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The distributional effects of carbon tax in EU countries

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Tartu 2023

Table of Contents

We have written this Masters' thesis independently. Any ideas or data taken from other authors or other sources have been fully referenced.

Abstract

This thesis explores how carbon taxation affects households across income quantiles and among adults living in urban, suburban and rural areas in 20 EU countries. Using data from the Household Budget Survey and Emission Intensity, we simulate 25 EUR carbon tax to examine its implications. Our study finds that, on average, the carbon tax burden is almost proportional across income levels in the EU. Western European countries generally have a similar impact, while Southern and Eastern European nations, except for Estonia, tend to experience regressive effects. Cyprus and Bulgaria stand out with the highest variation in the carbon tax burden. We look at the impact of the carbon tax on different spending categories, revealing differences across countries. The carbon tax on food and non-alcoholic beverages is regressive in Baltic and South European countries but proportional in Western European nations and Hungary. In contrast, the carbon tax on housing expenses is generally regressive, except in Estonia and Luxembourg. Notably, the carbon tax on transport has a progressive impact in most member states, except for Belgium, Cyprus, and Luxembourg. Examining urban, suburban, and rural areas, we observe modest variations in the monthly tax burden per adult for carbon taxes on food and non-alcoholic beverages. However, there are distinct patterns for carbon taxes on housing, water, electricity, gas, and other fuels, especially in low-income regions. In these regions, urban populations tend to bear a higher burden compared to rural areas.

1. Introduction

Preventing the potentially disastrous consequences of climate change requires significantly reducing global CO_2 emissions. The EU's share of global cumulative CO_2 emissions (CO_2) from fossil fuels and industry is around 17% for 2021, whereas the US and China contribute almost 24.3% and 14.3%, respectively (Global Carbon Budget, 2022). According to Eurostat, the consumption-based CO_2 emissions in the EU for 2020 was 19,399 million tones, 87.9 % of which was initially emitted in the EU during the production for final use of products within the EU economy (Eurostat, 2022). The EU's commitment to achieving "climate neutrality" by 2050 requires a significant shift in pricing CO_2 emissions to enhance climate goals for a sustainable economy. The focal target is to achieve a minimum 55% reduction in emissions by 2030, relative to the levels recorded in 1990 (*The European Green Deal*, 2021).

One of the policy measures to reduce carbon emissions is pricing the carbon emissions, either through carbon taxes or emissions trading schemes (ETSs). The carbon tax is a particular form of environmental tax imposed on individual activities causing negative externalities with the tax amount determined by the specific harm generated, aiming to align the cost of the action with its societal impact and providing incentives for more environmentally friendly choices (Baumol & Oates, 1971). A carbon tax would reduce energy consumption and expenditures in the long run. Shifting to a low-carbon economy has downsides, like households paying more for heating and transportation. The cost of fossil fuels increases for households due to carbon tax, as companies transfer the expense to consumers. Consequently, this shift is expected to affect the purchasing power of households, influencing day-to-day life. (Fullerton, 2008; Parry et al., 2005)

On the other hand, through ETSs, the government establishes a limit on overall emissions, distributing allowances to regulated firms through free allocation or auction. Each company is granted the privilege to emit within its allocated allowances and can engage in trading allowances with other companies. Unlike ETS, carbon taxes are easier to develop and implement, considering governments have experience collecting taxes; additionally, there is no limit on emissions (Green, 2021).

While Klimenko et al. (1999) shows carbon-tax implementation will only lead to short-term and insignificant changes in emissions, Baranzini et al. (2000) assesses the carbon tax as a cost-effective instrument for reducing emissions, and Hassler et al. (2018) demonstrates that the implementation of carbon taxes has a significant impact in mitigating global warming. However, it is only a little applied by countries worldwide. As of March 31, 2023, only 15 EU member countries have implemented carbon taxes, the lowest being € 2 per metric ton of carbon emissions in Estonia and the highest being € 115.34 in Sweden (see Appendix D). Each country has a different way of implementing a carbon tax, varying in share of greenhouse gas emissions covered. The highest share is 65% in Luxembourg, while Spain has the lowest percentage of its jurisdiction's emissions covered, with only 2% as of 2018. (Tax Foundation, 2023)

Successful carbon tax implementation relies heavily on gaining public acceptability (Bristow et al., 2010). One of the arguments against carbon taxes stems from concerns about their regressive distributional effects, meaning that low-income households spend more on energy-intensive goods like housing, electricity, gas, and, indirectly, food, which leads to a higher tax burden on the poor compared to the rich (Dorband et al., 2019).

However, the carbon tax to reduce emissions and tackle climate change may amplify economic inequalities. According to Chancel (2022) while the top 10% of the world's population emitted 48% of global emissions in 2019, the bottom 50% was 12%. Thus, the fair implementation of the carbon tax leads to one question: who will bear the burden most?

This paper aims to analyze the distributional effects of carbon taxes in selected 20 EU member states, exploring how this simulated carbon tax price may influence different income groups within the targeted nations for different consumption categories. Additionally, we analyze how the carbon tax burden varies by degree of urbanization for several reasons.

Keywords: Carbon tax, inequality, simulation, distributional effects, urbanization, income quantile, consumption, proportional impact, EU member states, progressive effect, regressive effect

Research Classification code(s) (CERCS): S180 - Economics, econometrics, economic theory, economic systems, economic policy

2. Related literature

At first, we explore studies that examine the distributional impact of carbon tax for a group of European countries. Our main focus is comparing data, methodology, indicators, and results across these papers.

Pearson & Smith (1991) study is one of the earliest examining the distributional impact of carbon tax in European countries like France, Germany, Italy, the Netherlands, Spain, Ireland, and the UK. Based on Eurostat data (1985) and the UK Family Expenditure Survey(1988), applying the microsimulation method and taking payments of a mixed carbon and energy tax as a percentage of household total expenditures as an indicator, authors show that the burden of carbon tax payments is only weakly related to income in first five countries. In contrast, their findings revealed a regressive impact in the UK and Ireland. (Pearson & Smith, 1991)

Barker & Köhler (1998) also find the same results for the UK, Ireland, and West Germany, having the most regressive. Still, the impact is weak, and the effect of taxation on domestic energy consumption is the main driving factor. The authors use a time-series, cross-section econometric model that included 11 EU member states to assess the distributional impact of implementing additional excise duties on energy products based on their carbon emission. The study shows the distributional effects by indicating the ratio of regressivity and also projects the impact on GDP, employment, and carbon emission for 2010.(Barker & Köhler, 1998)
Symons et al., (2002) also researched the distributive effects of carbon and energy taxes in France, Spain, Italy, Germany, and the UK using input–output analysis, estimating the energy and CO2 intensity for consumer expenditure categories for 15 commodity groups based on Eurostat (1988) and German Income and Consumption survey (1994), and ranking households in six groups according to their expenditure level. The results differ from the studies mentioned above; for example, the effect for the UK and Italy is neither regressive nor progressive. However, the implementation of the taxes in Germany and France, and slightly in Spain, demonstrated a regressive pattern. (Symons et al., 2002)

Padilla & Roca (2004) paper examines the intercountry distribution of European carbon tax by considering three different scenarios (CO_2 model, 50/50 energy-CO_2 model, and CO_2 model with a burden on nuclear power), assuming internal distribution were completely egalitarian in each of 15 EU member states. To observe the distributional impact of the carbon tax, authors calculated (1) tax burden (as % of GDP), (2) the Kawani index, which is the difference between the Gini concentration index of the tax and pre-tax Gini index, and (3) the Reynolds-Smolensky index which means the difference between the Gini inequality index before and after the tax. Using Eurostat (2001) and International Energy Agency (2001) data and a tax of 50 euros per ton of CO2, the result of the three scenarios is slightly regressive. (Padilla & Roca, 2004)

One of the most recent and comprehensive studies in the literature is the one by Feindt et al., (2021), which shows how the carbon tax affects households in 23 EU member states by applying the input-output and microsimulation models with the Household Budget Survey (2010) from Eurostat. The analysis includes Poland, Romania, Greece, and Bulgaria, which research is limited for these countries. The authors assess the impact by measuring the tax burden relative to expenditures based on European expenditure deciles.(Feindt et al., 2021) The impact for the EU at an aggregate level is regressive, similar to Padilla & Roca's (2004) results. However, it is neutral or progressive for most EU member states at a national level, contrary to Symons et al. (2002).

Table 1. Studies on the distributional impact of carbon tax in selected EU member states
source: compiled by authors

Authors	Country	Methodology	Indicators	Results
Pearson & Smith (1991)	7 EU member states	microsimulation	the proportion of household tax payment	France, Germany, Italy, the Netherlands, Spain weakly regressive, the UK and Ireland strongly regressive
Barker and Köhler (1998)	11 EU member states	econometric model	the ratio of regressivity	West Germany, the UK, Ireland the most regressive, other 8 EU members almost not regressive
Symons et al. (2002)	5 EU member states	input-output model	the change in tax burden	Italy and the UK proportional, Spain slightly regressive, Germany and France regressive
Padilla & Roca	15 EU	empirical analysis	tax burden (as % of GDP),	slightly regressive

(2004)	member states		Kawani index, Reynolds-Smolensky index	
Feindt et al. (2021)	23 EU member states	input-output model	tax burden relative to expenditure	Proportional or progressive at national level for most of countries, regressive at EU level

We continue looking at studies that examine the distributional impact of energy taxes for a group of European countries and the effects of carbon taxation in single member states. There are also several articles focusing solely on fuel or energy taxation and numerous studies analyzing the effect of carbon taxation in single EU-member states, specifically Northern and Western Europe in the literature. It is helpful to look at these papers as we also analyze the carbon tax on direct energy goods like electricity, gas and other fuels (CP04) and transport (CP07). Moreover, there is not many papers specifically focusing on the distributional effects of carbon tax across EU countries. Also, the studies mentioned in Table 1 focus on the vertical distributional effects among households along with income quantiles or deciles. Below we show the literature that also examines the horizontal effects, like differences regarding regions, household types, etc.

Sterner (2012) analyzed the distributional impact of fuel taxation in France, Germany, the United Kingdom, Italy, Serbia, Spain, and Sweden. While comparing the tax burden as % of annual disposable, fuel tax is weakly regressive for most countries except Serbia, the low-income country with a smaller share of the population having cars and an almost neutral impact with a relatively low burden in France. However, results with lifetime income are different; the impact is mainly proportional. Sweden is an exception when considering low population density areas but has high fuel demand due to increased urbanization. (Sterner, 2012)

Brännlund & Nordström (2004) also conclude that households living in less populated areas of Sweden bear a more significant proportion of the tax burden. It has also been demonstrated that raising the carbon tax causes welfare gaps between urban and rural areas (Berg, 2007).
Similar findings are provided by Andersson and Atkinson (2020), who find that the Swedish carbon tax on transportation fuel is progressive between 1999 and 2012 when assessed against yearly income but progressive when measured with lifetime income; additionally, on average, carbon tax burden (% of disposable income) for first income decile is 2.5 times higher in rural

areas than in 3 most prominent cities. (Andersson and Atkinson, 2020)

Contrary to Sterner's (2012) work, Berry (2019) builds a microsimulation model based on a representative sample of the French population, considering each household's consumption of energy on housing and transport, and finds out the regressive impact of carbon tax in France. It leads to an increase in fuel poverty. Moreover, it shows the carbon tax as the share of a household's disposable income is higher in suburbs and isolated towns rather than in cities (Berry, 2019). Similar results have been demonstrated by Bureau (2010), who found that households of the first quintile living in peri-urban or rural areas lose 90% more than the same income quintile in cities.

Another comprehensive study on the distributional impact of fuel taxes (taxes on transport, heating fuels, and electricity) was done by Flues & Thomas (2015), who used a micro-simulation model with expenditure micro-data from household budget surveys for 21 OECD countries (mainly European). According to the authors, the impact of taxes on electricity is regressive, heating fuels are marginally regressive, and transportation fuels have no regressive effects on average. Estimates also show that the larger the household is, the higher the share of their income and expenditure goes to energy taxes, and households in rural areas are more affected by energy taxes than those in urban areas. (Flues & Thomas, 2015)

The distributional impacts of carbon tax between urban and rural households and the effect depending on household size have been discussed in several studies. Wier et al., (2005) research Danish CO2 taxes and find them regressive; low-income households have a higher tax burden due to higher food and public transport consumption. Authors find that while indirect energy consumption does not vary considerably, there is a substantial difference in direct energy consumption between rural and urban households due to higher demand for transportation and heating (Wier et al., 2005). Similarly, Callan et al. (2009) conclude that the impact of the 20-euro carbon tax in Ireland would affect more families living in rural areas because of relatively longer trips by car and bigger houses, leading to more energy usage. Contrary to Flues & Thomas (2015), Weir et al. (2005), Callan et al. (2009) shows that the larger households are, the less they are affected by the carbon tax. Moreover, Feng et al. (2010) estimate the tax burden across different consumption categories for the UK's urban, suburban, and rural areas. Similar to studies on Danish and Irish carbon tax, families living in rural areas bear a higher share of their income for carbon tax than suburban and urban households; it is primarily due to the higher tax burden on housing and transport. Compared to rural areas, families living in suburban and urban areas have easy access to public transport services.

Finally, we continue our review with the categorization of studies based on the methodologies and indicators. The previous literature on the distributional effects of carbon tax varies in terms of the methods, the indicators used, the effects taken into account, and the data employed.
In Kirchner et al., (2018) analysis, the studies were categorized into three general types based on their methodologies:

1) studies that employ microsimulation models with household consumption surveys,
2) studies that integrate static input-output (IO) models with household data,
3) studies that simulate macroeconomic feedback, such as computable general equilibrium (CGE) models or macroeconomic IO models.

