The Distributional Effects of Gasoline Taxation: The Role of Income Inequality

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Abstract

We present a simple model that shows how the two parameters of income inequality and the income elasticity of demand determine changes in the distributional effect of a consumption tax; with rising inequality increasing the regressivity of a consumption tax on necessities. We test the model's predictions by analysing the Swedish carbon tax on transport fuel. We find that the tax is increasingly regressive over time, which is highly correlated with a rise in income inequality, and that the distributional effect moves from regressive to progressive when switching from annual income to the more evenly distributed measure of lifetime income. A cross-country analysis of gasoline taxes in high-income nations further supports our findings, establishing a strong correlation between higher inequality and greater tax regressivity. Our model provides policymakers with a useful framework to assess when complementary redistributive measures such as lump-sum transfers may be necessary.

JEL classification:

Keywords: Distributional effects, income inequality, gasoline taxation, climate change

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1 Introduction

A common perception among economists and policymakers is that transport fuel taxes, such as excise and carbon taxes, are regressive, disproportionately burdening lower-income households. However, this view is largely derived from empirical studies of the United States, which consistently finds strong regressivity (Poterba, 1991; Metcalf, 1999; Parry, 2004; West and Williams III, 2004; Bento et al., 2009; Grainger and Kolstad, 2010). Once we look beyond the US, the evidence is more mixed. European studies show lower levels of regressivity (Wier et al., 2005; Sterner, 2012a; Feindt et al., 2021), while in developing countries such as India and China, gasoline taxes are often highly progressive (Datta, 2010; Sterner, 2012b; Sager, 2023). Moreover, even within the US, the degree of regressivity has shifted over time (Hassett, Mathur, and Metcalf, 2009), and the results also depend strongly on the choice of income measure, with lifetime income showing a more progressive impact than annual income (Poterba, 1989, 1991; Hassett, Mathur, and Metcalf, 2009; Sterner, 2012a). In short, the empirical literature documents considerable variation in fuel tax progressivity across countries, across time, and across income measures, yet we lack a unifying framework to explain why.

This paper fills that gap. We develop a simple theoretical model that explains how changes in the distributional effect of consumption taxes depends jointly on two parameters: the income elasticity of demand for the taxed good and the underlying distribution of income. This dynamic perspective differs from most of the existing literature, which typically takes income distributions as given and estimates static tax progressivity for a single country and year. Our model instead asks how the burden of an already implemented tax changes as inequality rises or falls over time.[1] The results are intuitive but powerful: when the taxed good is a necessity, higher inequality increases regressivity, especially if income elasticities are heterogeneous with relatively lower elasticities among richer households. Conversely, if the good is a luxury, inequality growth makes the tax more progressive. Importantly, the model also shows why regressivity is lower when lifetime income, rather than annual income, is used – because lifetime income is typically more evenly distributed, reducing measured inequality and thus reducing regressivity, a theoretical result that holds for taxes on necessities and luxury goods alike.

The model generates two sets of testable predictions. First, it predicts how changes in inequality over time affect the progressivity of a given tax. Second, it predicts how variation in both inequality and income elasticities across countries explains cross-country differences in tax incidence. These predictions speak directly to current policy debates: transport fuel and carbon taxes are, for instance, central to climate and air pollution policies, but their long-term political sustainability is affected by distributional impacts.

[1] Income inequality refers to post-tax inequality, i.e., the distribution of disposable income after income taxes and transfers. This measure excludes the effects of consumption taxes.

A tax that is proportional or progressive at the time of implementation can become increasingly regressive as inequality rises, creating fertile ground for backlash and policy rollbacks, as illustrated by recent fuel tax cuts in Sweden – a sharp departure from the country's long-standing environmental tax trajectory (Andersson, 2025) – and the 'Yellow Vest' protests against the French carbon tax (Douenne and Fabre, 2022).

