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The incidence of a Dutch carbon tax: the direct effect on consumption prices

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ABSTRACT

Tackling the problem of global warming and increased levels of greenhouse gas emissions requires firms, governments and individuals to drastically change the ways in which they respectively produce, mobilize revenue and consume. Policies have to be put into place to accelerate this adaptation. The implementation of a carbon tax is a policy that has the potential to encourage people to move away from carbon-intense consumption. However, the implementation of this policy might also have a downside. Based on other studies, low income households are expected to be more severely impacted, as they spend a larger fraction of their income on carbon taxes. This paper explores the incidence of a tax on carbon by looking at the direct increase in consumption prices that the tax will bring about. To this end, three indicators of regressivity are presented, namely the Relative Impact, the Tax/Expenditure ratio and the Gini coefficient. Using these indicators, the regressivity of the carbon tax cannot be proven. Three policy recommendations are discussed that can help transform the carbon tax into a progressive tax, and guide consumers towards a more sustainable consumption pattern. These policies entail using differential tax rates for different consumption goods, and investing in insulation, energy-efficiency and low-carbon R&D.

TABLE OF CONTENTS

1 INTRODUCTION

In an attempt to avert dangerous human-induced climate change, leaders of 193 parties committed to the Paris Agreement in 2015. The main goal of the agreement is to keep the temperature increase on earth well under two degrees Celsius, in order to prevent enormous economic, social and ecological damages that could emerge if climate change is not managed effectively (Stiglitz et al., 2017). The Intergovernmental Panel on Climate Change (IPCC) recently published an extensive report on climate change. From 2021 until net CO_2 emissions are reduced to zero, there is a remaining global budget of 460 and 1310 gigaton CO_2 for an even chance of limiting global warming to 1.5 and 2 degrees Celsius respectively (Hausfather, 2021). Liu et al. (2022) report global CO_2 emissions of 34.9 gigaton in 2021. This means that the carbon budget could be used up in a matter of decades. To decrease global carbon consumption, integrated and transformative policies are required, such as economy-wide emission targets, increased climate finance, R&D innovation policies, energy efficiency improvements, lower carbon and energy intensity rates, and many more (Pörtner et al, 2022).

In 2021, the European Union committed to a new European Climate Law. Policy proposals were bundled to create a *Fit for 55* package, which aims at a reduction of 55% in the EU's greenhouse gas emissions by 2030 compared to 1990 levels (PBL, 2021). The agreement specifies a variety of instruments that can be used to achieve this goal, such as levying a carbon tax, increased use of renewable energy, increasing energy efficiency and a decrease in the number of permits issued in the European Trading Scheme.

1.1 Internalizing externalities

Putting a price on carbon emissions can be seen as a way to internalize the externalities that result from processes that generate such greenhouse gas emissions. Such externalities entail the negative consequences of an activity, which are (at least partly) borne by parties other than the party that produces the externality (Jaffe et al., 2005). In economic theory, this is called a market failure. Without explicitly adding a price component for the amount of carbon emitted, the negative consequences of these emissions on the environment are not included in product prices and thus not considered in decision-making. This results in levels of greenhouse gas emissions higher than socially optimal, leading to many increased climate risks. Taxing carbon ensures that private and social costs of polluting are equalized (Andersson, 2019). Explicitly pricing carbon emissions thus ensures that the polluter pays, which could stimulate emission reductions. One of the concerns related to the introduction of a carbon tax is that it might decrease international competitiveness as export prices increase. Schotten et al. (2021) analyze the effect of a carbon tax of €50 per ton CO_2 and conclude that the effect on production costs and export competitiveness is modest in most sectors and countries, including the Netherlands. A potentially negative impact of a carbon tax on domestic market competitiveness could be mitigated by using a Carbon Border Adjustment Mechanism (CBAM), which adds a tariff to the import prices of carbon intensive goods.

1.2 Research question

Adding a carbon tax to prices for consumption goods could be a great way to equalize social and private costs of carbon emissions and thereby steering consumers towards less carbon-intense consumption pathways. However, the implementation of this policy can also have a downside. A carbon tax will increase consumption prices for all households, but lower income households are likely to be more severely impacted if they spend a larger fraction of their income on carbon taxes. Previous work, e.g. by Bento (2013), indeed shows that a carbon tax is potentially regressive. This paper investigates the incidence of a tax on carbon in the Netherlands by looking at the direct increase in consumption prices that such a tax will bring about. It will investigate which income groups spend the largest share of their income on carbon taxes. Hence, this paper will answer the following research question:

What is the incidence of a carbon tax in the Netherlands and how can a potentially regressive impact be mitigated?

To this end, Chapter 2 will review the literature on carbon pricing and carbon taxation. Research on consumption patterns, carbon intensity and carbon tax levels will be discussed, which are part of a framework set up to calculate three indicators of regressivity, discussed in Chapter 3. The impact of levying a low, moderate and high level of carbon tax will be studied. Chapter 4 will elaborate on the results, after which specific policy recommendations to mitigate the impact on low income households will be proposed in Chapter 5. The last two chapters conclude and discuss the paper.

2 LITERATURE REVIEW

This chapter will discuss literature on carbon pricing and carbon consumption. It proposes estimates of carbon tax rates, discusses consumption patterns of different income quintiles and shows the carbon intensity and price elasticities of different consumption groups. All these estimates will be used in Chapter 3, where the incidence of the carbon tax will be determined.

2.1 CARBON PRICING

As part of a bundle of policies, carbon pricing can be a way to internalize carbon externalities, discourage carbon consumption and reduce carbon dioxide emissions. Carbon pricing can take the form of emission trading schemes or explicit pricing of greenhouse gas emissions through a carbon tax (Stiglitz et al., 2017). Carbon emitting firms pay the same price per unit of carbon emitted whether they are confronted with a carbon tax or a cap-and-trade system. Assuming firms minimize costs, they will reduce their emissions till the point where, at the margin, the cost of emission abatement is equal to the price of emissions (Goulder & Schein, 2013).

2.1.1 Cap-and-trade vs carbon taxation

Cap-and-trade

Under a cap-and-trade system, the government specifies the total allowable quantity of CO_2 emissions. The maximum amount of total emissions, i.e. the cap, is divided into allowances, which represent the right to emit one ton of CO_2 (Pellerin-Carlin et al., 2022). An example of such a system would be the EU Emissions Trading Scheme (EU ETS). In 2005, when the ETS was introduced, free allowances were handed out to installations and companies to prevent carbon leakage, which means companies could move operations outside the EU to avoid high prices for emissions. They received allowances equal to their historical emissions. As of 2013, the number of free allowances is determined based on a fixed benchmarking approach, where the 10% most efficient installations in each sector determine the amount of allowances the rest of the installations receive (Pellerin-Carlin et al., 2022). Companies can sell the allowances that they do not need, for example because of the use of more carbon-efficient technologies. A problem that comes with the determination of free allowances based on benchmarks is that these benchmarks can become outdated. Over time, technological and productivity changes can lower the emissions of companies. If allocation processes are not adjusted, a situation of overallocation could arise in which actors receive more allowances for free than they emit (Pellerin-Carlin et al., 2022).

Actors are thus allowed to buy and sell these allowances on a market with limited supply, and the price for a kg of CO_2 is established indirectly (Goulder & Schein, 2013). As a result of demand shifts in allowances, the price of emissions can be volatile. This can be seen as a downside of the cap-and-trade system, as this could hinder businesses to change their input mix or to invest in research on new technologies, as these become riskier (Goulder & Schein, 2013). An advantage of cap-and-trade is that total emissions are stipulated. However, Goulder and Schein (2013) mention that overall emissions never change because of this, and will always stay at the cap. They argue that when additional policies are introduced to reduce emissions in some sectors, the demand for allowances falls, which reduces their prices and will increase demand again till the cap is reached. Their criticism fails to consider the fact that the EU can decide to decrease the number of permits in circulation. The overall number of emission allowances is currently decreased with 2.2% annually and the goal is to increase this rate to 4.2%. In addition, the European Commission wants to phase out free allowances to encourage incumbents to innovate and to move to full auctioning of allowances by 2027 to create a strong price signal for the reduction of emissions (European Commission, 2021).

In the Netherlands, companies must report their emissions to the Dutch Emissions Authority (NEa) via a verified emissions report. With this, they have to submit enough allowances to compensate for their reported emissions. NEa monitors the compliance through visits by inspectors and necessary enforcement action (NEa, n.d.) and non-compliance is penalized. As Yeldan (2019) mentions, this control and monitoring leads to administrative concern. Often, the national monitoring systems are complemented with work by internationally accredited institutions, increasing the costs of surveillance.

Carbon tax

A carbon tax puts a direct price on the emission of a kg of CO_2. The emission price is thus equal to the tax rate and can simultaneously shift choices of consumers, producers, investors and innovators to accomplish a low-carbon transformation (Van den Bergh & Botzen, 2020). In a system with a carbon tax, there is relatively low price volatility. However, the aggregate level of emissions is uncertain, which means that the total level of emissions could potentially be much larger than what is needed to limit global warming (Goulder & Schein, 2013).

It is important to mention that both the carbon tax and the cap-and-trade method come with uncertainties. With the cap-and-trade method, carbon emissions are set, but the price of carbon will be unknown beforehand. The carbon tax gives a bit more certainty with respect to the price, but total emissions are unknown. The need for continuous re-estimation of the right level of the carbon tax also makes the carbon tax rate variable in the long-run. However, the carbon tax is also a means for governments to collect revenue, which is a strong positive in the eyes of public policy makers (OECD, 2022a). In this paper, the focus will be on the potentially regressive impact of a carbon tax. Since the current price of a kg of CO_2 can be determined by the government, this allows us to make a prediction of how the prices of different products and services will change after the implementation of the tax. From this, it can be investigated what the impact of such a policy would be on different income groups. Using the cap-and-trade system for this is not feasible, as the prices of allowances are very volatile. In addition, as the carbon tax money is collected by the government, policy recommendations can be provided on how to best recycle these revenues.

In this paper, the focus will be on households and individuals in the role of consumers. Ivanova et al. (2015) point out that consumption by households is responsible for more than half of global greenhouse gas emissions. Therefore, taxing carbon consumption has the potential to substantially decrease carbon emissions.