The main difference between the first and second methods is to what extent they capture the effect of the carbon tax. While microsimulations address only the direct price changes, input-output models capture indirect price changes. But both of these approaches are limited to only measuring how carbon tax affects relative income or expenditure in terms of distribution. On the other hand, in addition to the differences between after-tax and before-tax in consumption and income, CGE models explore the impact as changes in equivalent variation in terms of capital, labor, and energy, providing feedback on macroeconomic indicators like GDP and employment. (Kirchner et al., 2018)
In some research, the econometric models have also been employed as a methodology (see, for example, Barker & Köhler, 1998; Brännlund & Nordström, 2004; Bureau, 2010)

Considering the indicators used, Wang et al., (2016) classified the studies into four groups: (1) Inequality Index, Comparisons on (2) the carbon tax burden, (3) the welfare changes, and (4) income changes. Specifically, the inequality index includes different metrics like Gini, Theil, and Suits indexes as an indicator. In contrast, the second group indicators are based on the comparisons of absolute tax payment and the proportion of household tax payment in its total income or expenditure. On the other hand, welfare changes have been measured in terms of differences in expenditure and consumer surplus, while comparisons on income changes have taken annual or monthly disposable income and real or lifetime income as an indicator. (Wang et al., 2016)

To conclude, studies that examine the distributional impact of carbon tax for a group of European countries show that the effect is mainly regressive at national level (Pearson & Smith, 1991; Barker & Köhler, 1998; Symons et al., 2002; and Padilla & Roca, 2004), and only one recent study finds the distributional impact being mainly neutral, sometimes progressive (Feindt et al., 2021). Several studies show similar results comparing the effect of carbon, fuel and energy tax burden between different regions for different countries and years ; households in rural areas are more affected by these taxes than those in urban areas (Sterner, 2012; Brännlund & Nordström ,2004; Berg, 2007; Andersson and Atkinson, 2020; Berry, 2019; Bureau, 2010; Flues & Thomas , 2015; Wier et al., 2005; Callan et al. , 2009; Feng et al., 2010). Some studies have different results due to differences in data and methodology used. To look at a more extensive review of the distributional impacts of carbon and energy taxes, one can see Wang et al. (2016), Kosonen (2012) (specifically for Northern Europe) and Köppl & Schratzenstaller (2023).

Overall, previous literature mainly covers Northern, Western and Southern European countries. Thus, we contribute literature by showing estimates for 20 EU countries including countries like Bulgaria, Croatia, Cyprus, Estonia, Greece, Poland, Latvia, Lithuania, and Slovakia which has not been studied much in previous papers regarding the effect of carbon tax. Moreover, we show estimates on the proportion of carbon tax burden to total expenditures for households across income quantiles, which is not much discussed in previous literature. Finally, we extend the literature by adding the comparison of carbon tax burden differences between urban, suburban and rural areas across these countries. We calculate new indicator for this; the absolute differences in tax burden for month per adult. It is more accurate measurement as household size differs and results can be overestimated.

3. Data and Methodology

3.1 Data

To analyze the distributional effects of the carbon tax on households, first, we need to get detailed insights regarding a household's carbon footprint. For this reason, we employ the Household Budget Survey Data from Eurostat and greenhouse gas emissions induced by household consumption data by the European Environment Agency (EEA).

3.1.1 Household Budget Survey

Our analysis is based on the Household Budget Survey from Eurostat (Eurostat, 2020), which provides a comprehensive view of national expenditure patterns across all selected member states. It presents data from each selected country's National Household Budget Surveys (HBS). We take the Structure of consumption expenditure by income quintile and COICOP consumption purpose. The HBS conducts data collection every five years, and the most recent one is in 2020. We took the most recent survey and included 20 EU member states in our analysis[1]: Belgium, Bulgaria, Denmark, Germany, Estonia, Greece, Spain, France, Croatia, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Slovenia, Slovakia.

The HBS compiles data on Expenditure for Consumption, utilizing the Classification of Individual Consumption by Purpose (COICOP). We have chosen ECOICOP-2013 main divisions[2]:

- CP01: Food and non-alcoholic beverages
- CP022: Tobacco
- CP03: Clothing and footwear
- CP04: Housing, water, electricity, gas, and other fuels

[1] Data for Czechia, Ireland, Italy, Portugal, Finland, Sweden, and Romania was unavailable in the 2020 HBS round. The Cyprus, France, and Malta HBS Data for the year 2020 have been produced by converting the HBS Data for the year 2015 to 2020 Reference Year prices using the 2020 HICP coefficient.
[2] CP02 include Alcoholic beverages, tobacco, and narcotics but we had emission intensity data available only for Tobacco and we have taken to consideration only CP022.

- CP05: Furnishings, household equipment, and routine household maintenance
- CP06: Health
- CP07: Transport
- CP08: Communication
- CP09: Recreation and Culture
- CP10: Education
- CP11: Restaurants and hotels
- CP12: Miscellaneous goods and services

Our selected HBS dataset includes the annual expenditure cost of households based on the permille of annual mean expenditure and five income quantiles with 12 different consumption categories in 20 selected EU member states. Moreover, we use data on the structure of consumption expenditure by the degree of urbanization and COICOP consumption purpose.

Additionally, in order to examine and analyze absolute values, we have used annual mean consumption expenditure by degree of urbanization: This data looks at the spending in cities, suburbs, and rural areas, measured in purchasing power standard (PPS) per adult equivalent in euros. It covers the year 2020 for the same selected countries[3]. PPS allows for more accurate comparisons of economic indicators, such as GDP, income, and prices, across different countries. Since it considers the relative cost of goods and services, it provides a more realistic picture of the standard of living and economic conditions in various nations.

3.1.2 Emission Intensity Data

To estimate the carbon footprints, we use greenhouse gas emissions induced by household consumption data in 2007 by the European Environment Agency (EEA, 2012). The emissions are measured as CO2 kg per Euro of expenditure in 12 household consumption (COICOP) categories and include both directly emitted ones (electricity, gas, and other fuels) and indirectly emitted ones that are connected to the production of goods and services (food, clothing, etc.). The calculations are based on Environmentally Extended Input-Output Analysis

[3] We have excluded Malta in our analysis regarding urban and rural differences, reason being, Malta does not have rural population.

(EE-IOA) on Eurostat input-output tables and air emissions accounts for EU-27. The pressure associated with 60 NACE product categories had been then allocated to COICOP categories.

Table 2. Greenhouse gas emissions induced by household consumption, 2007
Source: European Environment Agency, 2012.

Categories	Abbreviations	kg CO2/euro
Food and non-alcoholic beverages	CP01	0.848
Tobacco	CP022	0.042
Clothing and footwear	CP03	0.14
Housing, water, electricity, gas and other fuels	CP04	0.977
Furnishings, household equipment, and routine household maintenance	CP05	1.084
Health	CP06	0.213
Transport	CP07	1.218
Communications	CP08	0.15
Recreation and Culture	CP09	0.262
Education	CP10	0.174
Restaurants and hotels	CP11	0.377
Miscellaneous goods and services	CP12	0.126

There is a primary limitation due to the time variance in the datasets used. While the Household Budget Survey (HBS) data is connected specifically to the year 2020, the data regarding GHG emissions induced by household consumption extends back to 2007. To address this limitation, we deflate annual mean consumption expenditure by degree of urbanization in 2020 to the year 2007 prices. We use the Harmonized Index of Consumer Prices (HICP) with annual data (average index and rate of change) covering the period from 2007 to 2020. However, we still employ the structure of consumption expenditure for the year 2020.

Our focus on carbon tax-related issues may present challenges when utilizing the GHG emissions induced by household consumption data, which covers a wide range of greenhouse gas emissions, not solely carbon emissions. Our perspective introduces limitations, emphasizing the need for careful consideration in aligning it with the carbon-related metrics we examine.

3.2 Methodology

In this section, we present our methodology, which means how we simulate the carbon tax and find carbon tax burden. This enables us to assess the distributional effects of carbon taxation at a granular level.

We employ a simulation methodology to assess the distributional effects of carbon tax in selected EU member states. This methodology has been used in previous literature (Pearson & Smith 1991; Tiezzi, 2005; Callan et al., 2009; Berry, 2019). Our simulation needs insights about household carbon footprints, which we find using the Household Budget Survey and GHG emission data that have been explained previously in this paper.
We then proceed to simulate the impact of a carbon tax burden across all selected consumption categories and socioeconomic rankings by taking ceteris paribus into consideration, meaning that households bear any other related and unrelated costs resulting from the carbon tax.

For the purpose of assessing the distributional impacts of a carbon tax, it is necessary to group households from rich to poor. There are a number of studies that sort households based on their annual income, but statistical data on the incidence of tax on households and consumption indicate that current consumption represents a better measurement of welfare than annual income in the tax incidence literature. (Poterba, 1989)
We assume that the existing national carbon pricing systems remain unaffected in our scenario, indicating that countries with established schemes embrace more ambitious carbon pricing strategies than those without such structures. This difference in ambition levels, spanning both European and national contexts, has been an ongoing phenomenon since the inception of the EU ETS. (Worldbank, 2020; Feindt et al., 2021). Thus, in our simulation, we set a 25 EUR/tCO2 carbon tax. This figure was derived from the EU ETS market average mean price over 2020, which was 24.48 euro/tCO2 (EEX EUA, 2020). We agreed to use approximation and set the price to 25 euro/tCO2 for our calculations.

The focal indicator in our analysis is the proportion of the carbon tax burden to the total consumption expenditure to understand the economic impact of carbon taxes on households. We calculate the tax burden of households for 12 COICOP consumption categories for each income quantile in 20 selected EU member states. Comparison on carbon tax burden has been commonly used in previous literature (Wier et al., 2005; Kerkhof et al., 2008; Verde & Tol, 2009; Flues & Thomas, 2015).

To calculate the proportion of the carbon tax burden to the total consumption expenditure, we first divide household expenditure share (per mille) by 1000 and multiply by GHG emissions induced (CO2 kg per Euro), respective of each consumption category, then multiply it by assumed carbon tax of 0.025 EUR/kg CO2. The equation for calculating the proportion of the carbon tax burden to the total consumption expenditure is as follows.

Let H_p^q be the share of consumption category p in total consumption for the household from income quintile q according to HBS, I_p be GHG emissions of consumer good p, T be the carbon tax, C^q the total consumption of household from income quintile q and Y^q be the carbon tax burden of household from income quintile q.

$$\boldsymbol{Y^q = \sum_{p=1}^{12} H_p^q \times I_p \times T \times C^q} \qquad \textbf{(1)}$$

In our analysis, we look at the coefficient of variation of tax burden relative to expenditures within income quantiles; it is useful for understanding how the variability of the tax burdens compares across different income groups. Moreover, we consider the difference between the tax burden shares of first and fifth quantiles to compare the poorest and richest households.

Secondly, we assess the effect of the carbon tax by degree of urbanization. We analyze it by the difference in carbon tax payments per month among adults living in cities, suburbs, and rural areas. A comparison of carbon tax burden by absolute values has been used previously by Callan et al. (2009), who took carbon tax payment per week as an indicator.

Our analysis and calculations are mainly done in the R programming language and Excel. We have done data cleaning, data structuring, data preparation, and data visualization using these software tools.

4. Results

In this section, we clarify the details of the carbon tax burden through a comprehensive analysis. In Section 4.1, we make a detailed examination of the impact of the carbon tax across income quantiles, resulting from our simulation covering 20 chosen EU member states. In Section 4.2, we extend our analysis to assess the effects of the carbon tax across varying degrees of urbanization.

4.1. Structure of consumption by income quintiles

We assess the impact of carbon taxation on different consumption categories across income quantiles in selected EU member states - this analysis includes consumption categories that are prioritized based on the structure of total mean expenditure of households. Firstly, we present a table illustrating the percentage distribution of selected consumption categories within the total annual mean expenditure, specifically focusing on CP01 (Food and non-alcoholic beverages), CP04 (Housing, water, electricity, gas, and other fuels), and CP07 (Transport). On average, these three categories collectively account for a substantial portion of household consumption expenditures, representing 60.8% of the total on the European level. The distribution of this average indicates percentages of 17.8%, 32.4%, and 10.6% for CP01, CP04, and CP07, respectively. Looking at the country-specific figures, it's interesting that Hungarian households, on average, allocate 73.6% of expenditures on these three categories, which is the highest among the countries we selected. In contrast, households in Malta have the lowest spending, dedicating 43.9% of their expenditures to CP01, CP04, and CP07 combined.