We test the model's predictions in two steps. First, we use the case study of the Swedish carbon tax on transport fuel to analyze both the importance of the income measure and to track changes in tax progressivity over time and explore its link with inequality. Second, we conduct a cross-country analysis, compiling results from studies of gasoline tax incidence in high-income countries. Matching these estimates to contemporaneous Gini coefficients, we explore the correlation between inequality levels and tax progressivity of gasoline taxation across countries.

The Swedish carbon tax was implemented in 1991 and mainly affects the consumer price of transport fuel (Andersson, 2019). Notably, Sweden experienced significant changes in inequality in the decades after the tax was implemented, with time periods of both decreases and increases in inequality, making it an ideal case study for exploring the role of inequality changes on the progressivity of taxes. Moreover, Sweden's relatively low level of income inequality, particularly compared to the US, allows us to explore the common perception that carbon and fuel taxes are regressive. To measure the distributional effect, we use time-series data from 1999 to 2012 on carbon tax expenditure from a national survey of household expenditure.

In line with the model's predictions, we first find that the distributional effect shifts from regressive to progressive when switching from annual income to the more evenly distributed measure of lifetime income. Second, we observe that increases in regressivity over time are highly correlated with rising income inequality. Finally, through a simulation, we test the impact of assuming heterogeneous income elasticities and find that this assumption is necessary to replicate the observed changes in regressivity over time.

For the cross-country analysis we collect findings from previous studies of the distributional effects of gasoline taxation in high-income countries (Hassett, Mathur, and Metcalf, 2009; Metcalf, 1999; Chernick and Reschovsky, 1997; West and Williams III, 2004; Wier et al., 2005; Sterner, 2012a). We assume similar income elasticities of gasoline demand across our sample (Dahl, 2012) and compare tax progressivity with income inequality levels at the time of each study. Again, we find a strong correlation between income inequality and tax progressivity; the higher the level of inequality, the more regressive are gasoline taxes.

Our paper contributes to the existing literature in several ways. First, we provide the first theoretical and empirical analysis of how changes in income inequality affect the redistributive effects of already implemented consumption taxes. We introduce a dynamic framework while existing work has mostly taken a static perspective, examining distributional outcomes at a fixed point in time. By allowing inequality itself to evolve, our approach highlights that the progressivity of a tax is not fixed once enacted but can change substantially over time. This dynamic lens explains why a proportional or progressive tax at implementation can become regressive as inequality grows, with direct consequences for public support and political sustainability.

Second, we unify disparate findings across the literature. Our model shows that it is the interaction between income inequality and income elasticities that explains the variation in tax progressivity found across countries (Sterner, 2012b; Dorband et al., 2019), across time (Hassett, Mathur, and Metcalf, 2009), and across income measures (Poterba, 1989, 1991; Sterner, 2012a). For example, the perception of regressivity is reinforced by the US case – a country with high inequality where gasoline is a necessity – but this finding does not generalize universally as inequality levels and elasticities vary (Sterner, 2012b). Likewise, the longstanding observation that regressivity falls when using lifetime rather than annual income emerges as a direct implication of our framework. By providing a single model that rationalizes these diverse findings, we help bring coherence to a literature that has often analyzed these findings separately.

Third, our results have policy and political economy implications. In the context of fuel and carbon taxation, our model offers policymakers a simple framework to anticipate when redistributive measures such as lump-sum transfers are needed to maintain fairness and public acceptability. Research shows that voters prefer progressive tax designs (Brännlund and Persson, 2012; Carattini et al., 2017; Tarroux, 2019), prompting a growing body of work on measures to reduce regressivity (Cronin, Fullerton, and Sexton, 2019; Goulder et al., 2019) and with calls from economists for carbon taxes to be complemented by 'carbon dividends' that return revenue to households to improve fairness and political viability (Akerlof et al., 2019). For political economy, our findings connect the distributional effects of fuel taxation to broader debates on inequality, redistribution and political support of environmental policy (Drews and Van den Bergh, 2016; Maestre-Andrés, Drews, and Van Den Bergh, 2019): if rising inequality makes consumption taxes more regressive, public opposition to such taxes should intensify, consistent with recent evidence from Sweden and France regarding the political backlash against fuel and carbon taxation. Our model is thus linked to the literature in political economics that theorize how growing inequality will lead the median voter to call for larger redistributive policies (Meltzer and Richard, 1981; Borge and Rattsø, 2004), as increasing inequality would make regressive consumption taxes less appealing to the decisive voter.