2.1.2 Appropriate carbon tax

While a carbon tax could be an appropriate method to incentivize consumers to decrease carbon emissions, implementing this tax does not come without challenges. Examples would be determining the carbon intensity of the consumption and production of goods/services and establishing the appropriate level of the carbon tax. The level essentially depends on the environmental damages that carbon emissions are expected to bring about. Additionally, depending on the estimation method used, input variables like the preference for equity, discount rates and expected growth rates play an important role in determining the tax level.

Chen et al. (2018) assess the significance of the uncertainties surrounding the baseline conditions that determine future CO_2 emissions. They use a dynamic multi-sector model of the US economy to forecast a baseline emission scenario, create alternative scenarios that depart from this baseline and find that changes in GDP growth rate and energy efficiency have large impacts on the level of future carbon emissions and baseline emissions. The assumptions and expectations used in a model are thus crucial to setting the appropriate carbon tax level. Litterman (2013) mentions two additional reasons why determining the right level of tax can be difficult. First, it is hard to value the environmental damages now, as they often occur over a long time horizon. Additionally, there is large uncertainty about the climate impacts and severity of climate-related damages. We do not know for sure whether these damages will be manageable or catastrophic. It is thus hard to price the possibility of catastrophic, future, unknown and low-probability outcomes (Litterman, 2013).

The determination of the right carbon tax rate thus depends on many uncertainties and assumptions. This section will discuss multiple methods to determine the carbon tax rate. Real-world examples will be presented to give an indication of what could be an appropriate carbon tax level.

2.1.2.1 Social costs of carbon (SCC)

In an attempt to monetize the climate damages caused by CO_2 emissions, Greenstone et al. (2013) calculate the social cost of carbon (SCC). Estimates of these costs allow for the incorporation of social benefits, e.g. increased air quality, when discussing regulatory actions that decrease CO_2 emissions. They mention the use of different Integrated Assessment Models (IAM), various socioeconomic and emission scenarios, and three different discount rates. These discount rates indicate the marginal rate of substitution between consumption in various time periods. For 2010, they present a central value of the SCCs of $21 per ton of CO_2 emissions at a 3% discount rate. For a 5% and 2.5% discount rate, the SCCs are equal to $5 and $35 respectively. For higher-than-expected economic impacts from climate change, they report an SCC of 65$. Estimates for emissions in 2025 at a discount rate of 5%, 3% and 2.5% are equal to $10, $30 and $46 respectively. In the case of extreme impacts from climate change, the SCC equals $90 per ton. The social cost of carbon increases over time because future emissions generate greater incremental damage to the economic system. As these systems have been through more years of climate change, the damages done to the climate and thus to economic systems become more severe and harder to reverse (Greenstone et al., 2013).

The SCC equals the present discounted value of future damages that happen due to the emission of one ton of carbon today. As mentioned by Van der Ploeg et al. (2022), the value of the SCC depends on the welfare function, economic growth, and the accumulation of emissions and temperature change that results from this. The authors emphasize that the SCC should be adjusted for both inter- and intragenerational income inequality and their evolution with economic growth to better reflect the welfare effect of climate change. Therefore, they include parameters for change in inequality and inequality aversion in their SCC model. They show that if economic growth does not affect intragenerational inequality, the SCC equals $85 (or €97.07) per ton CO_2 in 2020. If economic growth reduces intragenerational inequality, the discount rate increases and the optimal SCC is lower, especially if inequality aversion is higher. Based on historical data, they expect inequality to keep following the downward trend that started in 1990. Thus, they argue that the discount rate should increase and the SCC should decrease to $70 per ton CO_2 in 2020. The argument that the decrease in equality would lead to higher discount rates, is in line with statements by Hope (2008), who explains that incomes are expected to increase over a long time horizon. He argues that we should give extra weight to the impact of today's poorer generations rather than the future's richer ones, meaning that we should use higher discount rates, and end up with lower carbon tax rates.

While these studies advocate for higher discount rates, Newell and Pizer (2003) emphasize that there is a lot of uncertainty about the discount rate itself, especially about the future path of the rate. They use market data on US interest rates and a random walk model to measure the appropriate rate of discount in the future and conclude that the expected present value of climate change mitigation benefits almost doubles when uncertainty is considered. Therefore, they advocate a lower discount rate and thus a higher SCC.

As mentioned in the discussion of all SCC papers, the choice of the level of the discount rate is important for the outcome of the SCC and thus the appropriate carbon tax level. However, discounting the future also brings about ethical issues. If we discount the future because we are impatient and want to consume more today, we harm future generations without them having the possibility to intervene, simply because they are not born yet. The issue surrounding the discount rate will be discussed in Chapter 7.

Despite the interesting insights the SCC gives, its estimation has some flaws, such as the uncertainty about the severity of climate change, discussions about the appropriate discount rate and the uncertainty around the future path of the discount rate. Lemoine (2022) agrees with this, emphasizing that a regulator cannot set the tax optimally as they cannot observe all information about social costs that is scattered throughout society. He introduces the concept of carbon shares, a tradeable asset that emitters obtain after paying a deposit for their emissions. The government would then refund part of the deposit to shareholders based on the difference between expected and realized damages. As the value of the share reflects expected refunds, emitters want to reduce emissions to avoid having to give up the deposit for the carbon shares, which are less valuable. The carbon shareholders can even remove carbon from the atmosphere to recover the share's deposit. Share prices are based on beliefs about future climate change damages, meaning that individuals' information about the social costs of carbon will be used. The research by Lemoine shows an interesting perspective on the problem at hand, and his critique on the lack of information in the SCC seems valid. However, as the focus in this paper is on calculating the effects of a carbon tax, and considering that most methods will have their flaws, the SCC estimates mentioned above will still be used in this analysis.

2.1.2.2 Near-term to net zero (NT2NZ)

Kaufman et al. (2020) also criticize the use of the social cost of carbon (SCC) as an approach to set the price for CO_2 emissions, because this method comes with a lot of uncertainty. The parameters used in this estimate, such as the global CO_2 emissions over the next centuries, the effects of emissions on temperature and other climate impacts, and the impact of climate change on the economy and human welfare, are inherently uncertain (Kaufman et al., 2020). They instead propose to use a near-term to net zero (NT2NZ) approach, which avoids uncertainties in estimates of climate damages and the long-term costs of decarbonization. In addition, this method offers transparency about sensitivities. They select three net-zero CO_2 emissions dates, namely 2040, 2050 and 2060, and use a straight-line annual emissions pathway. These emission dates and pathways reflect a range of values discussed in recent years by policymakers in the US. The authors estimate CO_2 prices using these two variables and propose prices in 2025 of $32, $52 and $93 per ton CO_2 respectively. They also indicate that prices would increase over time, leading to a doubling of prices in 2030. The prices are expressed in 2018 dollars, so converting these to euros requires us to use the 2018 $/€ exchange rate equal to 0.8475 EUR/$. This leads to estimates of €27.12 (2040), €44.07(2050) and €78.82 (2060) per metric ton of CO_2 in 2025. The authors acknowledge that these prices could be increased or decreased depending on the implementation of complementary emission-reducing policies.

The fact that NT2NZ focuses on the near term indeed makes this method appealing. Various factors are less uncertain, such as short-term changes in technologies, preferences and policies. However, this method still includes estimates and uncertainties, such as the risks of more substantial temperature changes and near-term clean energy innovation (Kaufman et al., 2020). Aldy et al. (2021) criticize the use of cost-effectiveness analyses like the NT2NZ, arguing that the setting of the reduction goal is inherently political, hinges on subjective judgements and is thus subject to arbitrary change. They acknowledge that the SCC also is not free of political judgment, but that the SCC relies more on the science of climate change. In line with the critique by Kaufman et al. (2020), Aldy et al. (2021) mention the uncertainty that comes with basing estimates on assumptions about technologies that are not yet available. The NT2NZ method thus offers an interesting alternative perspective, but still has serious flaws.

2.1.2.3 Dutch Climate Agreement

In addition to analyzing what theory says about carbon tax levels, looking at the actual carbon tax rates and the impact on emissions can give interesting insights into what a carbon tax could bring about. Therefore, the following subsections delve into the cases of the Netherlands and other countries worldwide.

In 2019, the Dutch government published the Dutch Climate Agreement, which aims at reducing national greenhouse gas emissions in 2030 with 49% compared to 1990. Sector-specific targets regarding emission reduction are stated and industrial emissions are supposed to be reduced by 14.3 Mt (megaton) by 2030. The government relies on estimates from the Netherlands Environmental Assessment Agency (PBL), which looks at the marginal abatement cost curve to see which reduction measure would help achieve the reduction target in the cheapest way. PBL considers the fact that a carbon tax might not actually unlock the full potential of carbon reduction. They assume 80% of the potential will be realized. The government proposes to combine a carbon levy with the already existing EU ETS system and states that a carbon levy for industry of €30 per ton in 2021 would help achieve the carbon reduction target with a 75% probability. The levy would then increase linearly over the years until it reaches a level of €125-150 per ton in 2030. This includes the ETS price and would thus come down to a levy of €75-100 per ton on top of the ETS price (Government of the Netherlands, 2019). The exact reason for the linear increase in the carbon levy is not given, but the levy starts at a low level in 2021 to give businesses some time to start investing. The rate then increases to align with the emission reduction target. The Dutch government considers that businesses will need to deal with higher costs after the introduction of the levy. They argue that if enough subsidies are available, a limited levy would already stimulate businesses to take measures and emit less carbon. Two comments can be made with regards to this assessment. Firstly, the estimate is based on the target to reduce CO_2 emissions by 49% by 2030, while the recent *Fit for 55* package aims to accomplish a reduction of 55%. A higher carbon levy would be necessary to reach this goal. In addition, the urgency of the measures that need to be taken to prevent dangerous climate change and the fatal consequences that follow if we cannot avert this, might ask for higher probability rates than the 75% that was given. This also argues in favor of a higher levy, as this leads to more certainty on the realization of the reduction target (Government of the Netherlands, 2019).