Table 3: Structure of consumption expenditure by income quintile and Food and non-alcoholic beverages (CP01), Housing, water, electricity, gas, and other fuels (CP04), and Transport (CP07) consumption purposes, with %

Source: Authors' calculations based on Eurostat

	CP01					**CP04**					**CP07**				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Belgium	14.9	15.7	16.0	15.8	16.4	38.1	36.7	34.1	29.9	26.7	7.6	8.3	8.7	11.9	10.2
Bulgaria	32.5	28.4	26.7	24.3	20.2	41.6	41.7	37.6	34.6	28.7	1.4	3.4	5.5	7.7	9.7
Denmark	12.5	13.2	12.9	12.5	11.5	43.7	39.6	34.4	32.0	28.7	7.3	10.8	13.0	15.4	17.7
Germany	14.0	12.5	11.7	11.3	9.8	41.2	36.1	33.5	30.7	26.6	8.1	10.2	12.1	13.1	17.1
Estonia	27.2	21.3	20.4	19.1	14.4	29.6	34.1	33.0	31.0	34.0	5.2	9.7	9.1	11.8	13.8
Greece	22.2	22.7	21.1	19.7	17.6	38.6	36.8	33.2	31.0	28.7	5.2	6.8	8.4	10.1	10.6
Spain	19.7	18.8	17.7	17.0	14.7	42.6	36.8	35.3	34.1	34.1	7.2	9.8	10.5	10.8	10.6
France	14.7	15.0	15.4	15.0	12.8	34.7	32.8	30.5	27.9	25.5	10.2	11.3	12.1	13.9	14.9
Croatia	27.6	23.6	22.1	19.8	18.3	44.8	38.7	32.7	29.9	28.0	4.3	9.3	11.4	13.7	16.4
Cyprus	22.6	19.8	17.0	14.6	11.7	32.2	29.1	25.4	24.0	23.8	10.4	10.1	12.4	12.6	12.4
Latvia	26.5	23.8	21.8	21.7	16.7	40.6	33.8	26.8	22.1	18.9	3.1	6.6	11.6	14.1	16.8
Lithuania	28.2	24.2	23.8	24.2	21.3	38.6	39.8	35.5	35.6	26.8	5.1	7.0	8.3	8.4	12.9
Luxembourg	12.3	10.0	9.8	9.2	8.2	38.7	34.2	36.2	34.7	33.9	13.3	18.1	15.3	17.9	15.8
Hungary	17.3	16.9	17.1	16.3	15.2	57.4	55.4	50.6	49.0	42.9	2.9	4.2	6.7	7.4	8.7
Malta	25.6	25.1	20.7	18.6	16.1	16.2	10.9	8.1	6.6	6.3	9.1	10.6	13.7	14.3	17.6
Netherlands	11.8	11.5	11.7	11.6	11.4	38.5	36.2	33.3	28.9	24.9	5.2	7.8	9.6	10.9	13.4
Austria	14.1	12.7	12.8	11.8	10.7	32.5	28.5	25.2	23.4	19.8	9.6	12.5	13.1	14.6	16.2
Poland	24.5	25.9	26.3	25.5	22.5	40.2	38.6	34.4	30.9	26.9	5.3	5.5	7.4	8.2	10.1
Slovenia	18.2	15.8	14.1	13.0	11.6	37.5	30.9	25.2	21.7	18.6	9.5	13.9	17.7	20.0	22.7
Slovakia	22.4	21.4	20.6	19.9	18.5	43.3	36.3	32.5	31.0	30.2	3.6	8.4	9.4	9.3	9.6

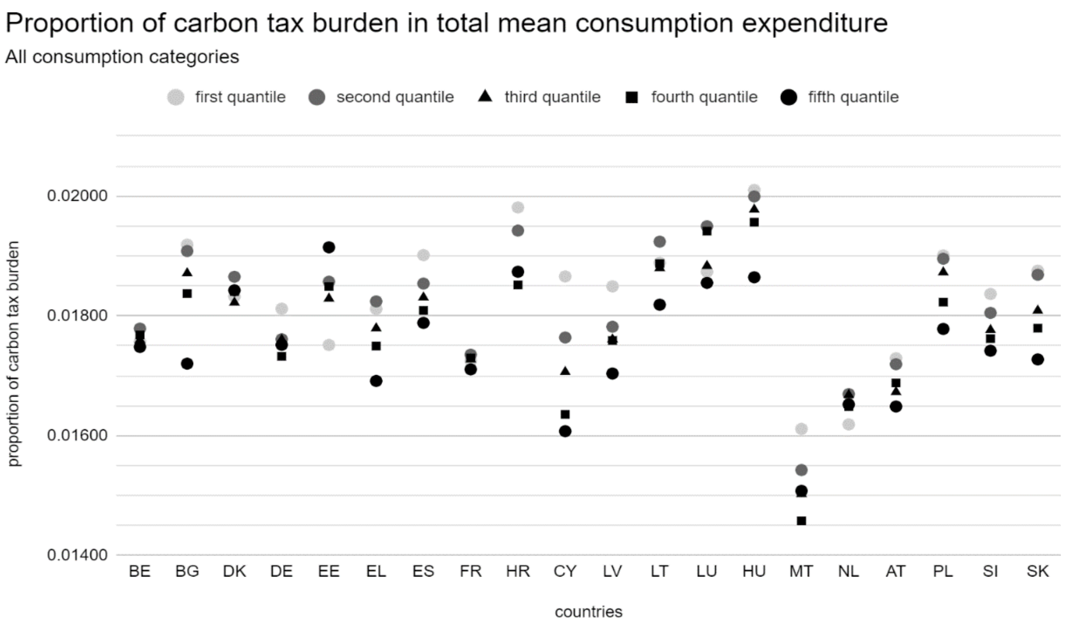
Moreover, on average, other nine categories constitute 39.2% of the total consumption expenditure on the European level. Among them, Miscellaneous goods and services (CP012) has the highest share on average with 7.9% of total consumption expenditure, whereas Education (CP10) has the lowest share on average with 0.98%. Looking at the country-specific figures, approximately 17% of total consumption of richest households in the Netherlands are Miscellaneous goods and services (CP012) which is the biggest among other nations. The fifth income quantile households in Cyprus are the ones with highest spending on Education, with

6.7% of their total consumption expenditure. We add the structure of all consumption categories across income quantiles more in detail in Appendix B.

4.2. Carbon tax burden by income quintiles

Figure 1 illustrates the ratio of the carbon tax burden across income quantiles, considering the annual mean expenditure of 20 EU states. Each dot provides a summary of the distribution of the tax burden among all households within the respective income quantile. On average, the proportion of the carbon tax burden to total consumption expenditure is approximately 1.8% in these nations, with a coefficient of variation of 3% across all income quantiles and 0.1 percentage point between the shares for the first and fifth quantile; meaning differences between tax burden of households across income quantiles is not high on the European level. In nations characterized by a relatively high annual mean consumption expenditure, particularly in Western European countries like Belgium, Germany, France, Luxembourg, and the Netherlands, the impact of the carbon tax is proportional, meaning there is no noticeable difference between the first and fifth quantile. Meanwhile, the impact in Southern and Eastern European nations tends to be regressive, with Estonia being an exception.

Figure 1. The proportion of the carbon tax burden in total mean consumption expenditure across income quantiles for all consumption categories
Source: Authors' calculations based on Eurostat



Compared to the European average, the highest variation of the carbon tax burden across quantiles is observed in Cyprus and Bulgaria, the coefficient of variation being 6.05% and 4.31%, respectively. For instance, the richest households in Cyprus would allocate 1.61% of their total annual consumption expenditure to carbon tax payments, while the poorest would contribute 1.87%. Bulgaria exhibits a noticeable contrast between the first and fifth quantiles, with percentages of 1.92% and 1.72%, respectively.

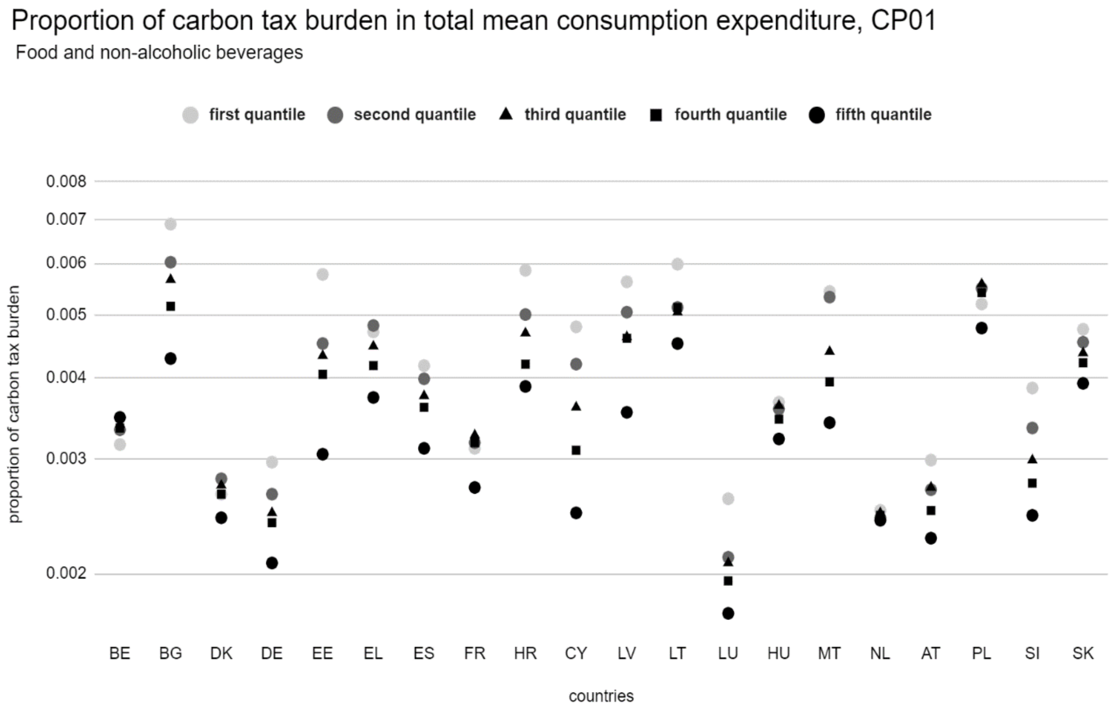
Contrary to Kerkhof et al. (2008), who found the carbon tax to be regressive for the Netherlands, our results show the effect to be almost proportional; we assume this difference is due to different data employed for years 2000 and 2020. Overall, the findings of Feindt et al. (2021) also confirm that the effect of carbon tax is neutral or progressive for most EU member states at a national level.

Figure 2 shows the share of the carbon tax burden in total expenditure across income quantiles for Food and non-alcoholic beverages (CP01). The high variation of the burden of the carbon tax on food and non-alcoholic beverages across quantiles is discovered mainly in Baltic and South European countries like Bulgaria, Estonia, Croatia, Cyprus, Latvia, Malta, and Slovenia; the impact is regressive.

The poorest Bulgarian household would bear almost 0.7% of total consumption expenditure as a carbon tax payment on the CP01 category, whereas the richest would pay 0.43%, 63% less than the first quantile in terms of share.

Figure 2. The share of the carbon tax burden in total expenditure across income quantiles for Food and non-alcoholic beverages (CP01)

Source: Authors' calculations based on Eurostat.

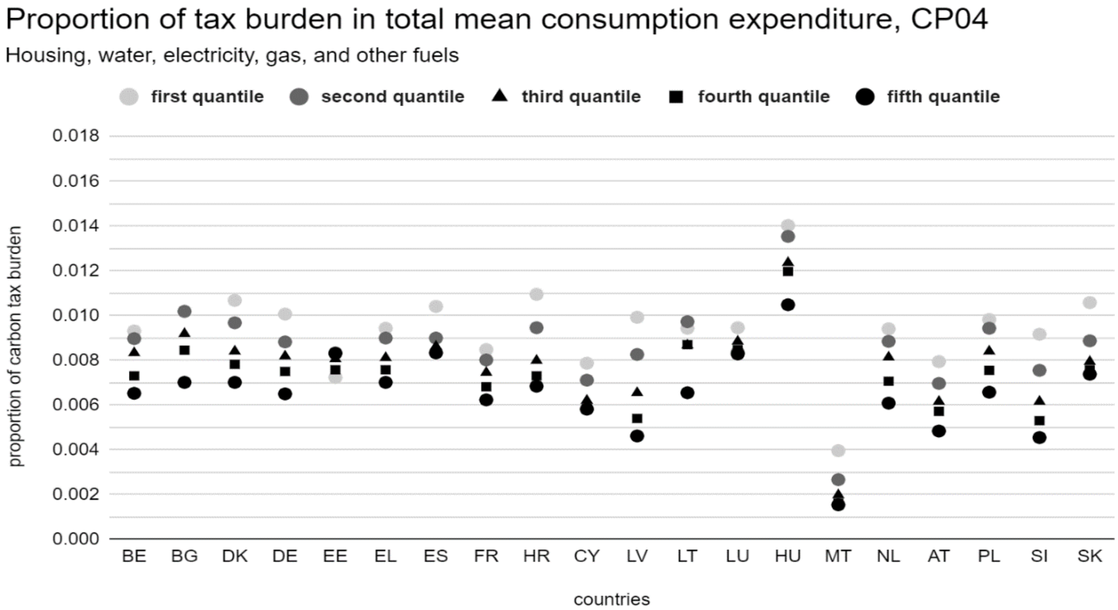


The lowest-income households in Estonia would have approximately 0.6% tax burden from food and non-alcoholic beverages, relative to expenditure, while this number for the fifth quantile household is around 0.3%. However, the impact of the carbon tax on this consumption category for Western European countries (Belgium, the Netherlands, and France) and Hungary is proportional. While on average, the coefficient of variation for the mentioned Baltics and South European countries is around 19%, this figure for Western European countries and Hungary is around 4%. The less degree of variation across quantiles, the more proportional effect it is.

We shift our focus to the CP04 consumption category, which includes electricity, gas, and other fuels, and also accounting for costs related to actual rentals for housing, regular maintenance and repair, and other services associated with the dwelling.

Overall, contrary to the carbon tax on the CP01 category, the effect of such tax on CP04 would be regressive in most of the selected EU countries, but two exceptions stand out: Estonia and Luxembourg, where the carbon tax impact is almost proportional. See Figure 4 below.

Figure 3. The share of the carbon tax burden in total expenditure across income quantiles for Housing, water, electricity, gas, and other fuels (CP04)
Source: Authors' calculations based on Eurostat.

