distinct price increases; however, so far, only Renner et al. (2018) discusses this issue in more detail and comes to a similar conclusion for Mexico, but the effects differ due to economic development as well as population structure and hence are not comparable to Austria or any other western, industrialised country.

We investigate the robustness of welfare effects by performing sensitivity tests. For instance, we simulated a 20% price increase for all three energy goods (fossil fuel-based heating, electricity and motor fuel) and find that it mirrors the summed costs of the three separate price increases. The welfare effects are still regressive but middle-income households are the most harmed. These results underscore that there is hardly any substitution between energy goods, and the different nature of a price increase in motor-fuel appears to be a dominant factor. Reaños and Wölfing (2018) observe the same trend when analysing the joint price increase of heating and electricity and come to a similar conclusion regarding substitution between energy goods. Additionally, we assume other CO_2 prices in the carbon tax scenario in order to enhance comparison of our findings with relevant studies. For example, results of a carbon price of EUR 30.5 /tCO_2 correspond to the findings of Berry (2018), regarding the resulting energy price increase and direction as well as the magnitude of overall effects; however, Berry (2018) excludes changes in electricity prices from her analysis. On a macro-level direction and magnitude of the regressive nature of a carbon price of EUR 60 /tCO_2, correspond to the findings of Kirchner et al. (2019). Finally, we analyse how a change in the transfer design shapes our findings. The amount of cash transfer is designed such that for each subset of the respective transfer multiplier, CV averages 1 %. A higher value per subset, for instance 1.3%, implies that households that are more affluent will not receive any transfer. Consequently, the proportion of the tax burden would shift regarding progressivity. A positive and higher value of the Suits index does not boost equality in a society. A target value lower than 1%, e.g. 0.8%, would imply high costs, that is to say compensation exceeds revenues and the incentive to reduce carbon emissions is annulled. For this analysis we use an equal tax burden as a percentage of expenditure as an indicator of a fair carbon tax. This, of course, is one way to define fairness; others, for example employ a proportional scheme as fair, where all households pay the same amount for taxes. It is argued that a proportional tax is more fair than a progressive tax system because it penalises high earners. An other example is Berry

(2018) who aims to offset regressivity, based on the Suits index.

Our results of a carbon tax scenario extend the findings of Kirchner et al. (2019) for Austria by underscoring the relevance of heterogeneity in distribution effects and the efficiency of target-based compensation schemes. Kirchner et al. (2019) focus regarding distribution only on income-based measures such as lump-sum transfers and homogeneous reductions of the labour tax rate or VAT. Other valuable studies rely solely on flat cash transfers, neglecting heterogeneity (Reaños and Wölfing (2018)) or limit transfers to the extremely poor such as social transfer receivers as in Berry (2018).

From a political perspective these results point to a change in Austria's current policy regime. In 2018 over 600,000 fossil fuel furnaces (16% of heating systems) are still operative and overall, around 40% of Austrian households use fossil fuel heating systems (Biermayer (2018)). In order to meet the stringent 2040 climate target they have to be replaced with renewable heating systems. Currently, the Austrian government subsidises this substitution, by means of a flat cash transfer. Our results clearly indicate that these measures miss the target and the affected households do not have the financial resources for such an investment. This calls for compensating measures as well as socially adjusted subsidies, not only based on income but also taking into account other socio-demographics. In a similar vein, year of construction and a low rate of refurbishment are an issue in the steering of price effects in Austria. 40% of Austrian households live in buildings built between 1945 and 1980, which characteristically have a high energy demand and use fossil fuel energy sources. Besides this, low-income households are more likely to rent their homes and in this context a well-known problem is the landlord/tenant dilemma, which is one of the greatest barriers for European building retrofitting (Ástmarsson et al. (2013)). This mix of a lack in energy-efficient buildings, fuel dependency and an extremely low rate of refurbishment already implies high energy costs and hence presents high vulnerabilities to price increases. Additional governmental support is necessary to overcome these barriers, and target based revenue recycling concepts, as shown in our simple example, form only one pillar of an effective policy mix.

7 Conclusion and Policy Implications

In a multi-step approach, we investigate the welfare and distributional effects of a carbon tax in Austria and study the ability of governmental transfer schemes to mitigate negative effects. First, by simulating stylised, separate price increases we identify how welfare effects differ, depending on the energy goods taxed, housing attributes and socio-demographics. Second, the effects of a CO_2 tax scenario reveal the importance of target-oriented compensation to mitigate negative effects and enhance equality. In this, we employ the EASI demand system of Lewbel and Pendakur (2009) which captures non-linear Engel curves and heterogeneous preferences, both crucial in the analysis of energy consumption.