2.1.2.4 Carbon tax rates in other countries

Investigating carbon tax rates worldwide, Sweden is an interesting example as it is one of the first countries in the world to have introduced a tax on carbon on heating fuels and transport fuels. At the time of the introduction of the Swedish carbon tax, the rate was US$32 per ton of CO_2 and it has increased ever since. The World Bank (2022) reports a carbon tax for Sweden of $129.89 in April 2022, which is one of the highest rates worldwide. Using a synthetic control method, Andersson (2019) looks at the impact of introducing a carbon tax on Swedish CO_2 emissions. The synthetic control unit is constructed from a group of OECD countries that are comparable to Sweden in terms of GDP per capita, number of motor vehicles, gasoline consumption per capita and the percentage of urban population. These predictors are weighted, with more weight given to relative important predictors of CO_2 emissions from transport. A so-called 'synthetic Sweden' is constructed by taking a weighted average of the control countries. Swedish CO_2 emissions from transport are best reproduced by using a combination of Denmark, Belgium, New Zealand, Greece, the United States, and Switzerland. Before the introduction of a VAT and carbon tax in 1990, Sweden and synthetic Sweden have similar trends in CO_2 emissions from transport. Andersson (2019) then compares emissions from Sweden, who introduced the carbon taxes, to those from synthetic Sweden, who did not. This synthetic control method seems like a credible approach to calculate the effect of the carbon tax, as the countries with similar trends in emissions before 1990 form a good proxy of Sweden's emissions path without a carbon tax. After disentangling the effect of the VAT and the carbon tax, Andersson (2019) concludes that the carbon tax decreased CO_2 emissions by 6.3% over the period of 1990-2005. He thus states that the Swedish carbon tax has been effective in cutting down CO_2 emissions, which leads us to believe that introducing a relatively high carbon tax can also be effective to decrease emissions in the Netherlands.

Other countries on the higher end of the carbon tax spectrum are Finland, Liechtenstein, Norway, Switzerland and Uruguay. On the first of April 2022, these countries had tax rates of US$85.10/US$58.58 (transport fuels/ other fossil fuels), US$129.86, US$87.61, US$129.86, and US$137.30 respectively (The World Bank, 2022). The rates in euros are reported in Table I in the Appendix. The World Bank (2022) emphasizes that these rates are not necessarily comparable, because they differ in the number of sectors they cover, compensation and allocation methods used, and specific exemptions. However, they do not elaborate on the differences with regards to the aforementioned variables. Nevertheless, these numbers are good indicators of the levels of taxes in the respective countries.

2.1.2.5 Overview and sensitivity analysis

Table I in the Appendix gives an overview of the estimates of the carbon tax rates mentioned in previous sections. Importantly, the rates that will be used throughout this paper are not set in stone. With new information and future scientific, economic and policy changes, we might be able to better forecast the impact that CO_2 emissions have on the earth. It is thus important to continuously re-estimate the SCC as well as the NT2NZ and other estimates using updated assumptions about socio-economic variables and emission trajectories that reflect new information. Carbon taxes need to be adjusted accordingly.

2.2 CARBON CONSUMPTION

The goal of this section is to give an overview of how different income quintiles spend their income. Determining their consumption patterns and the elasticity of consumption of different consumption categories is the first step towards establishing a framework that will be used throughout the paper. To complete this framework, the remainder of this chapter discusses the carbon intensity of the different consumption categories. By establishing these three matters, a foundation will be created for the analysis of the incidence of carbon taxation in Chapter 3.

2.2.1 Income and classification into quintiles

The classification of individuals into different quintiles will be done based on their income. Income can be defined in different ways, namely primary and secondary income (Caminada et al., 2021). Primary income consists of returns to labor and capital, whereas secondary income is corrected for benefits, transfers, taxes and premiums. In this paper, the focus will be on secondary or disposable income. Compared to primary income, disposable income is a better representation of what an individual/household is truly able to spend. In addition, we can distinguish between individual income and household income. Adhering to the method that Statistics Netherlands (CBS) uses, the household disposable income, adjusted for household composition, will be used to compose five income quintiles. From Caminada et al. (2021), we learn that 7,824,000 Dutch households received a disposable income in 2019. This means that there are 1,565,000 households per income quintile.

2.2.2 Consumption patterns

This section discusses the consumption patterns of different income groups. The idea that consumption patterns change when household income increases was first introduced by Ernst Engel in 1857. He concluded that the poorer the family is, the larger the share of income they spend on food (Zimmerman, 1932). As income increases, there is no proportional increase in food demand, so there is more room to spend the extra income on non-food consumption products.

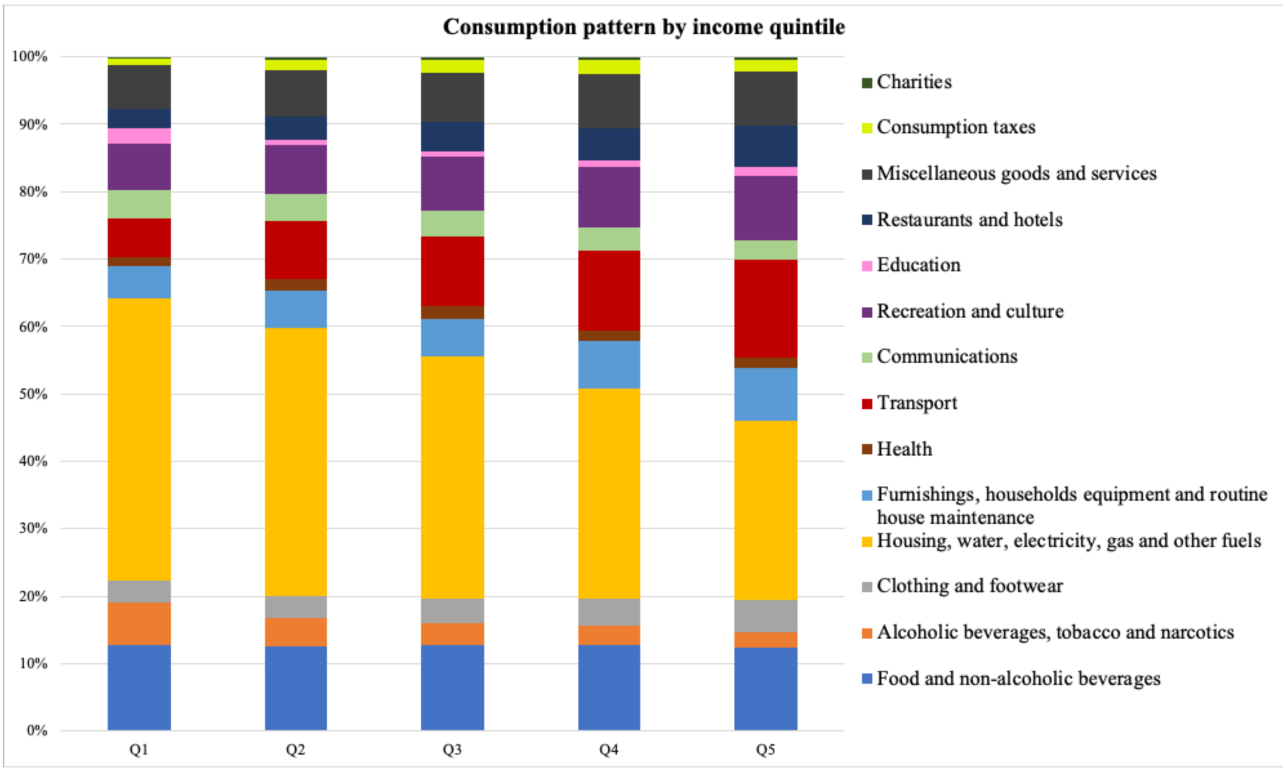
To assess the impact of carbon taxes on the purchasing power of households, it is necessary to know how households spend their incomes. Household expenditures are classified according to the Classification of Individual Consumption According to Purpose (COICOP). Statistics Netherlands (2022a) publishes information on household expenditures, but presents these per income decile. These numbers are combined to get consumption per income quintile and determine the fraction of income that different income groups spend on various consumption categories. An overview of the numbers and a visual representation of the consumption patterns can be found in Table 1 and Figure 1 below.

Table 1 - Average yearly consumption for a household (per income quintile)

	Consumption (€ x1.000 (% of total consumption))				
Consumption category	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*
1 Food and non-alcoholic beverages	5.20 (12.87%)	6.50 (12.52%)	8.40 (12.77%)	10.60 (12.73%)	13.80 (12.34%)
2 Alcoholic beverages, tobacco and narcotics	2.50 (6.19%)	2.20 (4.24%)	2.20 (3.34%)	2.40 (2.88%)	2.60 (2.33%)
3 Clothing and footwear	1.30 (3.22%)	1.70 (3.28%)	2.30 (3.50%)	3.40 (4.08%)	5.30 (4.74%)
4 Housing, water, electricity, gas and other fuels	17.00 (42.08%)	20.50 (39.50%)	23.70 (36.02%)	26.10 (31.33%)	29.90 (26.74%)
5 Furnishing, household equipment and routine house maintenance	1.90 (4.70%)	2.90 (5.59%)	3.70 (5.62%)	5.80 (6.96%)	8.60 (7.69%)
6 Health	0.60 (1.49%)	0.90 (1.73%)	1.20 (1.82%)	1.40 (1.68%)	1.80 (1.61%)
7 Transport	2.30 (5.69%)	4.40 (8.48%)	6.90 (10.49%)	9.90 (11.88%)	16.10 (14.49%)
8 Communications	1.70 (4.21%)	2.10 (4.05%)	2.40 (3.65%)	2.80 (3.36%)	3.20 (2.86%)
9 Recreation and culture	2.80 (6.93%)	3.70 (7.13%)	5.30 (8.05%)	7.50 (9.00%)	10.80 (9.66%)
10 Education	0.90 (2.23%)	0.40 (0.77%)	0.60 (0.91%)	0.90 (1.08%)	1.50 (1.34%)
11 Restaurants and hotels	1.20 (2.97%)	1.80 (3.47%)	2.90 (4.41%)	4.00 (4.80%)	6.70 (5.99%)
12 Miscellaneous goods and services	2.60 (6.44%)	3.60 (6.94%)	4.70 (7.14%)	6.70 (8.04%)	9.10 (8.14%)
13 Consumption taxes	0.40 (0.99%)	0.80 (1.54%)	1.30 (1.98%)	1.70 (2.04%)	1.90 (1.70%)
14 Charities	0.10 (0.25%)	0.20 (0.39%)	0.30 (0.46%)	0.40 (0.48%)	0.50 (0.45%)

Source: Statistics Netherlands (2022a)

Figure 1 - Consumption pattern by income quintile



Source: Statistics Netherlands (2022a), own reproduction.