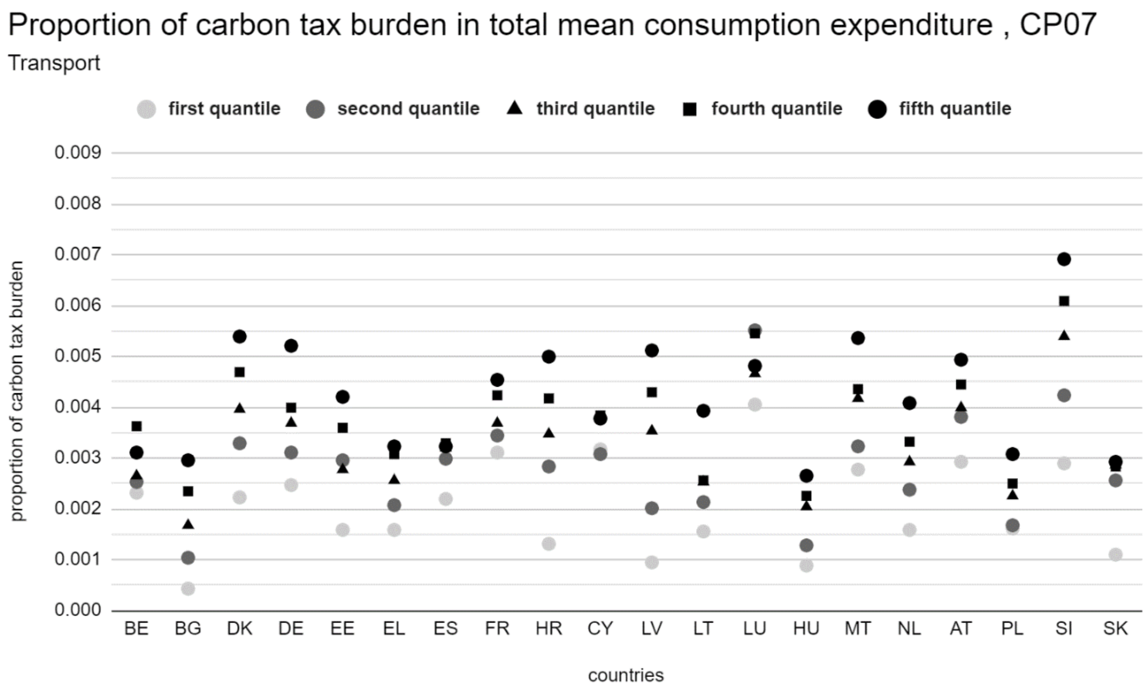


The high variation of burden across quantiles and big differences between the lowest and highest-income households, being two times more, are observed in Latvia, Croatia, and Slovenia. Although Malta's coefficient of variation is more than 42%, the difference between the first and fifth quantiles is below the European average. While the poorest household in Latvia would have approximately 1% carbon tax burden for housing, water, electricity, gas, and other fuels, the highest-income families would bear only 0.46% of their annual expenditure. The main reason for this high difference is related to the variation between income quantiles for the CP04 consumption category and annual mean expenditure. The share of housing, water, electricity, gas, and other fuels relative to total expenditure for the first quantile is 40.6%, while this number for the fifth quantile is around 19%. Additionally, the annual mean expenditure of the richest household in Latvia is 4.6 times more than that of the poorest.

Figure 4 shows the share of the carbon tax burden in total expenditure across income quantiles for Transport (CP07). This category includes expenditure regarding the purchase of vehicles, operation of personal transport equipment, and transport services. In contrast to the prior two consumption categories, the carbon tax on transport differs by having a progressive impact in most member states, exclusive of Belgium, Cyprus, and Luxembourg.

Figure 4. The share of the carbon tax burden in total expenditure across income quantiles for Transport (CP07)

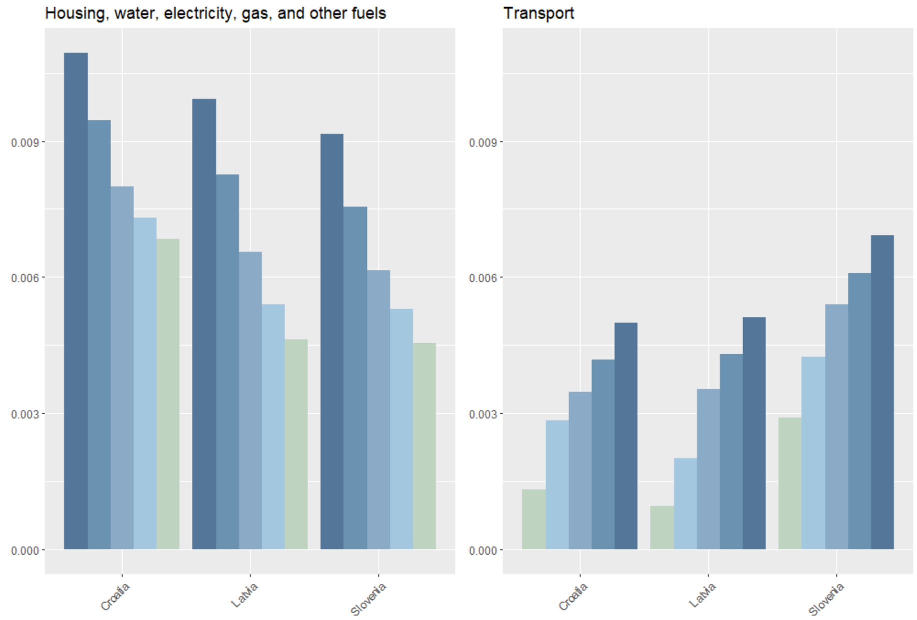
Source: Authors' calculations based on Eurostat.



It is interesting that the exact opposite of the pattern for the effect on CP04 is being observed for these three countries in terms of the impact of carbon tax on transport. The gap between the burden relative to expenditures of the first and fifth quantile households of Croatia (0.37%), Latvia (0.42%), and Slovenia (0.40%) is the highest compared to other member states. See Figure below.

Figure 5. The share of the carbon tax burden in total expenditure across income quantiles for CP04 and CP07 for Croatia, Latvia, and Slovenia

Source: Authors' calculations based on Eurostat



For the remaining consumption categories, the effect of the carbon tax has been shown in the following table.

Table 4. Summary of remaining consumption categories, with indicators showing mean tax burden (%), the average coefficient of variation (%), and the effect of carbon tax

Source: Authors' calculations based on Eurostat.

Category	mean tax burden (%)	average CV(%)	the effect
CP022	0.001	35	regressive
CP03	0.014	20	progressive
CP05	0.13	16	progressive
CP06	0.02	15	almost proportional and regressive in Bulgaria, Estonia, and Latvia
CP08	0.03	12	regressive for mainly high-income countries, progressive for others
CP09	0.014	22	slightly progressive

CP10	0.004	56	progressive
CP11	0.005	29	progressive
CP12	0.03	14	progressive

The impact of the carbon tax on these categories is mainly progressive, excluding CP022, CP06, and CP08. On average, at the European level, the share of tobacco (CP022) in total consumption expenditure is 1,3%, and the first quantile households consume slightly more than twice compared to the fifth quantile. This is the main reason behind the fact that the carbon tax on tobacco would be regressive.

In contrast with the other 11 consumption categories, the effect of the carbon tax on the health category (CP06) is neutral, excluding regressive impact for Bulgaria, Estonia, and Latvia, where tax burden relative to expenditures across quantiles is highly varied compared to other member states, the coefficient of variation is 25%, 47%, and 31%, respectively.

Another different trend is observed in the communication category (CP08), in which European households would have a 0,014% tax burden; the effect of the carbon tax would be regressive in high-income countries like Belgium, Denmark, Germany, France, and Luxembourg. This thorough examination underlines the importance of understanding carbon tax impacts not only across diverse income quantiles but also within specific consumption categories. More details can be acquired from Appendix A.

4.3. Carbon tax burden by urban density

We assess these differences by looking at the data on the mean consumption expenditure per adult equivalent and the structure of consumption expenditure by degrees of urbanization and COICOP consumption purpose. Detailed information can be found in Appendix C.

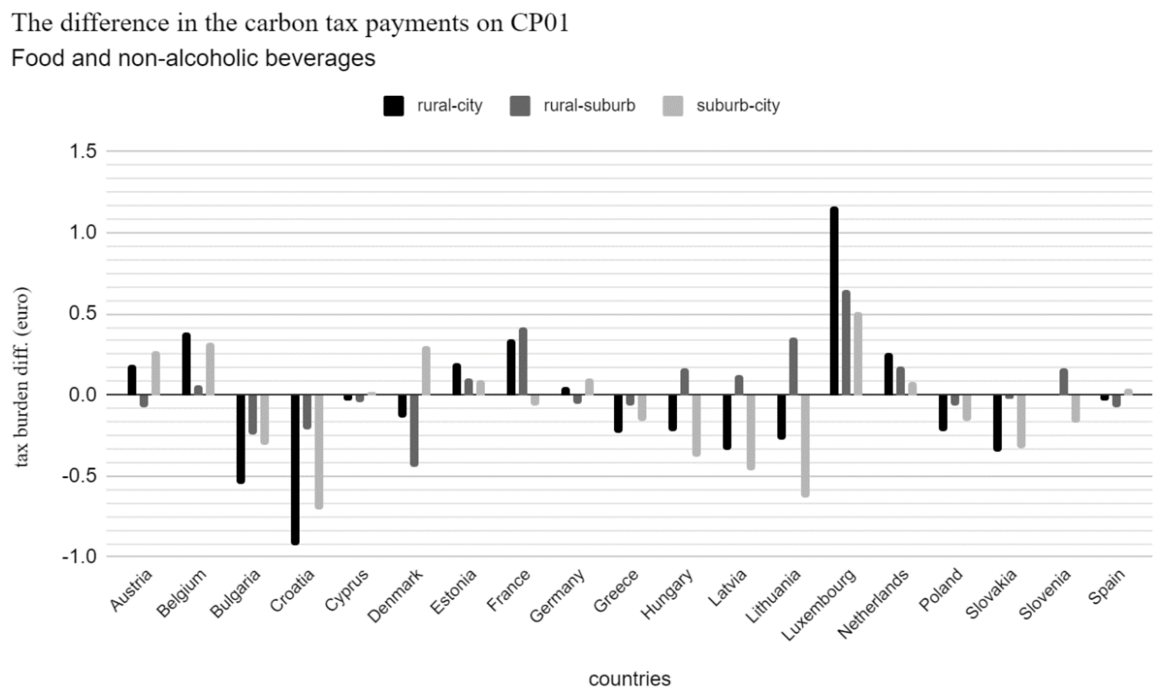
Table 5. The mean consumption expenditure per adult equivalent and the structure of consumption expenditure by degrees of urbanization and COICOP consumption purpose. Source: Authors' calculations based on Eurostat.

country	city				suburb				rural			
	Expenditure	CP01	CP04	CP07	Annual Expenditure	CP01	CP04	CP07	Annual Expenditure	CP01	CP04	CP07
Austria	28,594	12	25	11.2	30,614	12	24	14	28,522	12	24	16
Belgium	24,129	16	33	8.6	25,142	16	31	10	25,344	16	32	11
Bulgaria	13,014	21	37	7.3	9,535	27	32	6	7,924	31	29	6
Croatia	17,948	19	34	10.8	14,276	22	31	14	13,215	22	31	14
Cyprus	26,178	14	26	11.9	22,261	17	24	12	21,067	17	25	12
Denmark	23,600	12	35	12.9	25,839	12	33	15	22,229	13	32	15
Estonia	16,335	18	35	9.9	17,309	17	35	12	14,445	21	28	14
France	23,259	14	30	12	21,385	15	29	14	21,792	15	27	15
Germany	25,164	11	31	12.4	26,162	11	31	14	25,863	11	32	16
Greece	16,138	19	33	8.7	15,495	19	32	9	12,478	23	31	9
Hungary	21,444	16	47	6.6	19,453	16	51	7	18,740	17	51	7
Latvia	17,066	18	26	12	14,088	20	26	14	11,810	25	22	14
Lithuania	20,614	20	40	8.3	14,119	27	25	10	13,886	28	26	11
Luxembourg	43,400	9	34	15.2	40,256	10	35	16	48,193	9	36	19
Netherlands	26,495	12	31	9.8	27,385	11	30	11	26,608	12	30	11
Poland	14,614	22	34	7.4	12,514	25	34	7	11,122	28	30	9
Slovakia	12,647	18	38	7.5	10,507	20	31	9	9,868	22	32	9
Slovenia	22,079	12	28	16.2	17,944	14	24	18	18,344	14	23	20
Spain	22,022	16	38	8.8	20,502	17	33	12	18,449	19	34	12

When we look at the differences in annual mean expenditures per adult equivalent, people in cities spend more money than those in the suburbs and rural in most selected nations, except in countries like Belgium, Germany, and the Netherlands. Moving on to the share of food and non-alcoholic beverages (CP01) in total expenditure, overall, there is no considerable variation between households in cities, suburbs, and rural areas. But the difference between rural and urban households' shares of expenditure on the CP01 category in Bulgaria, Latvia, Lithuania, and Poland, on average, is around 8%. Moreover, Bulgaria and Lithuania are also an exception regarding differences in the share of Housing, water, electricity, gas, and other fuels (CP04) relative to expenditures, where households in cities allocate more of their annual spending to CP04 than those in rural areas.

Considering the share of transport in total expenditure, in general, there are small differences by degree of urbanization in most member states, excluding Austria, Estonia, and Spain, where families living in rural areas dedicate more of their total consumption than in cities.

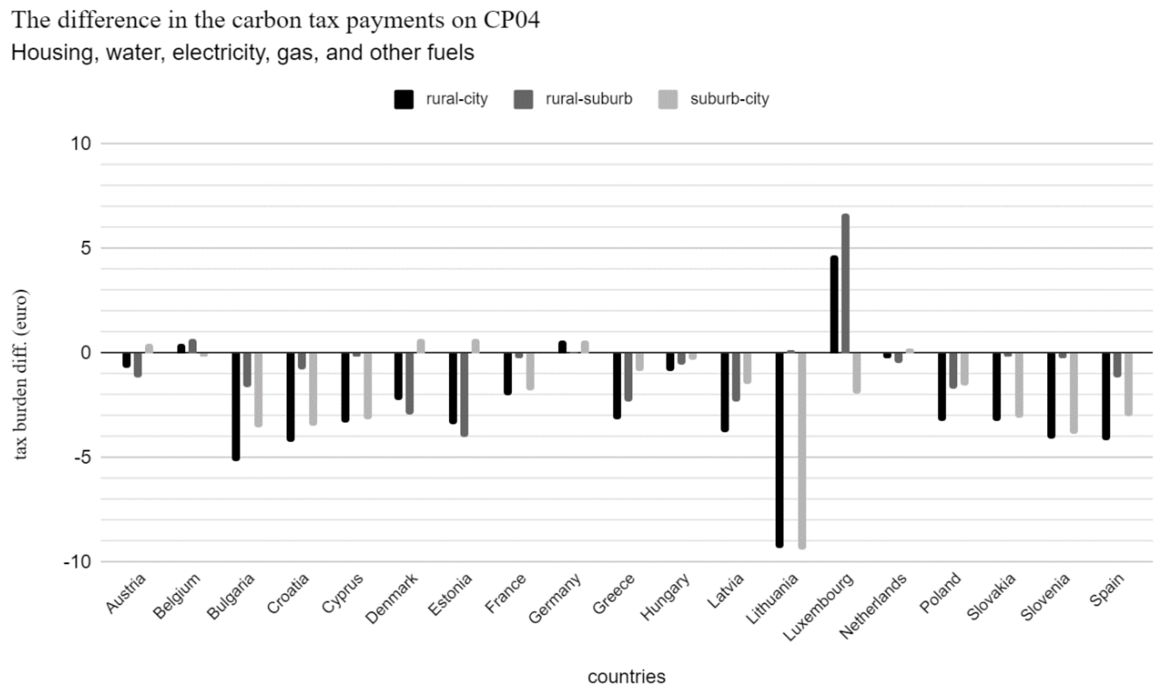
Figure 5. The absolute value difference in the carbon tax payments on food and non-alcoholic beverages (CP01)
Source: Authors' calculations based on Eurostat.