For the CO_2 tax scenario, we assume a carbon price of EUR 120 / tCO_2 which corresponds to price increases ranging from 12% (electricity) to 69% (coal). Findings report a clear regressive behaviour and when taking a closer look at heterogeneity and socio-demographics, the severity of effects differs strongly and so does the impact channel: (i) welfare loss is higher in rural regions than in urban areas, (ii) age of the household members matters, with elderly households more harmed than younger ones rooted in the heating system used and age of the building and (iii) couples with children are disproportionally more harmed, mainly due to the increase in motor fuel. Based on these findings we designed transfers aiming to mitigate the negative side effects of the carbon-oriented tax regime. The transfer schemes take different angles of household heterogeneity into account and are compared to a simple flat cash transfer. The latter is already applied in Switzerland as the so-termed "Ökobonus" and sits high on the political agenda in Austria and Germany. For instance, Germany is discussing a CO_2 price of at least EUR 50 / tCO_2 in combination with a yearly flat transfer (Umweltbundesamt (2019)). Generally, we find that every transfer scheme is able to enhance equality and cushioning negative welfare effects. Transfer schemes focussing on household size, or on particular groups who are vulnerable to price increases, show the strongest effects in terms of equality, proportionality of the tax burden and welfare. Consequently, in order to yield a socially fair energy or carbon tax regime, it is essential to take household heterogeneity into account.

The current debate, either scientifically (Kirchner et al. (2019), Reaños and Wölfing (2018) and Beck et al. (2015)) or politically (for example, Switzerland, Ireland and British Columbia according to Carl and Fedor (2016)), considers only flat cash transfers or different income levels when assigning transfers or recycling schemes. We find that, although the income based transfer decreases inequality and the regressive effects of carbon pricing, the most vulnerable groups stay undercompensated while others are overcompensated, hence fostering inequality in society. These household types are not extremely vulnerable towards carbon pricing because of low income but as a result of characteristics like heating systems, dwelling conditions or the region they live in. In fact, the role of financial support schemes is limited. They have the ability to mitigate negative side-effects of a carbon tax in the short term but to achieve the transformation to a carbon neutral society, other incentives and measures, such as regulatory policies, are indispensable in the long-term. We suggest the identification of and focussing on households vulnerable to price increases in the introduction phase of a carbon tax, in order to reduce the welfare loss and tax burden that mainly arise, due to structural factors and socio-demographics. Vulnerable households are not able to free themselves from their fossil fuel dependency; at least not in the short term.

Our analysis has two major limitations. First, the EASI demand system is a microeconomic model and thus indirect linkages and feedback effects of prices within the economy are not illustrated. In order to get a more complete picture, we encourage future studies to combine macroeconomic simulations with the EASI demand system, which may yield different or other vulnerable factors. For instance, price increases in food and beverages may imply different channels of welfare effects or vulnerable groups. Second, although monetary support in terms of transfers can be useful for short term compensation to prevent rising energy poverty and to weaken the regressive effects of carbon taxation, additional, far more stringent policy measures are needed. Our analysis highlights that specific population segments need considerably higher compensation than others depending on their socio-economic and socio-demographic characteristics. Future work should focus on these vulnerable groups and study long-term implications and developments, for instance, developing specific transformation pathways for the most deprived.

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APPENDIX

for

Distributional effects of carbon pricing when considering household heterogeneity: An EASI application for Austria

Anna Eisner, Veronika Kulmer and Dominik Kortschak

A Figures and Tables

	Mean	W. Mean	Std. dev.
Household:			
Sex of the main person	0.67	0.65	0.47
Age of the main person	50	51	16
Floor area	103.9	100.0	47.5
Household income	3,229.9.0	3,110.3	1,912.6
Household size	2.3	2.1	1.3
Tenants (dummy)	0.45	0.50	0.49
Urban (dummy)	0.34	0.37	0.47
Build year:			
Built before 1945 (dummy)	0.19	0.21	0.39
Built between 1945 and 1980 (dummy)	0.41	0.42	0.49
Built between 1980 and 2000 (dummy)	0.28	0.26	0.44
Built after 2000 (dummy)	0.11	0.10	0.27
don't know or no answer	0.01		
Primary energy source:			
Electricity (dummy)	0.10	0.10	0.10
Gas (dummy)	0.29	0.29	0.45
Oil (dummy)	0.20	0.19	0.40
Wood (dummy)	0.17	0.16	0.38
Coal (dummy)	0.02	0.02	0.15
Alternative heating systems (dummy)	0.02	0.02	0.15
District heating (dummy)	0.19	0.21	0.39
don't know or no answer	0.002		
Others:			
Car owner (dummy)	0.80	0.77	0.39
Car number	1.16	1.1	0.83

Table A.1: Descriptive statistics of household characteristics

	Absolute	Relative	w. Absolute	W.Mean
Household types:				
Single without children (S0)	6,715	30.4%	8595	38.9%
Single with children (S1)	1,731	7.8%	1392	6.3%
Couple without children (C0)	6,296	28.5%	5524	25.0%
Couple with children (C1)	7,354	33.3%	6585	29.8%
All	22,096	100%	22,096	100%