While the consumption patterns do not vary drastically, there are some differences that are worth pointing out. Firstly, the percentage of income spent on food does not seem to differ much between low- and high-income groups. The absolute numbers increase, but relative to total consumption, spending on food and non-alcoholic beverages is equal to 12% approximately. This is contrary to what we might expect based on Engel's theory from 1857. Secondly, the fraction of income spent on clothing and footwear, transport, recreation and culture, restaurants and hotels, furnishing, and miscellaneous goods and services increases with income. Most of these items can be classified as economic luxury goods, so this seems to be in line with theory that explains that both absolute and relative spending on luxury goods increase with income. Thirdly, the fraction of income spent on housing, water, electricity, gas and other fuels decreases with income. This is also true for communications, alcoholic beverages and tobacco. These items can be considered necessities and thus consumption of these goods is rather inelastic.

International research is mostly in line with the data reported by Statistics Netherlands. Léo et al. (2016) analyze consumption patterns in Mexico and find that people from lower socio-economic classes spend a larger part of their income on necessities such as retail products, gas, and telecom. In addition, and in line with the information on Dutch households from the OECD (2021), Duarte et al. (2012) find that for Spanish households, the fraction of income spent on energy and water decreases with income. However, Duarte et al. (2012) also find that the fraction of income spent on agriculture and food does decline gradually with income. This is consistent with research done in the EU-27 countries by Sommer and Kratena (2017), but does not match the data from Statistics Netherlands perfectly. Léo et al. (2016) also report that people from higher socio-economic backgrounds spend more money on luxury goods such as jewelry, automobiles, clothing, hotels, and airlines.

2.2.3 Carbon intensity

The next step in setting up the framework which can be used to assess the impact of carbon taxation, is to determine the carbon intensity of the different consumption categories. Following Kerkhof et al. (2009), carbon intensity is defined in this paper as the amount of CO_2 emitted per euro spent on the category. The focus will be on the categories' intensities of CO_2 and not on other greenhouse gas emissions, since the proposed carbon tax aims at pricing the CO_2 emissions. In this section, the methods to determine the carbon intensity of consumption goods will be explored, as well as proposed intensity numbers per consumption category. With this information, consumption patterns can be deconstructed, which can be used to analyze the carbon consumption per income quintile and determine the incidence of a carbon tax.

Many papers explore the relationship between national carbon emissions and the level of GDP in a country to evaluate the effects of economic growth. For instance, Hannesson (2020) investigates whether CO_2 intensity falls as countries grow richer. Studies like this define carbon intensity as CO_2 emissions per unit of GDP. They aggregate all national CO_2 emissions and divide these over GDP. While this definition is helpful to compare the CO_2 emission intensities between countries and over time, this measure is not detailed enough for the analysis performed in this study. More detailed information regarding emissions per sector or consumption group is required.

Taking on a sector-focused approach, Gemechu et al. (2014) use an environmental input-output model (EIO) to estimate sectoral life cycle CO_2 emission intensities. The EIO model accounts for resource consumption and environmental load by using national data to assess emission intensities per industry. It estimates the life cycle emissions of products and services by mapping interactions between industries. In addition, EIO can assess both direct and indirect emissions, which allows for an overview of emissions linked to the final demand of products and services. A drawback of the model is that it assumes fixed coefficients for the interactions between industries, while industry structures could change due to economic changes resulting from policy action.

Kok et al. (2006) also use input-output analysis, but investigate the energy requirements of household consumption groups to generate numbers on the carbon intensities of different product groups. These energy requirements can later be transformed to CO_2 emissions and coupled to expenditure data to find the carbon intensity of our product groups. Kok et al. (2006) investigate different methods for calculating the energy requirements related to household consumption. They distinguish between direct and indirect energy requirements. Direct requirements such as electricity and natural gas are consumed in or via households, whereas indirect energy requirements are needed for the production, distribution and disposal of goods and services consumed by households (Kok et al., 2006). The researchers identify three methods for determining the energy requirements, which are all based on input-output analysis. The energy intensity of each sector is calculated by combining data on energy usage and an input-output table, which describes the relations between the sectors and final demand in monetary units (Kok et al., 2006).

The first method, which is the input-output energy analysis based on national accounts, computes indirect energy requirements by multiplying the cumulative energy intensities of the sector with monetary data on household demand. It determines direct energy deliveries to households based on national physical energy data from energy statistics. This gives energy usage data on a national level and expenditure data for economic sectors. This method allows for quick calculation of the energy requirements of sectors or commodities of average households at an aggregated level. It is helpful to compare environmental loads of countries, but not detailed on the household level.

The second method combines input-output energy analysis with household survey data. The cumulative energy intensities of sectors are calculated similarly as with the first method, but now the data on consumption by households is derived from expenditures instead of input-output tables. This method results in more specific information, as the direct energy requirements are based on energy usage data collected for households instead of at a national level, and data on expenditures are divided over consumption items instead of over economic sectors. Energy requirements are obtained at the household level, which allows for comparison of household types, per consumption item and per consumption category. A limitation of this method is that consumption items from the same sector have the same energy intensity, which may not be true in real life. In addition, consumption items from the household survey may not match the input-output sector perfectly.

The last method discussed by Kok et al. (2006) is the hybrid energy analysis, which combines input-output analysis and process analysis. The life cycle of household consumption items is divided into stages, for which either process analysis or input-output analysis is used to determine energy usage.

Process analysis combines the physical data and energy data of consumption items, whereas input-output analysis combines financial data with energy intensities, derived using the first method. With this hybrid method, energy requirements per consumption item and total energy intensities of goods and services can be obtained.

Kok et al. (2006) apply the three methods to Dutch household data from 1996 and compare the outcomes. They conclude that the methods give comparable results in terms of energy requirements, but that the requirements resulting from input-output analysis based on national accounts is slightly lower than those resulting from the other two methods. The estimates for the hybrid analysis are the highest. The potential explanation for this is that the input-output analysis concerns economic sectors, while the hybrid approach considers the whole life cycle of consumption items. The latter thus also include transport, trade and waste, which leads to higher energy intensities.

For the analysis performed in this study, information is needed on the carbon intensity of different consumption groups, for which the hybrid approach is most useful. Kerkhof et al. (2009) use this hybrid approach to study the determinants of variation in household CO_2 emissions between the Netherlands, the UK, Sweden and Norway, and within these countries. They determine the CO_2 emission intensities of different goods and services in the COICOP expenditure classification. They determine the CO_2 emissions associated with the production of materials, transport, household use and disposal using process analysis, which combines physical data with energy data. Furthermore, the researchers apply input-output analysis to determine the CO_2 emissions of the rest of the life cycle of consumption items, including production of residual and capital goods, manufacturing and trade. They sum the CO_2 emissions of all the processes and divide them by the products' retail price to find the CO_2 emissions intensities. These intensities are linked to household expenditures to find the CO_2 emissions for households, which are compared within and between the four countries.

For the Netherlands, the researchers find decreasing CO_2 emission intensities of household consumption patterns with increasing income because of consumption patterns shifting to less CO_2 emission intensive products. The share of household expenditures on housing decreases with income, while the share spent on transport and recreation and culture increases. Since the first consumption group is more CO_2 intense than the last two, the total CO_2 emission intensity of consumption decreases with increasing income. Total emissions do not decrease when income increases, but the ratio of carbon emissions over income does. The carbon intensity numbers discussed by Kerkhof et al. (2009) will be used in the analysis of carbon consumption and the impact of a carbon tax in the next chapters. The results of their carbon intensity analysis are shown in Table 2 below.

Table 2 - Carbon intensity of consumption categories

Consumption category	**CO_2 emission intensities (kg CO_2/€)**
Food and non-alcoholic beverages	0.86
Alcoholic beverages, tobacco and narcotics	0.41
Clothing and footwear	0.35
Housing, water, electricity, gas and other fuels	1.23
Furnishing, household equipment and routine house maintenance	0.47
Health	0.51
Transport	1.06
Communications	0.28
Recreation and culture	0.60
Education	0.24
Restaurants and hotels	0.80
Miscellaneous goods and services	0.28

Source: Kerkhof et al. (2009)

Combining the carbon intensity numbers with the consumption pattern data from Statistics Netherlands (2022a), the carbon consumption for the five income quintiles can be determined. We leave out the carbon consumption for the categories consumption taxes and charities, because information on their carbon intensities is not available. Examples of consumption taxes in this context are the taxes paid for the use of motor vehicles and municipal charges, and thus do not relate to expenses for VAT on consumption goods. The impact of leaving out these categories will most likely be limited, since the fraction of income spent in these categories is rather small. The carbon consumption numbers are displayed in Table 3. Total carbon taxes per income group are presented in Table 4.