Firstly, the absolute value difference in carbon tax burden per month on food and non-alcoholic beverages (CP01) is relatively high in Luxembourg compared to other countries, meaning people in rural areas would bear 1.2 euros more carbon tax in a month than those in cities. Overall, in most countries, the difference is below 1 euro per month, and the tax burden for rural and suburban residents is more than for urban ones.

Figure 6. The absolute value difference in carbon tax payments on housing, water, electricity, gas, and other fuels (CP04)

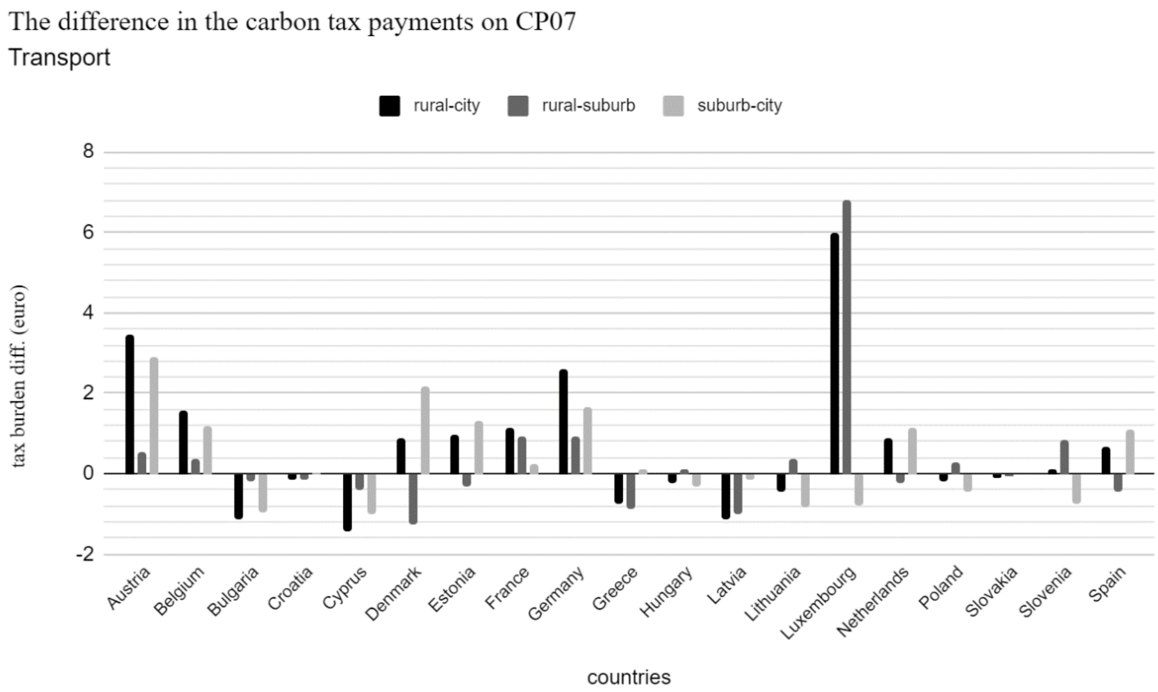
Source: Authors' calculations based on Eurostat



Secondly, housing, water, electricity, gas, and other fuels (CP04), a visible pattern emerges, particularly in countries such as Bulgaria, Croatia, Cyprus, Greece, Lithuania, Latvia, Poland, Slovakia, Slovenia, and Spain, where urban population experience particularly higher payments compared to rural; the highest difference being more than 9 euros in a month in Lithuania.

Denmark and Estonia show an interesting contrast, as suburban residents spend more on CP4 than rural ones. Turning our attention to Luxembourg, the same figure is higher for rural areas, where people bear a heavier burden, paying more than the urban population; the absolute difference is around 5 euros in a month.

Figure 7. The absolute value difference in the carbon tax payments on transport (CP07)
Source: Authors' calculations based on Eurostat



Lastly, looking at CP07, covering transport-related expenses, we observe noticeable variations in the carbon tax payments between rural and urban households. In Austria, Germany, and Belgium, households in rural areas bear a relatively higher burden, showing that people in those areas pay 3.5, 2.6, and 1.6 euros more, respectively. However, there is a singular exception between suburb and rural, and it's in Luxembourg, where the difference spikes to 6.81. Comparing city and suburb regions, noticeable differences are observed, particularly in Austria, Denmark, Germany, and Estonia.

5. Conclusion

In this paper, we studied the impact of 25 EUR/tCO2 carbon tax on households by income quantile and degree of urbanization by employing a simulation model in 20 selected EU member states. Our analysis is based on a comparison of carbon tax payments: (1) the proportion of carbon tax burden to total expenditures for households across income quantiles and (2) the absolute differences in tax burden per adult living in urban, suburban, and rural areas.

Our findings suggest that, on average, the carbon tax burden is almost proportional across income quantiles at the European level. While Western European countries generally exhibit proportional impact, Southern and Eastern European nations, with exceptions like Estonia, tend to experience regressive effects. Cyprus and Bulgaria stand out with the highest variation in the carbon tax burden across quantiles.

Some EU countries did not implement the carbon tax and in countries like Estonia, Latvia, Poland, and Slovenia, the carbon tax rate is below 25 EUR per ton. Our findings can be useful while considering the implementation or increase of carbon tax.

The high variation of the burden of the carbon tax on food and non-alcoholic beverages across quantiles is discovered mainly in Baltic and South European countries like Bulgaria, Estonia, Croatia, Cyprus, Latvia, Malta, and Slovenia; the impact is regressive. This means the implementation of a 25 EUR carbon tax or an increase in the current carbon price can lead to an increase in inequality between the poorest and richest households in these countries. Similarly, the effect of a 25 EUR carbon tax on housing, water, electricity, gas, and other fuels (CP04) is regressive in most of the selected EU countries. Thus, the implementation or increase of carbon tax on industries related to this consumption category may cause more inequality between rich and poor households. However, the effect of a carbon tax on categories like Clothing and footwear (CP03), Furnishings, household equipment, and routine household maintenance (CP05), Education (CP10), Restaurants and hotels (CP11), Miscellaneous goods and services (CP12) is progressive. We expect that applying a 25 EUR carbon tax will not lead to a disparity among income quantiles in terms of these consumption categories.

The effect of carbon tax on food and non-alcoholic beverages for urban, suburban, and rural areas is not highly varied, in most countries, the absolute difference in monthly tax burden per adult is below 1 euro per month. The urban population experiences a particularly higher burden compared to rural when looking at the carbon tax on housing, water, electricity, gas, and other fuels.

The analysis of transport-related expenses (CP07) reveals noticeable variations in carbon tax payments between rural and urban households across countries, with Austria, Germany, and Belgium showing higher burdens for rural areas, a considerable increase in Luxembourg, and noticeable differences in city and suburb regions.

As a future research direction, before and after Covid periods can be studied due to the change in consumption patterns in this period. Moreover, the different methodology, such as computable general equilibrium (CGE) models, can be applied to see the effect of the carbon tax on macroeconomic indicators like GDP and employment.

6. References

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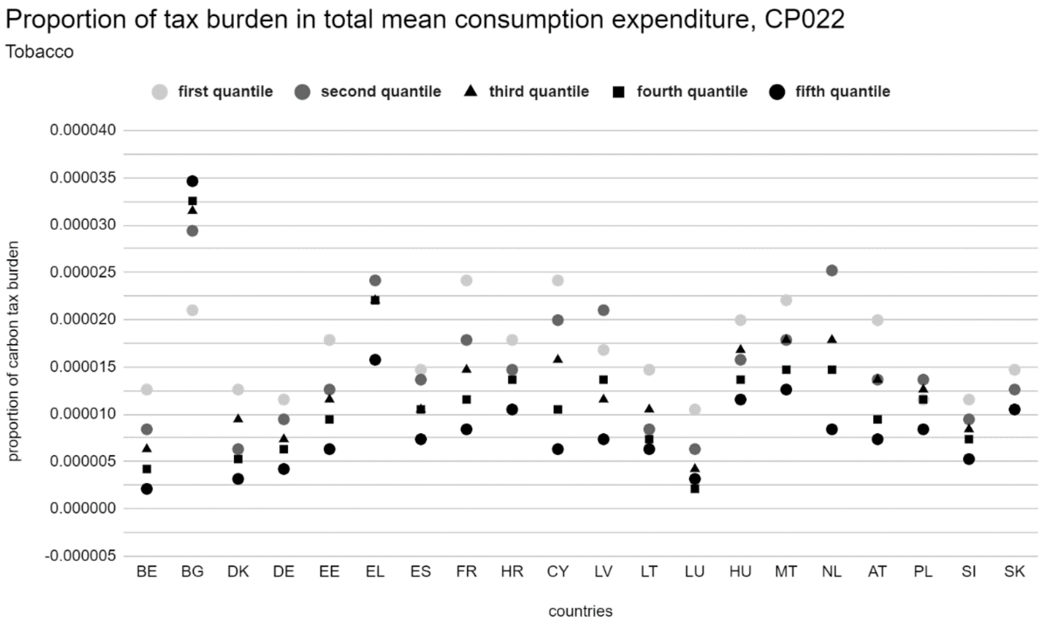
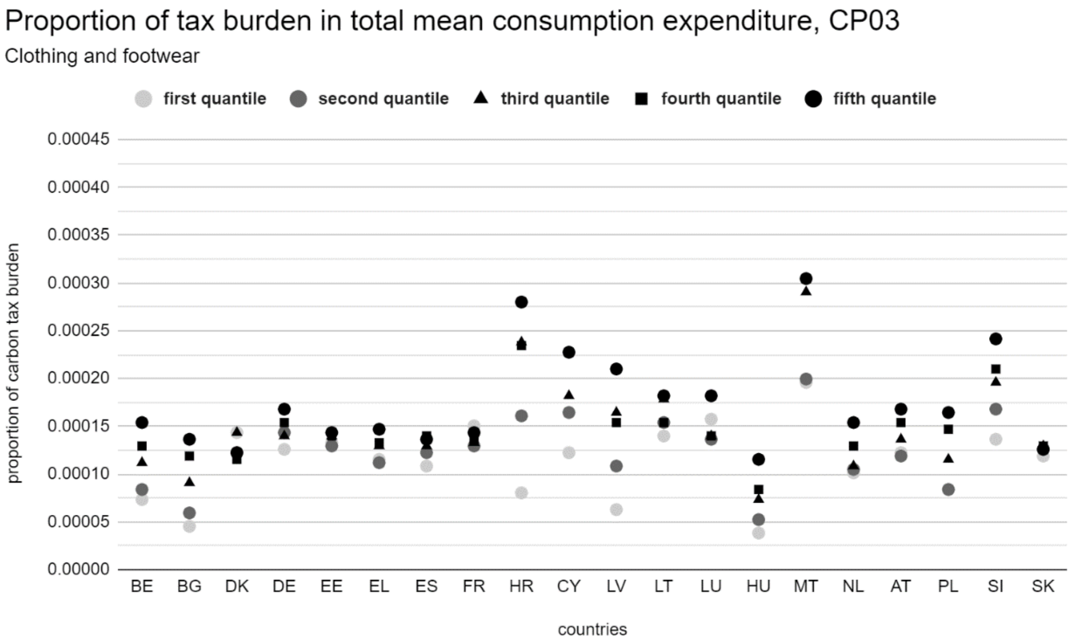
7. Appendices

Appendix A

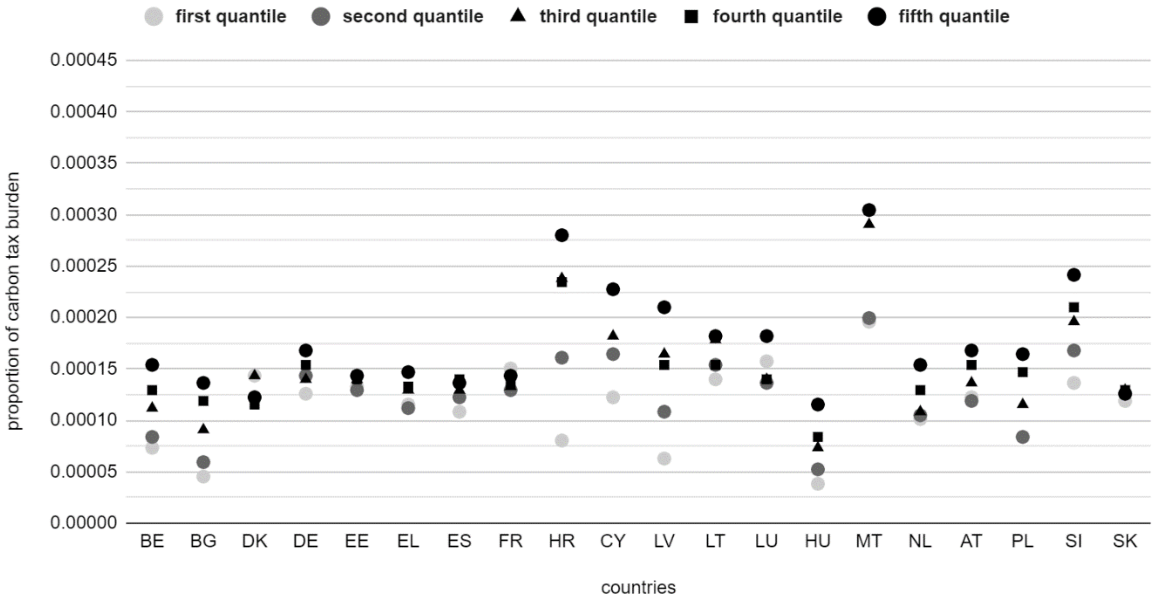
Proportion of tax burden in total mean consumption expenditure across consumption categories