Table A.2: Summary statistics of household types

	Mean	W.Means	Std. dev.
Goods:			
Motor fuels	3.7%	3.5%	0.04
Electricity	2.5%	2.6%	0.02
Heating	3.0%	3.1%	0.03
Living	21.8%	22.4%	0.11
Food	16.9%	17.0%	0.09
Other non-durables	12.7%	13.0%	0.09
Durables	30.3%	29.3%	0.16
Other costs	9.1%	9.1%	0.07
Sum	100%	100%	

Table A.3: Summary statistics of expenditure shares

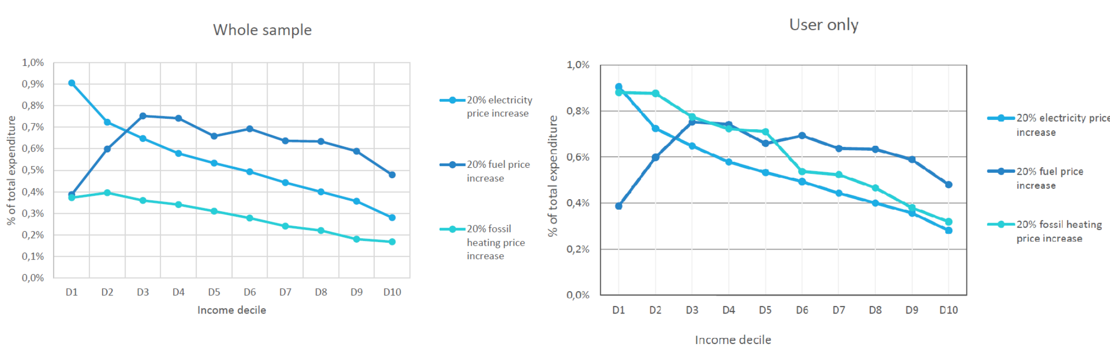

Figure A.1: Difference of price effects between the whole sample and users only

	Motor fuels	Electricity	Heating
Couple without Child		0.0107	
Single with Child	-0.0197	0.0203	
Couple with Child	-0.0143	0.0155	
Gas			0.0709
Heating oil			0.0991
Wood	0.0302		0.0308
Coal			0.0797
District heating			0.0738
Buildyear after 2000		-0.0095	
Ownerhsip flat	-0.0159		
Ownerhsip house		0.0165	0.0292
Ager 55+	-0.0254		0.0075
Car owning	0.0907	-0.0090	
Urban	-0.0153		-0.0171
Livingsize	-0.0003	0.0002	0.0004
y × Couple without children		-0.0026	
y × Single with child	0.0055	-0.0045	
y × Couple with child	0.0046	-0.0036	
y × Gas			-0.0135
y × Heating oil			-0.0195
y × Coal			-0.0166
y × District heating			-0.0141
y × Ownership house		-0.0027	-0.0061
y × Age 55+	0.0054		-0.0023
y × Car owning	-0.0191	0.0021	
y × Urban			0.0029
y × Livingsize	0.0001	0.0000	-0.0001
Price Motor fuels	-0.1409	-0.1409	
Price Living		0.0089	-0.0149
Price Food	-0.2907	-0.3969	
Price Durables			0.0587
Couple without child × Price Motor fuels	-0.0736		
Couple without children × Price Durables	0.0568		-0.0322
Couple with children × Price Living			0.0130
Couples with children × Price Durables			-0.0397
Ownership house × Price electricity		-0.0755	
Ownership house × Price Heating			-0.0541
Ownership house × Price Living	-0.0150	-0.0065	
Ownership house × Price Food		-0.1899	
Ownership house × Price Non Durables			
Ownership house × Price Durables			-0.0389
Car owning × Price Motor fuels		0.0723	
Car owning × Price Electricity	0.0723		
Car owning × Price Food		0.2764	
Urban × Price Heating			0.0457
Urban × Price Living		-0.0077	0.0064
Urban × Price Food	-0.1634		
Urban × Price Non Durables			
Urban × Price Durables			-0.0305

Note: Here only the results of the energy goods that have a significance level of 1% are presented due to the large amount of parameters in the EASI model. Full set of parameters and standard errors available from the authors upon request.

Table A.4: Regression results for motor fuels, electricity and heating

Decile	Without transfers	Flat cash	Geography based	Composition based	Target based	Income based
1st	1.8%	-0.5%	-0.5%	0.0%	0.0%	0.6%
2nd	2.0%	0.5%	0.5%	0.7%	0.7%	1.2%
3rd	2.0%	0.9%	0.8%	1.0%	0.9%	1.0%
4th	1.9%	1.0%	0.9%	1.0%	1.0%	1.0%
5th	1.7%	0.9%	0.9%	0.9%	0.9%	1.0%
6th	1.7%	1.0%	0.9%	1.0%	0.9%	1.0%
7th	1.5%	0.9%	0.8%	0.9%	0.9%	1.0%
8th	1.4%	0.9%	0.8%	0.9%	0.9%	1.0%
9th	1.3%	0.8%	0.8%	0.8%	0.8%	1.0%
10th	1.1%	0.8%	0.8%	0.8%	0.8%	1.0%

Table A.5: Compensating variation before and after receiving transfer schemes