Table 3 - Average yearly carbon consumption for a household (per income quintile)

	Carbon consumption (in kg, x1000)				
Consumption category	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*
Food and non-alcoholic beverages	5.20*0.86 = 4.472kg	6.50*0.86 = 5.590kg	8.40*0.86 = 7.224kg	10.60*0.86= 9.116kg	13.80*0.86= 11.868kg
Alcoholic beverages, tobacco and narcotics	1.025	0.902	0.902	0.984	1.066
Clothing and footwear	0.455	0.595	0.805	1.19	1.855
Housing, water, electricity, gas and other fuels	20.91	25.215	29.151	32.103	36.777
Furnishing, household equipment and routine house maintenance	0.893	1.363	1.739	2.726	4.042
Health	0.306	0.459	0.612	0.714	0.918
Transport	2.438	4.664	7.314	10.494	17.172
Communications	0.476	0.588	0.672	0.784	0.896
Recreation and culture	1.68	2.22	3.18	4.5	6.48
Education	0.216	0.096	0.144	0.216	0.36
Restaurants and hotels	0.96	1.44	2.32	3.2	5.36
Miscellaneous goods and services	0.728	1.008	1.316	1.876	2.548

Table 4 - Average yearly carbon tax per household (per income quintile)

	Q1	**Q2**	**Q3**	**Q4**	**Q5**
t = €30 per ton CO_2	€1036.77	€1324.20	€1661.37	€2037.09	€2680.26
t = €51 per ton CO_2	€1762.51	€2251.14	€2824.33	€3463.05	€4556.44
t = €117 per ton CO_2	€4043.40	€5164.38	€6479.34	€7944.65	€10453.01

It is shown that total consumption of carbon increases with income, which is in line with research performed by Sommer and Kratena (2017) and Kennedy et al. (2014). Sommer and Kratena (2017) study the macroeconomic impact of consumption and calculate the carbon footprint of private consumption in the 27 countries of the EU. They define the total carbon footprint of a quintile as the sum of the direct footprint, the indirect domestic footprint and the indirect imported carbon footprint of this quintile. With this, they acknowledge that consumption in one quintile will create disposable income in another quintile, meaning final demand for consumption is induced by both income and price effects. They find that carbon emissions increase considerably with income, with about 37% of CO_2 emitted by the fifth income quintile, being responsible for about 42% of the total consumption. Additionally, Kennedy et al. (2014) combine household survey data on energy consumed for heating, cooling, cooking and lighting, for ground transportation and for air travel to calculate the partial household carbon footprint, representing direct CO_2 emissions. They find that Canadian household carbon footprints increase steadily with income. These studies indicate that the higher income groups have a greater contribution to CO_2 emissions than lower income quintiles.

Duarte et al. (2012) study Spanish carbon emissions using a Social Accounting Matrix (SAM) model, which captures the relationship between economic accounts and provides disaggregated information about the structure of households and their consumption patterns (Duarte et al., 2010). Like the studies discussed above, they distinguish between direct and indirect emissions. Emission values, expressed in kg CO_2 per euro spent in the household, are determined by summing the vector of production pollution values and the vector of direct household emission coefficients. These emission values are accumulated for different sector blocks. While these sector blocks do not match the standard COICOP expenditure groups, some of their results are worth mentioning.

Duarte et al. (2012) find considerably higher estimates for emission intensity of the energy and water sector. Instead of the 1.23 kg CO_2/€ that Kerkhof et al. (2009) find, these researchers report a value of 4.55 kg CO_2/€. This might be explained by the fact that Kerkhof et al. (2009) also include housing, gas and other fuels in their consumption category. If these items have lower emission intensities, not including them will give higher estimates. In addition, the estimates for transport and communication reported by Duarte et al. (2012) are substantially larger than those from Kerkhof et al. (2009). They find estimates of 3.34 kg CO_2/€ and 1.06 or 0.28 kg CO_2/€ respectively. While the production of communication and transport goods is not that CO_2 intense, the majority of the high CO_2 emission intensity for this sector can be explained by the large amount of pollution directly generated by households (Duarte et al., 2010). However, Kerkhof et al. (2009) also include household usage in their estimates, so this should bring about such large differences. For the other sectors, the differences are not as large. In this paper, the numbers reported by Kerkhof et al. (2009) will be used as a guideline, since these numbers are based on Dutch households and match the COICOP expenditure categories well. However, the change in impact of the carbon tax from using the numbers from Duarte et al. (2012) will be shown in section 4.3.

2.2.4 Elasticity of consumption

To say something about how households shift their consumption after the carbon tax, it must be shown how strongly they adjust their consumption to a price increase. A distinction will be made between elastic and inelastic consumption categories. Demand for price inelastic products is likely to stay relatively stable when prices increase, as this usually concerns necessities. For price elastic products, demand responds more to a change in price. This section discusses estimates of the price elasticities of different products in the COICOP consumption categories. These estimates are used to classify the consumption categories as either elastic or inelastic.

Andreyeva et al. (2010) review 160 studies on the price elasticity of demand for food products in the US. They pool estimates across studies by food category and compute the mean elasticity, for which estimates range from -0.27 to -0.81, depending on the food type. This is in line with research done by Green et al (2013), who identify 136 studies reporting price elasticities from 162 different countries worldwide. They use a meta-regression model to calculate the relationship between price and demand in different food groups and report a price elasticity of -0.56 for all food groups combined in high income countries. As both studies present elasticities with an absolute value smaller than 1.0, we can conclude that the demand does not change considerably after a price increase, and that food is a rather inelastic good.

For the consumption category representing alcoholic beverages and tobacco, we combine research done by Nelson (2013) and USNCI & WHO (2016). Nelson (2013) presents a meta-analysis of 182 studies that focus on price elasticities of alcoholic beverages, which are grouped into beer, wine, spirits and total alcohol. The author reports a price elasticity of -0.50, but performs an additional analysis to account for publication bias, outliers, dependence and heterogeneity. While the price elasticities for beer, wine and spirits decrease as a result of this, the estimate for total alcohol price elasticity remains almost unchanged with a value of -0.48. In a report on the economics of tobacco, the USNCI & WHO (2016) compare different studies on the responsiveness of tobacco demand to price changes, mainly performed during the 1980s and 1990s. While the range of price elasticity estimates reported in these studies differ depending on the country, time period, method and model used, the estimates all fall within the range of -0.2 and -0.6. Based on aggregate demand analyses, they conclude that the short-run price elasticity of demand for cigarettes in high income countries is approximately -0.4. From these estimates, it can be concluded that alcoholic beverages and tobacco are also inelastic. The estimates reported in the aforementioned studies seem credible as they combine many results from many different researches. One drawback is that the data used is not very up-to-date.

Kim (2003) determines the price elasticity of demand for clothing and shoes by using the almost ideal demand system (AIDS) model, which allows for analysis of the budget allocation patterns of US consumers. Using annual time-series data from 1929 to 1994, budget shares and consumption expenditures were calculated. Using these budget shares and mean prices for consumption categories, the elasticities were calculated, which range between -0.38 (shoes) and -0.80 (clothing). Kalwij et al (1998) also use the AIDS model, but use Dutch expenditure data from an annual budget survey conducted between 1980 and 1991. Household expenditures are divided into six consumption categories. Combining this information with budget shares and price indices for the different categories, the price elasticities are determined. For 1990, the price elasticities of housing, clothing, and education, recreation & culture equal -0.23, -0.19, and -0.96 respectively.

Elasticity estimates for some other relevant consumption categories can be found in Table II in the Appendix. To keep this section somewhat compact, not all methods will be discussed here. However, a classification into elastic and inelastic goods will be provided. The consumption categories with inelastic demand are food and non-alcoholic beverages, alcoholic beverages, tobacco and narcotics, clothing and footwear, housing, water, electricity, gas and other fuels, and communications. Health, recreation and culture, and restaurants and hotels all have elastic demands. The elasticity of transport depends on the type of transport, but will be classified as inelastic overall.

3 METHODOLOGY

Three different measures will be used to estimate the regressivity of the carbon tax, which indicates whether lower income households pay a relatively larger share of the carbon tax burden than higher income households. For the calculations of these measures, an estimate for an appropriate carbon tax in 2022 is needed. Estimates from Greenstone et al. (2013), discussed in chapter 2, with a discount rate of 3% will be used. While Greenstone et al. (2013) show the results of various discount rates, they mention that the 3% rate is most in line with rates used in other economics literature. Transforming these into 2007 euro rates and then using a 1.97% inflation rate over the period of 2007-2022, we get a price of €38.85 in 2010 and €54.93 in 2025. The authors do not specify the rate of the price increase between 2010 and 2025. For this analysis, a linear increase in the tax rate will be assumed, since this is also the approach used by the Dutch government (Government of the Netherlands, 2019). Assuming linearly increasing carbon tax rates over time, we get a value of €51.71 per ton CO_2 in 2022. From Kaufman et al. (2020) we learn that the carbon tax should be €44.07 in 2025 (in 2018 euro rates) if we want to accomplish net-zero by 2050, which is the goal in the EU. Using an average annual inflation rate of 3.42% between 2018 and 2022, a price of €50.33 per ton CO_2 in 2022 is determined.

For the analysis, three different estimates of the tax rate will be used, which are classified as low, moderate, and high. The low estimate comes from the carbon tax rate that was introduced in the Netherlands in 2021 and equals €30 per ton CO_2. The moderate rate is derived by combining the numbers from Greenstone et al. (2013), Kaufman et al. (2020) and Van der Ploeg et al. (2022) and equals €51 per ton CO_2. The high estimate is derived from the scenario in which the Swedish example of setting a very high carbon tax rate would be followed and equals €117 per ton CO_2.

3.1 Relative Impact

The first measure of regressivity is a new variable called Relative Impact (RI), which is calculated for all income quintiles. The RI is equal to the ratio of new consumption costs (NCC) over old consumption costs (OCC). The NCC is determined by multiplying the consumption in each category by the carbon intensity and the proposed carbon tax rate. Comparing the Relative Impacts of different quintiles will give an indication of how much the costs of their normal consumption basket has increased. A larger RI means that prices for that income quintile have increased relatively more compared to those with a smaller RI. The following formula will be used:

$$Relative\ impact\ (RI) = \frac{NCC}{OCC} = \frac{\sum_{cc=1}^{12} C^{cc} + (C^{cc} * I^{cc} * t)}{\sum_{cc=1}^{12} C^{cc}}$$

where cc = consumption category

C = consumption

I = carbon intensity

t = carbon tax

3.2 The tax / expenditure ratio

Following Vogt-Schilb et al. (2019) and Wier et al. (2004) who study the effects of carbon taxes in Latin America and the Caribbean and Denmark respectively, the second method used to study the distributional impact will be examining the carbon tax relative to total expenditures after tax. Here it is assumed that households will (want to) consume the same amount of products after the introduction of the tax. In reality, they will have to change their consumption patterns. This possibility will be discussed in section 4.3.