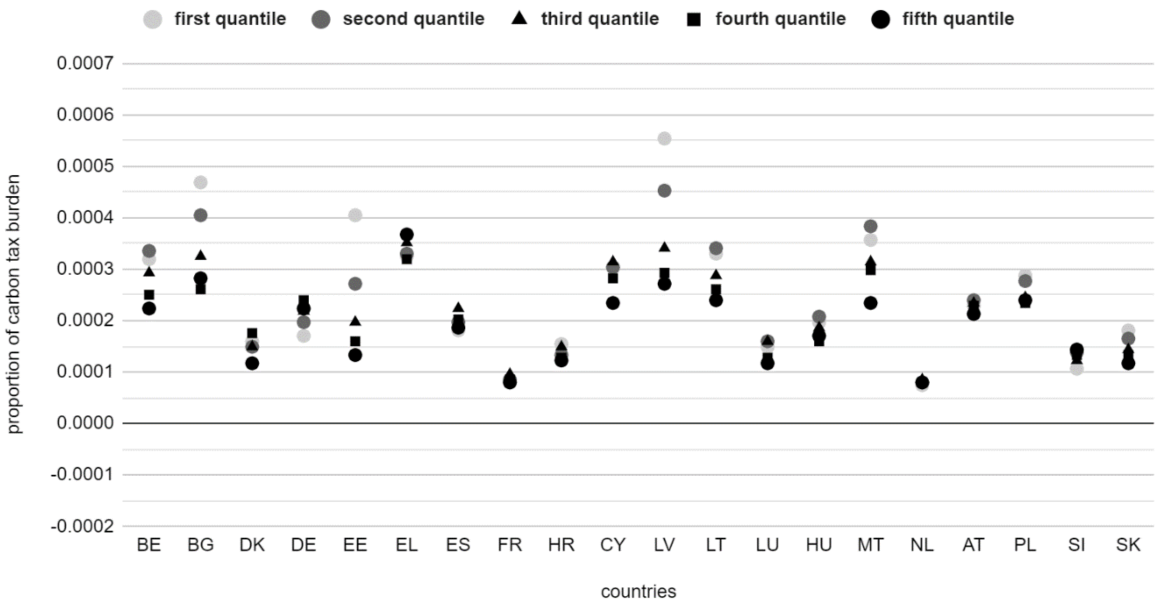
Proportion of tax burden in total mean consumption expenditure, CP03

Clothing and footwear



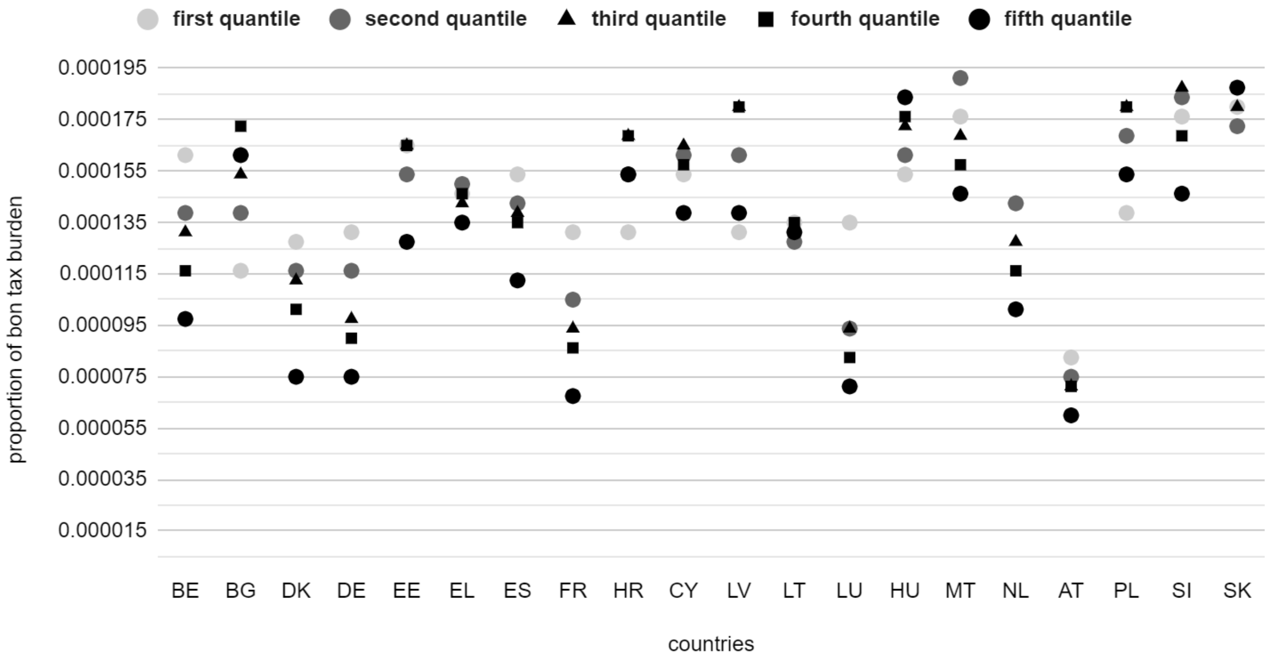
Proportion of carbon tax burden in total mean consumption expenditure, CP06

Health



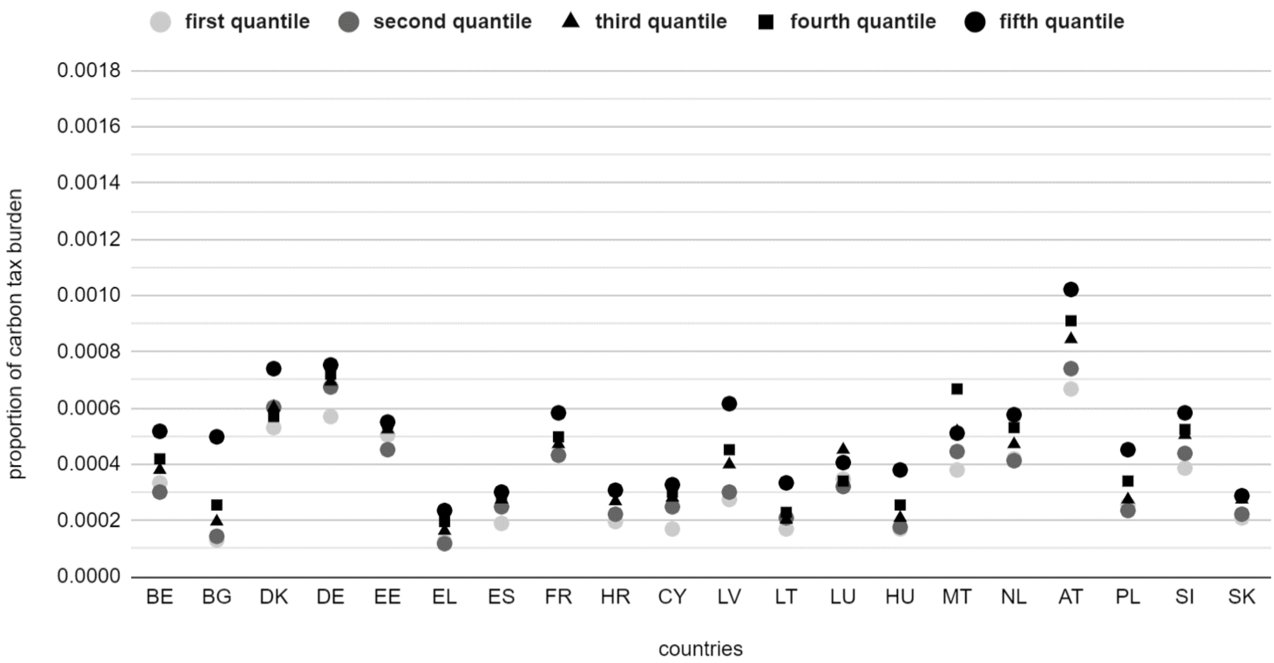
Proportion of tax burden in total mean consumption expenditure , CP08