This tax/expenditure ratio will be computed for all five income quintiles, which allows for a comparison. Looking at expenditures is relevant as these form the tax base (Wier et al, 2004). The following formula will be used:

$$\frac{Tax}{NCC} = \frac{\sum_{cc=1}^{12} C^{cc} * I^{cc} * t}{\sum_{cc=1}^{12} C^{cc} + (C^{cc} * I^{cc} * t)}$$

3.3 Gini coefficient

The third and last indicator of regressivity that will be used is the Gini coefficient, which measures the inequality in a country. If one were to look at a Lorenz curve, the Gini coefficient would be equal to the proportion of the area under the diagonal that lies between the Lorenz curve and the diagonal (Wier et al., 2004). The Lorenz curve relates the cumulative percentage of aggregate household expenditures after tax to the cumulative percentage of the households. The Gini coefficient will thus be estimated relative to household expenditures. Household expenditures after the carbon tax are defined as household expenditures before the tax plus the carbon tax. To analyze the incidence of the carbon tax, a comparison will be made between the Gini coefficient before and after the introduction of the carbon tax. If the carbon tax increases the coefficient, inequality increased and the tax is thus regressive.

4 RESULTS

This chapter will discuss the outcomes of the three measures of regressivity proposed in the previous chapter. In addition, potential changes to household consumption patterns after the introduction of the carbon tax will be examined. Lastly, a sensitivity analysis will be performed to investigate how the results would change when using different values for the carbon intensity of consumption products.

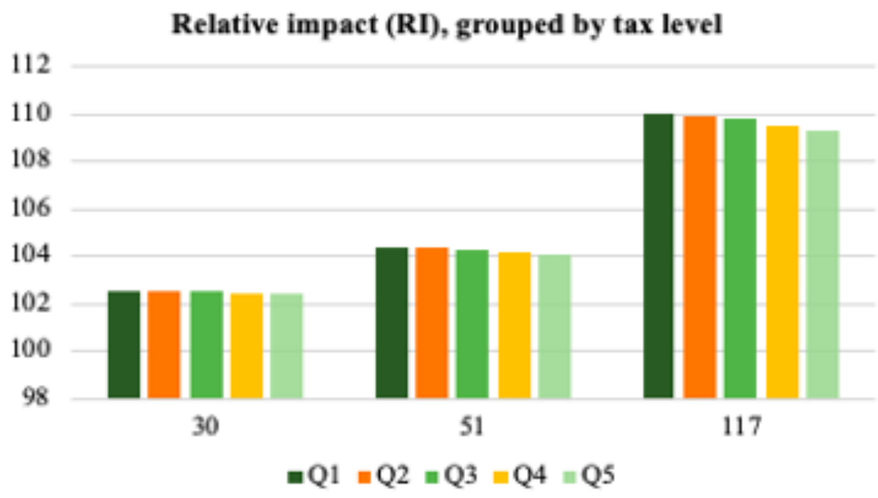
4.1 Three indicators

Looking at the Relative Impact, it can be noted that costs of consumption increased slightly more for the lower income groups. If a normal basket of goods would cost €100 before the carbon tax, the introduction of a tax of €51 per ton CO_2 would increase the price to €104.36, €104.34, €104.29, €104.16 and €104.08 for the first to fifth quintile respectively. The differences get larger as the tax rate increases, but appear rather small. This leads us to believe the impact does not differ much between lower and higher income households. All RI estimates are shown in Table 5 and Figure 2 below.

Table 5 - Relative Impact estimates

	Q1	Q2	Q3	Q4	Q5
t = €30 per ton CO_2	1.0257	1.0255	1.0253	1.0245	1.0240
t = €51 per ton CO_2	1.0436	1.0438	1.0429	1.0416	1.0408
t = €117 per ton CO_2	1.1001	1.0100	1.0985	1.0954	1.0935

Figure 2 - Relative Impact, grouped by tax level

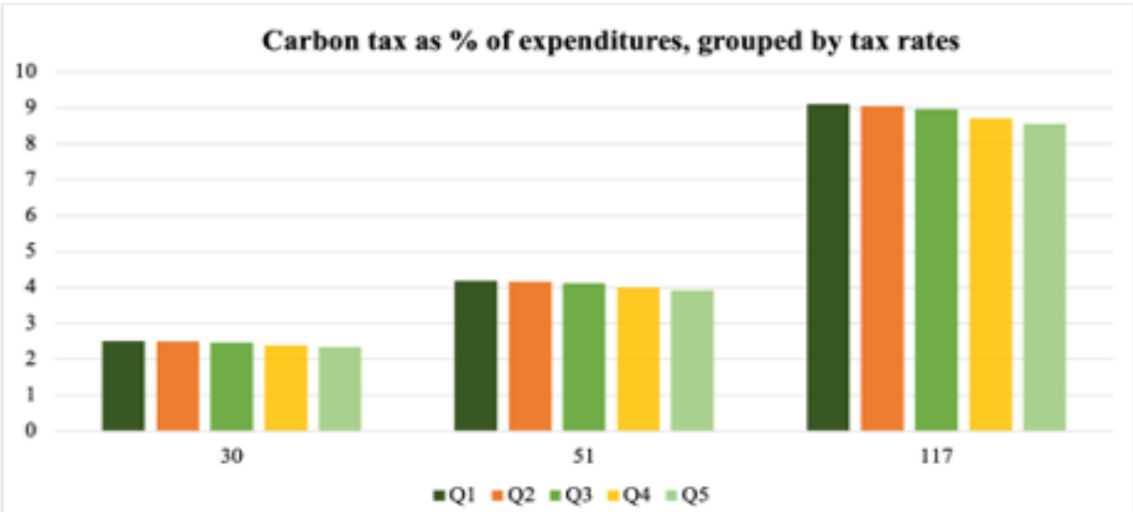


The results from calculating the tax to expenditure ratio resemble the RI results. Table 6 and Figure 3 indicate that, based on our second indicator, the carbon tax does not put a significantly higher burden on lower income households. Tax payments increase with income, as can be seen in Table 4, but constitute an almost steady share of total expenditures across income groups. The share of income spent on carbon tax obviously increases with an increasing tax rate. The carbon tax to expenditure ratio decreases slightly with income, but the difference is not substantial.

Table 6 - Carbon tax to Expenditure ratios

	Q1	**Q2**	**Q3**	**Q4**	**Q5**
t = €30 per ton CO_2	2.50%	2.49%	2.46%	2.39%	2.34%
t = €51 per ton CO_2	4.18%	4.16%	4.12%	3.99%	3.92%
t = €117 per ton CO_2	9.10%	9.05%	8.96%	8.71%	8.55%

Figure 3 - Carbon tax relative to total expenditures, by tax rates (t= €30, €51 or €117 per ton CO_2)



In line with the results from the first two indicators, the Gini coefficient does not change substantially when the costs for the carbon tax are considered. As can be seen in Table 7 below, the Gini coefficient decreases only slightly. Inequality thus is not strengthened nor reduced by the introduction of a tax on carbon. The estimates range between 0.196 and 0.198, which is quite small compared to the Gini of 0.292 that was published for the Netherlands by the World Bank (2019). The difference between these values might be explained by the fact that this paper only compares five income quintiles, while the World Bank analyzes the income differences between all incomes in the country. The calculations used to compute the numbers below are based on the expenditures after the introduction of the tax, for which the tax costs are added to the total expenditures per quintile. Instead, the Gini coefficient can also be calculated using so-called net expenditures, which are defined here as the expenditures minus tax costs. This represents what the households can spend net of taxes. Calculations with net expenditures give increasing values of the Gini coefficient, with values of 0.197643, 0.197906 and 0.1988 for a tax of €30, €51 and €117 respectively. Even with these new calculations, the Gini coefficient thus does not increase or decrease significantly after the introduction of the tax.

Table 7 - Comparison of Gini coefficients

	Gini coefficient
Before introduction of carbon tax	0.197282
After introducing a tax of €30 per ton CO_2	0.196939
After introducing a tax of €51 per ton CO_2	0.196708
After introducing a tax of €117 per ton CO_2	0.196031

4.2 Changing consumption patterns

The calculations in the previous sections were based on the idea that expenditure costs after the introduction of the carbon tax would increase. To this end, tax costs were added to the total expenditures before the introduction of the tax. However, this seems unrealistic in real life. Households only have their disposable income to consume. One option for them would be to decrease their savings and use this money to make up for the increase in costs caused by the carbon tax. While this may partly be what will happen, they will probably also adjust their consumption patterns, taking new product prices into account (Kerkhof et al., 2008). The results presented should therefore be seen as a short-term indication of the effect of a price increase. The price elasticities of demand will determine which consumption categories will be affected the most by this adjustment. This section discusses the potential impact that a change on consumption patterns will have.

As discussed in section 3.4, household consumption composition consists of elastic and inelastic goods. Lower income households spend a relatively larger share of their income on inelastic goods such as housing, water, electricity, gas, food and clothing. Consumption in these three categories constitutes over 58% of expenditures for the lowest income quintile, compared to almost 44% in the highest income quintile. These goods are basic needs and households are rather limited in their ability to decrease consumption in these categories after a price increase. The carbon intensity of these products is relatively large. Even if lower income households can cut down consumption in elastic consumption categories such as transport, restaurants and recreation and culture, the main share of their consumption will be in the inelastic carbon-intensive sectors. Higher income households consume a larger share of their income on luxury goods such as transport, restaurants, hotels, recreation and culture. These categories have high carbon intensities, but are also rather elastic. Therefore, higher income households would be able to adjust their consumption patterns in a way that would decrease their carbon footprint without depriving them too much in their consumption of basic needs. Carbon consumption is thus less avertible for low income households, meaning that they would pay a relatively larger share of the carbon tax costs. If our analysis would include the change in consumption patterns, the tax might turn out to be more regressive.

4.3 Sensitivity analysis carbon intensity numbers

The results that were presented in this section depend on the values of the input variables that were used, such as the carbon intensity numbers and the level of tax imposed. While this paper showed the impact of using various carbon tax levels, the influence of using different carbon intensity numbers is yet undiscussed. Therefore, this section presents the effect of using carbon intensity numbers from a study discussed in section 2.2.3, namely that of Duarte et al. (2012). They study carbon consumption by Spanish households and use a different classification of consumption into categories. While their setup thus does not conform perfectly to the one used in this paper, their numbers give interesting insights. Examples of emission values used in their analysis are shown in Table 8 below.

Table 8 - Emission values Duarte et al. (2012)

Consumption sector	**Emission values (kg CO_2/€ spent)**
Food products	0.96
Textiles, clothes and footwear	0.94
Energy and water	4.55
Health	4.20
Transport and communication	3.34
Education	0.22
Hotels and restaurants	0.52

Replacing the carbon intensities in consumption categories 1, 3, 4, 6, 7, 8, 10 and 11 with the emission values reported by Duarte et al. (2012) gives slightly more pronounced values for the three indicators used throughout this paper. This means using these emission values, carbon taxes would be slightly regressive. The numbers are reported in Tables 9 to 11 below. The Relative Impact as well as the Tax/Expenditure ratio increases for all income groups and differences between the quintiles increase. The Gini coefficient also increases compared to when using the carbon intensity numbers from Kerkhof et al. (2009). Using the numbers from Duarte et al. (2012), the tax is more regressive, but still the differences are rather small.

Table 9 - Relative Impact estimates using Duarte et al. (2012)

	Q1	**Q2**	**Q3**	**Q4**	**Q5**
t = €30 per ton CO_2	1.0759	1.0749	1.0722	1.0675	1.0638
t = €51 per ton CO_2	1.1291	1.1274	1.1227	1.1147	1.1084
t = €117 per ton CO_2	1.2962	1.2923	1.2815	1.2632	1.2487

Table 10 - Carbon tax to Expenditure ratios using Duarte et al. (2012)

	Q1	**Q2**	**Q3**	**Q4**	**Q5**
t = €30 per ton CO_2	7.06%	6.97%	6.73%	6.32%	5,99%
t = €51 per ton CO_2	11.43%	11.30%	10.93%	10.29%	9,78%
t = €117 per ton CO_2	22.85%	22.62%	21.97%	20.84%	19,92%

Table 11 - Comparison of Gini coefficients using Duarte et al. (2012)

	Gini coefficient
Before introduction of carbon tax	0.197282
After introducing a tax of €30 per ton CO_2	0.194942
After introducing a tax of €51 per ton CO_2	0.193477
After introducing a tax of €117 per ton CO_2	0.189600

5 POLICY RECOMMENDATIONS

When levying a carbon tax, the Dutch government will see a great flow of money into the treasury. Using the fact that 7,824.000 Dutch households received a disposable income in 2019, this amount could add up to more than 13, 23 and 53 billion euros per year for the tax rates of €30, €51, and €117 per ton CO_2 respectively. Table III in the Appendix shows the exact numbers. The government will have to decide on how to spend the carbon tax revenue. From an efficiency point of view, decisions on how to raise and spend revenue are separate. However, targeting revenues and clearly communicating policy reform packages and revenue recycling plans can be helpful to gain support and public acceptability for the carbon pricing policy (OECD, 2019). While commitments to spending revenues in a specific way can thus be beneficial, broad and flexible spending constraints can achieve more efficient public spending.

The impact of the carbon tax is not proven to differ between the five income quintiles. According to this, the government does not need to undertake action to support lower income households. However, there are reasons to believe it is beneficial to put policies into place that target lower income households. The main reason would be that targeting revenues towards the poor can increase public acceptability and support for the CO_2 tax policy. Klenert et al. (2018) argue that public acceptability of carbon pricing is of major importance. Brannlund and Persson (2012) research this in the Swedish setting and find that Swedes prefer a progressive-like cost distribution over a regressive one. Sweden and the Netherlands might not be perfectly comparable, but the Dutch government generally also prefers to reduce market inequalities rather than increase them, and thus aims to make taxes it collects to be progressive if possible. An example would be the progressive taxation of labor income. Using the carbon tax revenues in a progressive manner could be a way for the government to redistribute from higher to lower income households. This paper proposes three recommendations for policies that should be used to achieve these redistributive goals and/or that can promote sustainability in the Netherlands.

5.1 Policy number 1 - Differential tax rates

The first proposed policy is to introduce differentiated carbon taxes for different types of goods. This can be a way of aligning the private and social costs of consumption. Differentiating tax rates is also done for other taxes, such as the Dutch VAT. This standard VAT is equal to 21%, but a discount applies to products of which the government wants to promote consumption. For products like food, medicine and books, a VAT of 9% is applied. A similar principle should be used for the consumption of carbon. For example, a standard carbon tax rate of €51 per ton CO_2 could be applied to most consumption categories, but some could be given an exemption. A distinction can be made between consumption goods that satisfy needs and luxury goods. Keeping necessities affordable should be prioritized, as this is essential to all individuals' well-being. Consumption categories like clothes, food and non-alcoholic beverages and housing, electricity and water could be subjected to a lower carbon tax rate. This allows for households from all income groups to provide for their basic needs and could be a first step towards socio-ecological justice. Since lower income households also spend a considerable fraction of their disposable income in these consumption categories, the lower tax rate for these products will decrease the burden for the lower income quintiles. Since the lower tax rate is imposed on inelastic goods, consumption in any of the income groups is not expected to increase drastically when prices are relatively low compared to those in other consumption groups.

More sustainable choices should still be encouraged, even within the consumption categories comprising basic needs. Therefore, a division can be made between sustainable and non-sustainable consumption within the basic needs consumption categories. Rabès et al. (2020) compare the environmental impact of omnivorous, vegetarian and vegan diets in France. They conclude that the first brings about considerably larger amounts of CO_2 emissions than the two latter. This is caused by animal-sourced food consumption. Subjecting low-carbon products like plant-based meat alternatives to a lower carbon tax rate would make these more attractive and gives lower income households the option to consume sustainable basic needs for a lower price.

Additionally, it could be an option to increase the tax rate implemented on goods that satisfy the needs of the very wealthy. Benoit (2020) discusses the implementation of a luxury carbon tax on luxury items that generate significant emissions to discourage this carbon-intense consumption. Examples would be superyachts, first class air travel, high-end sports cars and private jet travel. Even if very wealthy individuals would not adjust their consumption after the implementation of a very high carbon tax, this would allow governments to invest more tax revenue than before.

Two caveats apply to the introduction of a differential tax policy. Firstly, the implementation might be hindered by problems with the IT systems at the Dutch tax authority. Bolsius (2022) notes that implementation of current plans to decrease the VAT rates for fruit and vegetables are hindered by the systems through which these have to be operated. The IT systems need several modifications and updates to make the practical implementation of a carbon tax possible. Implementing differential tax rates might require even more advanced systems. Secondly, the differential carbon tax does not address the root of the problem of why lower income households spend such a large share of their income on housing, electricity, water and gas. The second policy proposal will elaborate on this.

5.2 Policy number 2 - Investing in insulation and energy-efficiency

The second policy proposal focuses on how the collected tax revenues can be spent to achieve additional emission reductions, while mainly targeting low income households. Putting the revenues from carbon taxes to socially beneficial use is crucial to the realization of the taxes' potential to improve welfare (OECD, 2019). Insulating homes of lower income households and making their energy use more efficient can help bring about long-term, sustainable change.

The Dutch government already has regulations in place to transition towards more sustainable housing. The aim is to get rid of gas as an energy source for all households by 2050 and poorly insulated houses cannot be rented out anymore from 2030 onwards. Dutch houses are all given energy labels rated from A to G, indicating their energy-efficiency. Housing associations, providing housing to mainly low income households, must improve the energy efficiency of houses with energy labels E to G. From 2026 onwards, hybrid heat pumps must be installed when the central heating is replaced. Additionally, low income households can borrow money rent-free at the so-called Warmtefonds and subsidies are available for households that want insulation or want to install a (hybrid) heat pump (Rijksoverheid, 2022).

Marron and Morris (2016) criticize such 'belt and suspenders' policies that aim at the same behavioral changes that the tax wants to bring about, because subsidies will flow to households and businesses that would have already transitioned to cleaner energy sources because of the tax. This seems plausible but does not consider the fact that low income households do not have the financial means to improve their houses' energy efficiency. The regulations put into place by the Dutch government acknowledge this. The government could still play a more proactive role in making houses more sustainable and energy efficient (Croon & Brouns, 2022). Instead of individuals requesting subsidies, authorities could actively approach households and stimulate them to invest in insulation, heat pumps and other sustainable initiatives, possibly through offering even higher subsidies. Implementing this should start at homes with the worst energy labels (Croon & Brouns, 2022). An additional measure could be to fix the rents for energy inefficient houses (van der Burg, 2022), which motivates landlords to invest timely in making their houses more energy efficient, as this is a prerequisite for increasing the rent. An important caveat for investing into making houses more energy efficient is the shortage of workers and thus capacity to install energy-efficient technologies (Croon & Brouns, 2022). Even if the funds are available to improve the situations of low income households, this shortage constrains the ability to do this in the short-term.

5.3 Policy number 3 - Subsidies and targeted tax allowance for low-carbon R&D

Besides investments in installing greener technologies for low income households, part of the carbon tax revenue should be spent on research into new low-carbon technologies and innovations. While higher carbon prices are already a motivator for firms to innovate and work with low-carbon technologies, companies and innovators might underinvest in developing new technologies because these require large upfront investments. Additionally, they might not fully consider the social benefits and knowledge spillovers that can be the result of their investments. If we want to reach the goals that were formulated in the Paris Agreement in 2015, technologies need to develop faster. 'Low-carbon R&D investment improves the competitive advantage of low-carbon technology and facilitates the energy transition from fossil fuels to clean energy, which has a significant impact on emission abatement.' (Yin & Chang, 2020, p.4). Investments can be directed towards research performed in the public sector, but if companies see potential for private return, public policies can counterbalance the problem of knowledge spillovers by subsidizing research in the private sector (Jaffe et al., 2005). Additionally, tax allowances could be introduced in the corporate income tax for investments into low-carbon technologies (OECD, 2022b). A type of tax allowance is already in place in the Netherlands, with the WBSO R&D tax credit scheme compensating R&D costs through tax returns. This allowance could be increased for research into green technologies.