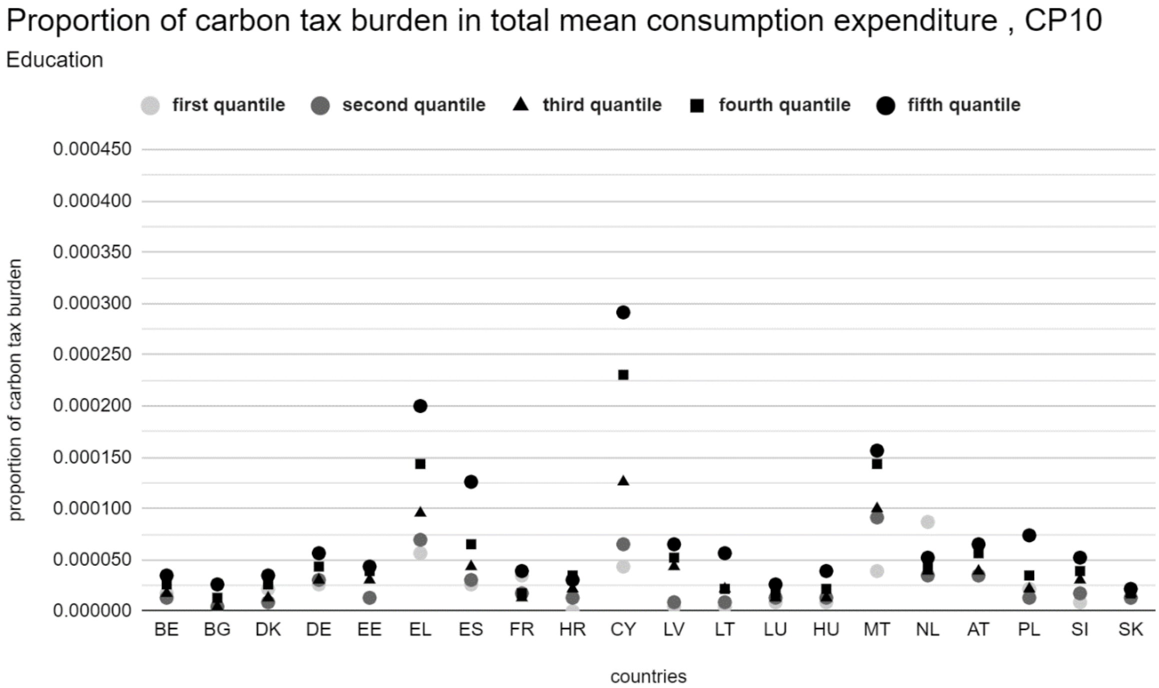
Communication

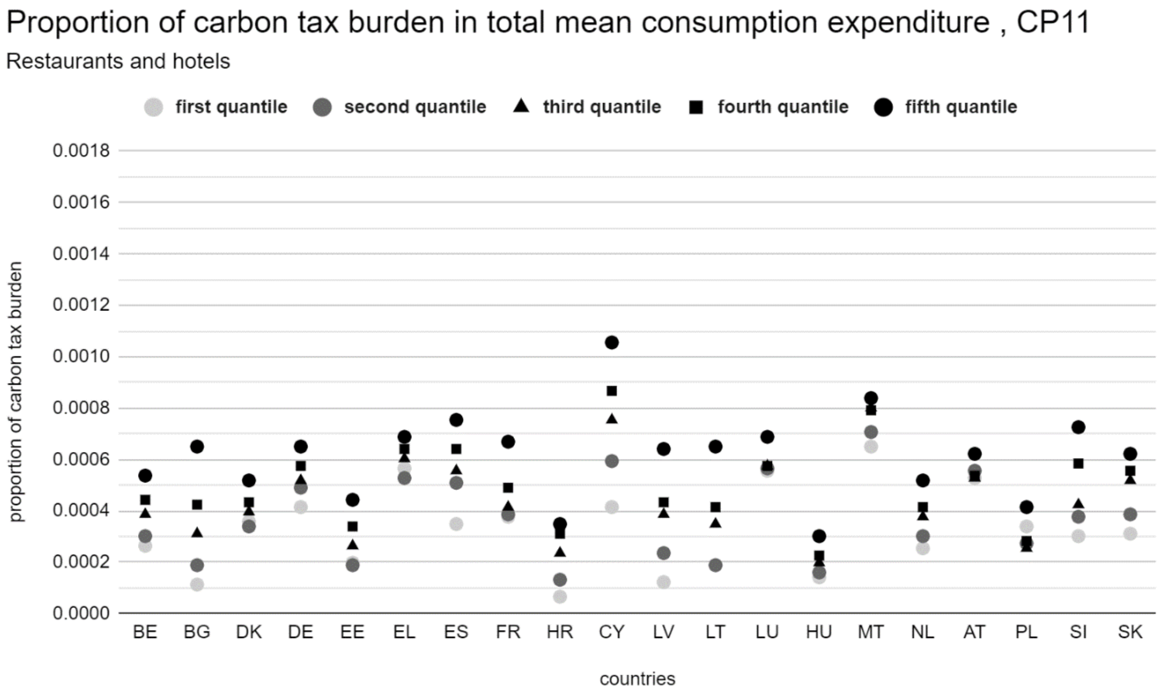


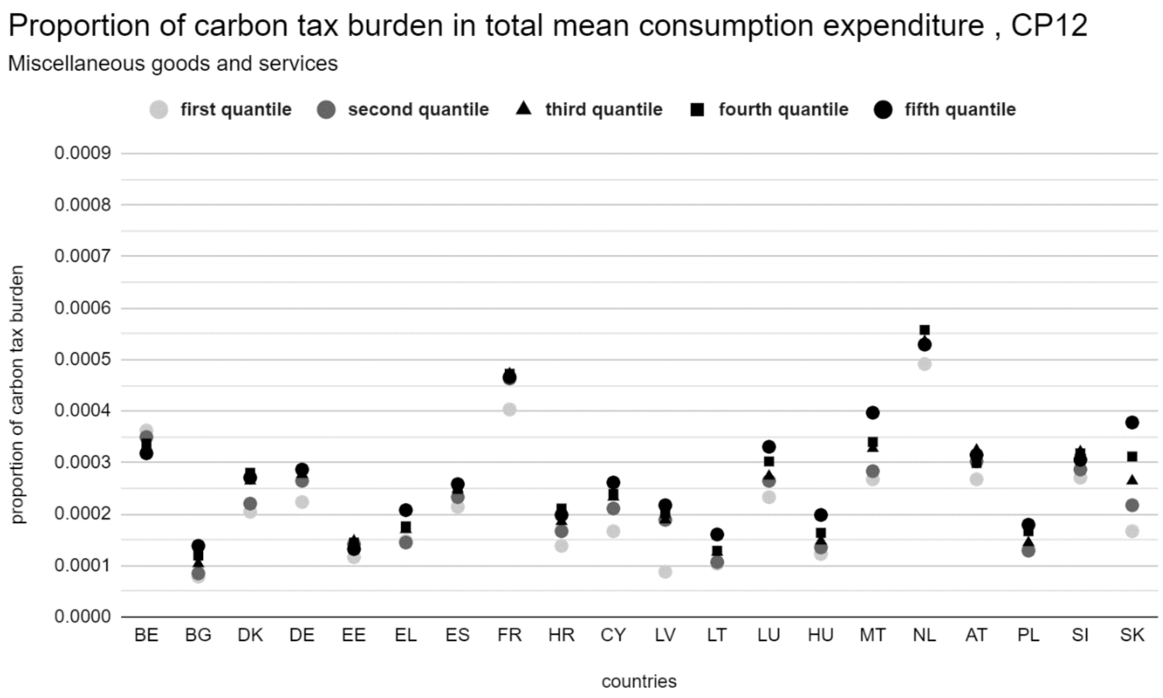
Proportion of carbon tax burden in total mean consumption expenditure , CP09

Recreation and Culture




Proportion of carbon tax burden in total mean consumption expenditure , CP10
Education
first quantile
second quantile
third quantile
fourth quantile
fifth quantile
0.000450
0.000400
0.000350
0.000300
0.000250
0.000200
0.000150
0.000100
0.000050
0.000000
proportion of carbon tax burden
BE
BG
DK
DE
EE
EL
ES
FR
HR
CY
LV
LT
LU
HU
MT
NL
AT
PL
SI
SK
countries


Proportion of carbon tax burden in total mean consumption expenditure , CP11
Restaurants and hotels
first quantile
second quantile
third quantile
fourth quantile
fifth quantile
0.0018
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
proportion of carbon tax burden
BE
BG
DK
DE
EE
EL
ES
FR
HR
CY
LV
LT
LU
HU
MT
NL
AT
PL
SI
SK
countries



Appendix B

Structure of consumption categories across income quantiles

First quantile

countries	CP01	CP022	CP03	CP04	CP05	CP06	CP07	CP08	CP09	CP10	CP11	CP12
Belgium	14.9	1.2	2.1	38.1	4.6	6.0	7.6	4.3	5.1	0.4	2.8	11.5
Bulgaria	32.5	2.0	1.3	41.6	2.7	8.8	1.4	3.1	2.0	0.1	1.2	2.5
Denmark	12.5	1.2	4.1	43.7	4.5	3.0	7.3	3.4	8.1	0.5	3.8	6.5
Germany	14.0	1.1	3.6	41.2	3.5	3.2	8.1	3.5	8.7	0.6	4.4	7.1
Estonia	27.2	1.7	3.8	29.6	5.1	7.6	5.2	4.4	7.7	0.3	2.1	3.7
Greece	22.2	2.3	3.3	38.6	3.3	6.1	5.2	3.9	1.9	1.3	6.0	4.7
Spain	19.7	1.4	3.1	42.6	3.7	3.4	7.2	4.1	2.9	0.6	3.7	6.8
France	14.7	2.3	4.3	34.7	3.4	1.5	10.2	3.5	6.6	0.8	4.0	12.8
Croatia	27.6	1.7	2.3	44.8	3.4	2.9	4.3	3.5	3.0	0.0	0.7	4.4
Cyprus	22.6	2.3	3.5	32.2	5.3	5.7	10.4	4.1	2.6	1.0	4.4	5.3
Latvia	26.5	1.6	1.8	40.6	2.8	10.4	3.1	3.5	4.2	0.1	1.3	2.8
Lithuania	28.2	1.4	4.0	38.6	3.1	6.2	5.1	3.6	2.6	0.1	2.0	3.3
Luxembourg	12.3	1.0	4.5	38.7	3.8	2.8	13.3	3.6	5.3	0.2	5.9	7.4
Hungary	17.3	1.9	1.1	57.4	2.5	3.7	2.9	4.1	2.6	0.2	1.5	3.9
Malta	25.6	2.1	5.6	16.2	6.9	6.7	9.1	4.7	5.8	0.9	6.9	8.5
Netherlands	11.8	4.4	2.9	38.5	4.0	1.4	5.2	3.8	6.4	2.0	2.7	15.6

Austria	14.1	1.9	3.5	32.5	5.5	4.3	9.6	2.2	10.2	0.8	5.6	8.5
Poland	24.5	1.1	2.4	40.2	4.1	5.4	5.3	3.7	3.9	0.5	3.6	4.2
Slovenia	18.2	1.1	3.9	37.5	3.9	2.0	9.5	4.7	5.9	0.2	3.2	8.6
Slovakia	22.4	1.4	3.4	43.3	4.2	3.4	3.6	4.8	3.2	0.3	3.3	5.3
Average	20.4	1.8	3.2	38.5	4.0	4.7	6.7	3.8	4.9	0.5	3.5	6.7

Second quantile

countries	CP01	CP022	CP03	CP04	CP05	CP06	CP07	CP08	CP09	CP10	CP11	CP12
Belgium	15.7	0.8	2.4	36.7	5.3	6.3	8.3	3.7	4.6	0.3	3.2	11.1
Bulgaria	28.4	2.8	1.7	41.7	2.9	7.6	3.4	3.7	2.2	0.1	2.0	2.7
Denmark	13.2	0.6	3.5	39.6	4.9	2.8	10.8	3.1	9.2	0.2	3.6	7.0
Germany	12.5	0.9	4.1	36.1	4.1	3.7	10.2	3.1	10.3	0.7	5.2	8.4
Estonia	21.3	1.2	3.7	34.1	5.2	5.1	9.7	4.1	6.9	0.3	2.0	4.5
Greece	22.7	2.3	3.2	36.8	3.3	6.2	6.8	4.0	1.8	1.6	5.6	4.6
Spain	18.8	1.3	3.5	36.8	4.0	3.7	9.8	3.8	3.8	0.7	5.4	7.4
France	15.0	1.7	3.7	32.8	4.0	1.6	11.3	2.8	6.6	0.4	4.1	14.7
Croatia	23.6	1.4	4.6	38.7	4.2	2.5	9.3	4.1	3.4	0.3	1.4	5.3
Cyprus	19.8	1.9	4.7	29.1	5.5	5.7	10.1	4.3	3.8	1.5	6.3	6.7
Latvia	23.8	2.0	3.1	33.8	3.8	8.5	6.6	4.3	4.6	0.2	2.5	6.0
Lithuania	24.2	0.8	4.4	39.8	4.1	6.4	7.0	3.4	3.2	0.2	2.0	3.4
Luxembourg	10.0	0.6	3.9	34.2	7.2	3.0	18.1	2.5	4.9	0.3	6.0	8.4
Hungary	16.9	1.5	1.5	55.4	2.5	3.9	4.2	4.3	2.7	0.3	1.7	4.3
Malta	25.1	1.7	5.7	10.9	7.0	7.2	10.6	5.1	6.8	2.1	7.5	9.0
Netherlands	11.5	2.4	3.0	36.2	5.2	1.5	7.8	3.8	6.3	0.8	3.2	16.8
Austria	12.7	1.3	3.4	28.5	6.1	4.5	12.5	2.0	11.3	0.8	5.9	9.6
Poland	25.9	1.3	2.4	38.6	4.3	5.2	5.5	4.5	3.6	0.3	2.9	4.1
Slovenia	15.8	0.9	4.8	30.9	4.8	2.6	13.9	4.9	6.7	0.4	4.0	9.1
Slovakia	21.4	1.2	3.6	36.3	5.2	3.1	8.4	4.6	3.4	0.3	4.1	6.9
average	18.9	1.4	3.5	35.4	4.7	4.6	9.2	3.8	5.3	0.6	3.9	7.5

Third quantile

countries	CP01	CP022	CP03	CP04	CP05	CP06	CP07	CP08	CP09	CP10	CP11	CP12
Belgium	16.0	0.6	3.2	34.1	5.8	5.5	8.7	3.5	5.8	0.4	4.1	10.5
Bulgaria	26.7	3.0	2.6	37.6	3.6	6.1	5.5	4.1	3.0	0.1	3.3	3.3

Denmark	12.9	0.9	4.1	34.4	5.3	2.8	13.0	3.0	9.2	0.3	4.2	8.4
Germany	11.7	0.7	4.0	33.5	4.7	4.1	12.1	2.6	10.6	0.7	5.5	8.8
Estonia	20.4	1.1	4.0	33.0	6.1	3.7	9.1	4.4	8.0	0.7	2.8	4.7
Greece	21.1	2.1	3.7	33.2	3.6	6.6	8.4	3.8	2.5	2.2	6.4	5.4
Spain	17.7	1.0	3.7	35.3	4.1	4.2	10.5	3.7	4.2	1.0	5.9	7.9
France	15.4	1.4	3.8	30.5	4.3	1.8	12.1	2.5	7.2	0.3	4.4	15.0
Croatia	22.1	1.0	6.8	32.7	4.8	2.8	11.4	4.5	4.1	0.5	2.5	5.9
Cyprus	17.0	1.5	5.2	25.4	5.2	5.9	12.4	4.4	4.3	2.9	8.0	7.4
Latvia	21.8	1.1	4.7	26.8	4.4	6.4	11.6	4.8	6.1	1.0	4.1	6.0
Lithuania	23.8	1.0	5.1	35.5	4.6	5.4	8.3	3.5	3.1	0.5	3.7	4.0
Luxembourg	9.8	0.4	4.0	36.2	5.7	3.0	15.3	2.5	6.9	0.3	6.1	8.7
Hungary	17.1	1.6	2.1	50.6	2.7	3.5	6.7	4.6	3.2	0.3	2.1	4.7
Malta	20.7	1.7	8.3	8.1	7.2	5.9	13.7	4.5	7.9	2.3	8.5	10.4
Netherlands	11.7	1.7	3.1	33.3	5.1	1.6	9.6	3.4	7.2	0.9	4.0	17.0
Austria	12.8	1.3	3.9	25.2	6.2	4.4	13.1	1.9	12.9	0.9	5.6	10.3
Poland	26.3	1.2	3.3	34.4	4.6	4.6	7.4	4.8	4.2	0.5	2.7	4.6
Slovenia	14.1	0.8	5.6	25.2	5.3	2.3	17.7	5.0	7.7	0.7	4.5	10.2
Slovakia	20.6	1.0	3.7	32.5	5.1	2.7	9.4	4.8	4.2	0.4	5.5	8.4
Average	18.0	1.3	4.2	31.9	4.9	4.2	10.8	3.8	6.1	0.8	4.7	8.1

Forth quantile

countries	CP01	CP022	CP03	CP04	CP05	CP06	CP07	CP08	CP09	CP10	CP11	CP12
Belgium	15.8	0.4	3.7	29.9	6.2	4.7	11.9	3.1	6.4	0.6	4.7	10.7
Bulgaria	24.3	3.1	3.4	34.6	3.8	4.9	7.7	4.6	3.9	0.3	4.5	3.8
Denmark	12.5	0.5	3.3	32.0	5.7	3.3	15.4	2.7	8.7	0.6	4.6	8.9
Germany	11.3	0.6	4.4	30.7	4.9	4.5	13.1	2.4	11.0	1.0	6.1	9.1
Estonia	19.1	0.9	4.0	31.0	6.4	3.0	11.8	4.4	8.3	0.9	3.6	4.6
Greece	19.7	2.1	3.8	31.0	3.3	6.0	10.1	3.9	3.0	3.3	6.8	5.6
Spain	17.0	1.0	4.0	34.1	4.2	3.8	10.8	3.6	4.4	1.5	6.8	7.9
France	15.0	1.1	3.9	27.9	4.7	1.6	13.9	2.3	7.6	0.4	5.2	15.0
Croatia	19.8	1.3	6.7	29.9	5.3	2.4	13.7	4.5	4.7	0.8	3.3	6.7
Cyprus	14.6	1.0	6.5	24.0	4.6	5.3	12.6	4.2	4.6	5.3	9.2	7.6
Latvia	21.7	1.3	4.4	22.1	5.6	5.5	14.1	4.8	6.9	1.2	4.6	6.4
Lithuania	24.2	0.7	4.4	35.6	4.2	4.9	8.4	3.6	3.5	0.5	4.4	4.1
Luxembourg	9.2	0.2	4.0	34.7	7.2	2.4	17.9	2.2	5.2	0.4	6.1	9.6

Hungary	16.3	1.3	2.4	49.0	2.9	3.0	7.4	4.7	3.9	0.5	2.4	5.2
Malta	18.6	1.4	8.7	6.6	7.2	5.6	14.3	4.2	10.2	3.3	8.4	10.8
Netherlands	11.6	1.4	3.7	28.9	6.5	1.5	10.9	3.1	8.1	1.0	4.4	17.7
Austria	11.8	0.9	4.4	23.4	7.2	4.3	14.6	1.9	13.9	1.3	5.7	9.5
Poland	25.5	1.1	4.2	30.9	5.1	4.4	8.2	4.8	5.2	0.8	3.0	5.3
Slovenia	13.0	0.7	6.0	21.7	5.5	2.5	20.0	4.5	8.0	0.9	6.2	10.1
Slovakia	19.9	1.0	3.7	31.0	5.7	2.5	9.3	5.0	4.3	0.4	5.9	9.9
Average	17.0	1.1	4.5	29.5	5.3	3.8	12.3	3.7	6.6	1.3	5.3	8.4