6 CONCLUSION

From the last chapter, it can be concluded that a carbon tax is not proven to be regressive and that it does not increase within-country inequality. While higher income households pay the largest absolute value of carbon taxes, their tax payments for carbon are comparable to those of lower income households when compared to their total expenditures. If a normal basket of goods would cost €100 before the carbon tax, the introduction of a tax of €51 per ton CO_2 would increase the price to €104.36, €104.34, €104.29, €104.16, and €104.08 for the first to fifth quintile respectively. In addition, the Gini coefficient does not change substantially after the simulation of a carbon tax, indicating that inequality in society would remain broadly unchanged. For all three measures, the results become somewhat more extreme when considering a higher tax rate per ton CO_2, but these numbers still do not demonstrate that the tax is regressive. The impact seems unrelated to the income level.

As a result of the carbon tax, households are expected to change their consumption behaviors. Higher income households might be able to cut in their consumption of carbon-intensive, elastic goods such as transport, restaurants, and recreation. For lower income households however, the main share of consumption takes place in carbon-intensive, inelastic sectors such as housing, electricity, water, and food. For them, carbon consumption is less avertable. When this change in their consumption pattern is considered, the tax is expected to be more regressive, meaning they would pay a relatively larger share of the carbon tax costs.

As the regressive effect of carbon taxation is thus not proven, the government does not need to undertake action to support lower income households. However, there are reasons to believe it is beneficial to put policies into place that target lower income households. The main reason would be that targeting revenues towards the poor can increase public acceptability and support for the CO_2 tax policy. The government can use the carbon tax revenues to redistribute from higher to lower income households, which is also the aim of other taxes. This paper proposes three recommendations for policies that should be used to achieve these goals. The first recommendation entails differentiating the carbon tax rates for different types of goods, with lower carbon tax rates assigned to products that provide households with their basic needs. Within consumption categories, a distinction should be made between sustainable and non-sustainable products, and tax rates should be determined accordingly. The second policy that is proposed requires pro-active assistance for low income households in making their houses more energy efficient. The third policy aims to invest in low-carbon R&D and introduce a targeted tax allowance for low-carbon R&D.

7 DISCUSSION

This paper investigated the impact of levying a tax of €30, €51, and €117 per ton CO_2 on consumption goods for five income quintiles. By identifying consumption patterns and the carbon intensity of different consumption categories, the increase in the price of a consumption bundle was determined. This study adds to the extensive literature on carbon tax by quantifying the direct impact of a range of carbon tax rates which are based on social costs, emission pathways and real-life numbers. Combining these rates with carbon intensity numbers and updated COICOP-classified household expenditure data, the impact for different income groups was studied. By investigating three different indicators, the regressivity of the carbon tax could not be demonstrated. This is not in line with conclusions on the impacts of a carbon tax investigated by Andersson and Atkinson (2020) in Sweden, by Kerhof et al. (2008) in the Netherlands, and by Bento (2013) and Marron et al. (2015) in the US. These studies do find that lower income households bear a relatively larger share of the burden of a carbon tax. The difference in results might be because we used fairly broad consumption categories in our analysis, meaning that the data on household consumption and carbon intensity of the items in these categories were aggregated. This means that valuable information might have been lost, potentially leading to a different outcome compared to a situation in which disaggregated categories were used. The choice to study the consumption using the COICOP classification was that information was available on this aggregate level for Dutch households. In addition, we only looked at the households in their role as consumers. However, their income through work and assets might also be impacted by the introduction of a carbon tax. For example, if someone works in a carbon-intense sector and the company's profit margins decrease because of a carbon tax, the boss might decide to implement wage cuts. This would lead to a reduction in household income, and thus to a reduction in households' consumption spending. If this would have been considered, the carbon tax might have ended up being more or less regressive, depending on which income groups would have been impacted the most on the income side. The analysis of the effect on household incomes would have been interesting, but is out of the scope of this paper.

Input variables

The analysis and calculations performed in this paper are largely dependent on the input variables used. While the values of the carbon tax rate, consumption patterns and carbon intensity of products were acquired from knowledgeable and reliable sources, certain circumstances might impact the value of these variables. This might change the outcomes of the indicators that were presented. While the estimates that were used for the carbon tax rate and consumption patterns originate from up-to-date information sources from 2020, the carbon intensity rates date from 2000. As indicated by Statistics Netherlands (2022b), CO_2 emission intensities in the Dutch economy are on a decline. Processes become more efficient and thus less carbon intense. If this decline happens faster in some sectors than in others, the impact of a carbon tax will have differential impacts on households. Over time, other indicators might adjust as well. For example, consumption patterns might change due to increased awareness of the negative impact of carbon. It is thus essential that data and research like this is updated regularly, so that the incidence of the tax rate can be explored frequently and policies can be adjusted accordingly.

This paper uses consumption and carbon intensity estimates for the consumption categories as grouped in the COICOP classification, because the data matches these categories well. Further research could explore the consumption categories more thoroughly, as this might unfold interesting information on consumption of certain products by certain income groups. For example, looking at carbon intensities of specific food groups and the degree of consumption per income group would allow us to adjust tax rules and policies accordingly.

Discount rates

In the section on the social cost of carbon, it was discussed how the estimate for the carbon tax rate crucially depends on the discount rate that is used. Dasgupta (2008) provides two justifications for discounting future consumption costs and benefits, namely impatience and rising future consumption. If society is impatient, an additional unit of consumption today is more valuable than a unit of consumption tomorrow. Furthermore, if future generations are expected to have higher consumption due to rising consumption over time, a unit of their consumption could be valued less than a unit consumed today (Dasgupta, 2008). Arrow et al. (2013) add a third rationale, which is that of investment. When the rate of return on investment is positive, we have to invest less than a euro to obtain future benefits equal to a euro. Many authors have investigated the issue of determining the right discount rate, too many to be discussed here. The main point that should be discussed is the fact that there is a lot of uncertainty regarding the growth of consumption and the return on investment, leading to uncertainty about future discount rates. Because of this uncertainty, Arrow et al. (2013) argue in favor of a declining discount rate (DDR). A DDR would increase the SCC substantially compared to using a constant discount rate. Dasgupta (2008) also questions whether basing discount rates on impatience is ethically indefensible, because it discriminates against future generations' well-being only on the grounds that they are not born yet. There is no clear-cut answer to the question of which argument should be weighted the most heavily. The uncertainty about the severity of future climate damages caused by emissions today, might argue in favor of decreasing the discount rate. This might hurt current polluters more, but improves the chances of future generations getting the same opportunities that were given to us.

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9 APPENDIX

Table I - Overview of carbon tax rates

Source	**Country**	**Method**	**Price - $/ton CO_2**	**Price - €/tonCO_2**	**Price - €/ton CO_2**
Greenstone et al. (2013)	US	SCC	*2007 dollar values* 2010 $5 (5% discount); **$21 (3% discount)**; $35 (2.5% discount); $65 (extreme, 3%). 2025 $10 (5% discount); **$30 (3% discount)**; $46 (2.5% discount); $90 (extreme, 3%).	*2007 euro values* 2010 €6.85 (5%) **€28.77 (3%)** €47.95 (2.5%) €89.05 (extr., 3%) 2025 €13.70 (5%) **€41.10 (3%)** €63.02 (2.5%) €123.30 (3%)	*2022 euro values* 2010 €38.85 (3%) €54.93 (3%) (((54.93-38.85)/15)*12)+38.85 = **€51.71**(2022)
Van der Ploeg et al. (2022)	US	SCC	2020 $85 (if growth does not affect inequality) **$70** (if growth decreases inequality)	2020 €97.07 (if growth does not affect inequality) **€79.94** (if growth decreases inequality)	 **€79.94+**
Kaufman et al. (2020)	US	NT2NZ	*2018 dollar values* $32 (net-zero 2040); **$52 (net-zero 2050)**; $93 (net-zero 2060).	*2018 euro values* €27.12 (n-z 2040); **€44.07 (n-z 2050)**; €78.82 (n-z 2060).	*2022 euro values* **€50.33 (n-z)**

Climate Agreement (2019)	NL	-	-	€30 (in 2021) €75-100 (in 2030)	**€30+**
The World Bank (2022)	NL, SE, FIN, LI, NO, CH, UY	Actual rates on April 1, 2020 Exchange rate used is 0.9051€/ US$ (Exchange Rates, 2022)	$46.14 (NL) $129.89 (SE) $85.10/58.58 (FIN) $129.86 (LI) $87.61 (NO) $129.86 (CH) $137.30 (UY)	€41.76 (NL) €117.56 (SE) €77.02/53.02 (FIN) €117.54 (LI) €79.29 (NO) €117.54 (CH) €124.27 (UY)	**€41.76** **€117**

Table II - Price elasticities by consumption category

Consumption category	Price elasticity - Literature		Elastic/ inelastic
Food and non-alcoholic beverages	-0.27 to -0.81 (Andreyeva et al., 2010)	-0.36 to -0.77 (-0.56 combined) (Green et al., 2013)	Inelastic
Alcoholic beverages, tobacco and narcotics	-0.50 (Nelson, 2013)	-0.40 (USNCI & WHO, 2016)	Inelastic
Clothing and footwear	-0.29 (Kalwij et al., 1998)	-0.38 to -0.80 (Kim, 2003)	Inelastic
Housing, water, electricity, gas and other fuels	-0.23 (Kalwij et al., 1998)	Housing: -0.5 to -1.0 (CPB, 2007) Water: -0.40 (Garonne et al., 2019) Electricity: -0.638 (Trotta et al., 2022)	Inelastic
Health	-1.25 (Kalwij et al., 1998)		Elastic
Transport	-0.96 (Kalwij et al., 1998)	Public transport: -0.59 (short-term) (Holmgren, 2007)	Depends on transport type
Communications	Mobile voice: -0.37 (short-term), -1.12 (long-term) (Sawadogo, 2021)	Mobile communication: -0.097 (short-term), -0.52 to -0.61 (long-term) (Growitsch et al., 2010)	Inelastic
Recreation and culture	-0.96 (Kalwij et al., 1998)		Elastic
Restaurants and hotels	-0.6 to -0.8 (Crouch, 1994)	Restaurants: -1.25 (Frick et al., 2014)	Elastic

Table III – Overview of carbon revenues raised

	Carbon tax revenue in €
t = €30	(1036.77*1,565,000) + (1324.20*1,565,000) + (1661.37*1,565,000) + (2037.09*1,565,000) + (2680.69*1,565,000) = 13,677,614,850
t = €51	23,251,945,245
t = €117	53,342,697,915