Fifth quantile

countries	CP01	CP022	CP03	CP04	CP05	CP06	CP07	CP08	CP09	CP10	CP11	CP12
Belgium	16.4	0.2	4.4	26.7	9.2	4.2	10.2	2.6	7.9	0.8	5.7	10.1
Bulgaria	20.2	3.3	3.9	28.7	3.8	5.3	9.7	4.3	7.6	0.6	6.9	4.4
Denmark	11.5	0.3	3.5	28.7	6.3	2.2	17.7	2.0	11.3	0.8	5.5	8.6
Germany	9.8	0.4	4.8	26.6	5.6	4.2	17.1	2.0	11.5	1.3	6.9	9.1
Estonia	14.4	0.6	4.1	34.0	7.4	2.5	13.8	3.4	8.4	1.0	4.7	4.2
Greece	17.6	1.5	4.2	28.7	3.5	6.9	10.6	3.6	3.6	4.6	7.3	6.6
Spain	14.7	0.7	3.9	34.1	4.9	3.5	10.6	3.0	4.6	2.9	8.0	8.2
France	12.8	0.8	4.1	25.5	5.8	1.5	14.9	1.8	8.9	0.9	7.1	14.8
Croatia	18.3	1.0	8.0	28.0	5.8	2.3	16.4	4.1	4.7	0.7	3.7	6.3
Cyprus	11.7	0.6	6.5	23.8	5.4	4.4	12.4	3.7	5.0	6.7	11.2	8.3
Latvia	16.7	0.7	6.0	18.9	5.9	5.1	16.8	3.7	9.4	1.5	6.8	6.9
Lithuania	21.3	0.6	5.2	26.8	5.3	4.5	12.9	3.5	5.1	1.3	6.9	5.1
Luxembourg	8.2	0.3	5.2	33.9	7.0	2.2	15.8	1.9	6.2	0.6	7.3	10.5
Hungary	15.2	1.1	3.3	42.9	3.3	3.2	8.7	4.9	5.8	0.9	3.2	6.3
Malta	16.1	1.2	8.7	6.3	8.0	4.4	17.6	3.9	7.8	3.6	8.9	12.6
Netherlands	11.4	0.8	4.4	24.9	7.1	1.5	13.4	2.7	8.8	1.2	5.5	16.8
Austria	10.7	0.7	4.8	19.8	7.3	4.0	16.2	1.6	15.6	1.5	6.6	10.0
Poland	22.5	0.8	4.7	26.9	6.2	4.5	10.1	4.1	6.9	1.7	4.4	5.7
Slovenia	11.6	0.5	6.9	18.6	4.8	2.7	22.7	3.9	8.9	1.2	7.7	9.7
Slovakia	18.5	1.0	3.6	30.2	4.8	2.2	9.6	5.0	4.4	0.5	6.6	12.0
Average	15.0	0.9	5.0	26.7	5.9	3.6	13.9	3.3	7.6	1.7	6.5	8.8

Appendix C

Structure of consumption categories across regions

City

countries	CP01	CP02 2	CP03	CP04	CP05	CP06	CP07	CP08	CP09	CP10	CP11	CP12
Austria	12.0	1.2	4.3	25.1	6.3	4.4	11.2	2.1	15.4	1.7	6.5	8.5
Belgium	15.8	0.6	3.6	32.9	5.4	5.5	8.6	3.4	6.3	0.5	5.0	10.9
Bulgaria	21.4	2.4	2.9	37.2	3.1	5.4	7.3	4.1	5.3	0.4	5.5	3.8
Croatia	19.4	1.1	6.5	34.4	4.3	3.0	10.8	4.1	5.0	0.7	3.6	6.4
Cyprus	14.0	1.1	5.8	26.3	5.5	5.0	11.9	3.9	4.8	4.4	9.1	7.8
Denmark	12.3	0.5	3.8	34.9	5.6	2.4	12.9	2.4	9.6	0.7	5.6	7.5
Estonia	17.8	0.8	4.2	34.7	6.1	3.7	9.9	3.8	7.9	0.9	3.9	4.6
France	13.5	1.3	4.1	30.0	4.6	1.6	12.0	2.3	8.0	0.8	6.3	14.4
Germany	11.3	0.6	4.5	31.4	4.7	4.3	12.4	2.6	11.1	1.1	6.6	8.4
Greece	18.9	1.8	3.7	33.4	3.2	6.2	8.7	3.8	3.0	3.2	7.2	5.7
Hungary	15.7	1.2	2.7	46.6	3.1	3.9	6.6	4.8	4.7	0.7	3.3	5.6
Latvia	18.3	1.0	5.1	25.8	4.7	6.4	12.0	3.8	7.8	1.2	5.5	6.9
Lithuania	19.9	0.7	4.0	39.8	3.7	5.3	8.3	3.0	3.8	0.7	5.2	4.0
Luxembourg	8.7	0.2	5.3	34.2	6.4	2.5	15.2	2.4	5.5	0.6	8.5	9.5
Netherlands	11.6	1.8	3.6	30.9	5.9	1.5	9.8	3.2	7.6	1.3	4.7	16.7
Poland	22.1	0.9	3.6	33.9	4.9	5.0	7.4	4.3	5.6	1.2	4.3	5.2
Slovakia	18.4	0.9	3.5	37.6	4.4	2.3	7.5	4.9	4.0	0.4	5.7	9.0
Slovenia	11.9	0.7	6.0	28.0	4.8	2.9	16.2	4.3	8.4	0.9	6.8	8.6
Spain	16.0	0.8	3.8	37.6	4.4	3.6	8.8	3.5	4.1	1.9	6.8	8.0

Suburb

countries	CP01	CP02 2	CP03	CP04	CP05	CP06	CP07	CP08	CP09	CP10	CP11	CP12
Austria	11.7	1.1	4.2	24.1	7.0	4.2	14.2	1.7	13.4	1.1	6.0	10.0
Belgium	15.9	0.5	3.4	31.2	7.5	4.9	10.1	3.2	6.3	0.6	4.4	10.3
Bulgaria	27.4	4.1	3.2	32.4	4.0	6.2	6.0	4.0	4.1	0.3	3.6	3.6

Croatia	21.6	1.4	6.1	31.3	5.6	2.3	13.6	4.3	4.1	0.4	2.5	6.0
Cyprus	16.5	1.4	6.0	24.0	4.8	5.5	12.2	4.3	4.0	4.8	8.7	7.4
Denmark	11.9	0.6	3.4	33.2	5.9	2.9	15.1	2.6	9.4	0.4	4.3	8.7
Estonia	17.1	0.9	3.9	34.6	6.5	2.9	12.3	3.9	8.2	0.9	3.3	4.1
France	14.5	1.3	4.0	28.5	4.9	1.7	13.5	2.4	7.4	0.4	5.0	15.1
Germany	11.1	0.6	4.3	31.3	5.1	4.0	14.4	2.4	10.5	0.9	5.4	9.1
Greece	19.1	2.0	3.8	32.0	3.7	6.5	9.4	3.7	3.1	3.4	6.1	6.0
Hungary	16.2	1.4	2.2	50.5	2.9	3.1	6.6	4.7	3.8	0.5	2.1	5.1
Latvia	20.3	0.9	5.0	26.1	5.2	5.7	14.1	4.5	6.8	1.0	4.1	5.2
Lithuania	26.5	1.1	6.9	25.3	5.4	5.8	9.8	3.9	4.4	0.8	3.7	5.1
Luxembourg	10.1	0.5	4.4	34.5	6.6	2.6	15.6	2.6	6.1	0.5	6.0	9.7
Netherlands	11.4	1.7	3.6	30.3	5.9	1.5	11.1	3.1	7.9	0.9	4.0	17.1
Poland	25.1	1.1	3.7	33.6	5.0	4.8	7.2	4.4	5.0	0.8	3.2	4.8
Slovakia	20.4	1.1	3.9	30.9	5.6	3.1	8.9	4.7	4.3	0.4	5.7	9.2
Slovenia	14.1	0.8	5.9	23.9	4.5	2.5	18.3	4.7	8.3	0.8	5.6	9.7
Spain	17.3	1.1	3.8	33.2	4.2	4.0	11.6	3.5	4.6	1.5	6.4	7.9

Rural

countries	CP01	CP02 2	CP03	CP04	CP05	CP06	CP07	CP08	CP09	CP10	CP11	CP12
Austria	12.4	1.0	4.0	23.9	6.8	4.2	16.0	1.8	11.8	0.8	5.5	10.5
Belgium	15.9	0.6	3.3	32.2	6.1	5.0	10.6	3.2	6.1	0.3	3.3	11.6
Bulgaria	31.2	3.8	3.1	28.9	4.3	8.5	6.3	4.2	3.1	0.1	2.2	3.3
Croatia	22.4	1.1	6.7	30.9	5.4	2.1	14.2	4.3	3.5	0.5	2.1	5.7
Cyprus	17.3	1.2	5.6	25.0	4.9	5.4	12.1	4.1	3.8	4.5	8.7	6.9
Denmark	12.7	0.7	3.5	32.1	5.4	2.9	15.3	3.0	10.0	0.5	3.7	8.5
Estonia	20.9	1.2	3.6	27.7	7.2	3.5	13.9	4.4	8.3	0.4	2.8	4.1
France	15.3	1.2	3.7	27.4	5.0	1.4	14.9	2.4	7.5	0.3	4.5	14.9
Germany	11.1	0.7	4.0	31.7	4.8	3.4	16.0	2.4	10.1	0.7	4.8	9.4

Greece	23.4	2.3	4.0	30.6	3.6	6.8	8.9	3.8	2.0	2.2	6.3	5.0
Hungary	17.3	1.7	2.2	51.0	2.7	3.0	7.1	4.3	3.5	0.4	1.4	4.7
Latvia	24.8	1.6	3.7	21.6	5.6	6.5	13.5	4.9	6.2	0.8	3.9	5.3
Lithuania	28.4	0.9	5.1	26.1	5.6	4.8	11.0	4.3	3.7	0.7	3.6	4.3
Luxembourg	9.2	0.4	4.0	35.6	6.3	2.7	18.6	2.0	5.4	0.3	5.9	8.6
Netherlands	12.1	1.3	3.6	30.3	6.2	1.6	11.1	3.1	7.3	0.9	3.5	17.7
Poland	27.9	1.2	3.8	30.1	5.5	4.3	9.1	4.4	4.5	0.5	2.3	4.8
Slovakia	21.6	1.2	3.4	32.0	5.2	2.5	9.2	5.0	3.8	0.3	4.9	9.2
Slovenia	14.3	0.7	5.7	22.8	5.3	2.3	19.7	4.5	7.2	0.8	5.3	10.2
Spain	19.0	1.3	3.6	33.7	4.2	3.6	11.9	3.5	3.9	1.0	5.9	7.4

Appendix D

Table. Carbon Taxation in the European Union, 2023

Country	Year of Implementation	Carbon Tax Rate (CO2e ton)	GHG covered (2018)
Austria	2022	€32.50	40%
Denmark	1992	€24.37	35%
Estonia	2000	€2.00	6%
Finland	1990	€76.92	36%
France	2014	€44.55	35%
Germany	2021	€30.00	40%
Ireland	2010	€48.45	40%
Latvia	2004	€14.98	3%
Luxembourg	2021	€44.19	65%
Netherlands	2021	€51.07	12%
Poland	1990	€13.27	4%
Portugal	2015	€23.90	36%
Slovenia	1996	€17.30	52%
Spain	2014	€14.98	2%
Sweden	1991	€115.34	40%

Source: table made by authors, based on World Bank

Resümee

The distributional effects of carbon tax in EU countries

Nijat Ilyasov, Tural Karimov

Käesolev uurimistöö vaatleb, kuidas süsinikumaks mõjutab leibkondi sissetulekukvantiilide lõikes ning linna-, eeslinna- ning maapiirkondades elavaid täiskasvanuid 20 Euroopa Liidu liikmesriigis. Kasutades andmeid leibkonna eelarveuuringusst (Household Budget Survey) ja emissioonide intensiivsuse uuringust (Emission Intensity), simuleerime selle mõju uurimiseks 25-eurost süsinikumaksu.

Meie uurimus leiab, et keskmiselt on süsinikumaksu maksukoormus Euroopa Liidu sissetulekute tasemetega peaaegu proportsionaalne. Lääne-Euroopa riikidel on üldiselt sarnane mõju, aga Lõuna- ja Ida-Euroopa riigid, välja arvatud Eesti, kalduvad kogema regressiivseid mõjusid. Küpros ja Bulgaaria tõusevad esile suurima erinevusega süsinikumaksu maksukoormuses.

Vaatleme süsinikumaksu mõju erinevatele kulukategooriatele näidates riikidevahelisi erinevusi. Toidu ja mittealkohoolsete jookide süsinikumaks on Baltiriikides ja Lõuna-Euroopas regressiivne, aga Lääne-Euroopas ja Ungaris proportsionaalne. Eluasemekulude süsinikumaks on aga vastupidiselt üldiselt regressiivne välja arvatud Eestis ja Luksemburgis. Transpordi süsinikumaksul on progresseeruv mõju enamikes liikmesriikides välja arvatud Belgias, Küprosel ja Luksemburgis.

Uurides linna-, eeslinna ja maapiirkondi, on märgatavad mõõdukad erinevused igakuises maksukoormuses täiskasvanu kohta toidu ja mittealkohoolsete jookide süsinikumaksu osas. Siiski on eristatavad mustrid eluaseme, vee, elektri, gaasi ja muude kütuste süsinikumaksude puhul, eriti madala sissetulekuga piirkondades. Nendes piirkondades kalduvad linnaelanikud kandma maapiirkondadega võrreldes suuremat koormust.

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