Lastly, we contribute to the environmental economics literature on how inequality influences a wide range of issues, such as the public acceptability of environmental policies (Nicolli, Gilli, and Vona, 2022), the social discount rate (van der Ploeg, Emmerling, and Groom, 2023), the environmental Kuznets curve (Magnani, 2000), and green innovation (Vona and Patriarca, 2011; Zou et al., 2024).

2 The role of Income Inequality

In this section we develop the model of how changes in tax progressivity are determined by income inequality and the income elasticity of demand. The model assumes that the consumption tax is already implemented and levied at a constant rate over time. We then shift the underlying distribution of income and derive the resulting changes in the distributional impact of the tax.

To be clear, our theoretical framework focuses on how exogenous changes in disposable income inequality influence the distributional effects of an individual consumption tax. These exogenous changes in inequality can stem from structural shifts in pre-tax inequality or adjustments to income tax rates and transfers. However, the specific reasons for these changes in inequality are not central to our model.

We start by deriving the formula for the relationship between budget shares and income growth.

First, assume that the consumer decides how much to purchase of a certain good q_i, given prices p and total expenditure x:

$$q_i = d_i(x, p) \tag{1}$$

We refer to this as a Marshallian demand function. Furthermore, the consumer faces a linear budget constraint:

$$x \geq \sum_k p_k q_k \tag{2}$$

and the Marshallian demand function is subject to the adding-up restriction:

$$\sum_k p_k d_k(x, p) = x \tag{3}$$

The use of the equality indicates that all of income is spent and that the total value of Marshallian demands is equal to total expenditure.

Now, the budget share for good i are defined by

$$w_i = \frac{p_i q_i}{x} \tag{4}$$

where we know from the Marshallian demand function that q_i depends on both prices and total expenditure.

Then, taking logs of both sides of (4) and the derivative with respect to x gives

$$\frac{1}{w_i}\frac{\partial wi}{\partial x} = \frac{1}{q_i}\frac{\partial q_i}{\partial x} - \frac{1}{x} \tag{5}$$

Lastly, multiplying both sides by x we get

$$e_{i,w} = e_i - 1 \tag{6}$$

where $e_{i,w}$ is the income elasticity of the budget share for good i and e_i is the familiar income elasticity of demand for good i.

From (6) it follows that the budget share for good i will increase or decrease with changes to total expenditure (or income) depending on the size of the income elasticity of demand. If the good has an income elasticity above one, $e_i > 1$, the budget share increases as income increases, and if $e_i < 1$ the budget share decreases. Thus, whether or not e_i is above or below unity is commonly used to define goods as either luxuries or necessities, respectively.

Now, by introducing multiple households, we can develop a simple dynamic model of the changes to tax progressivity that follows from changes to the underlying distribution of income over time.

Consider an economy composed of two types of households, labeled A and B. Income in time period t is $x^A(t)$ and $x^B(t)$ and we assume that $x^A(t) < x^B(t)$ for all t; i.e. there is some existing level of inequality in the distribution of income, and household B remains richer in every period (no re-ranking occurs).[2]

Furthermore, we assume that prices are fixed and p_i is normalised to unity. Both the tax rate and the pre-tax price are thus constant over time.[3]

The budget share for good i for household B, in time period t, is thus:

$$w_i^B(t) = \frac{q_i^B(t)}{x^B(t)} \tag{7}$$

Then, if the growth rates of the budget share differs for households A and B over time:

$$\frac{w_i^B(t+1) - w_i^B(t)}{w_i^B(t)} \neq \frac{w_i^A(t+1) - w_i^A(t)}{w_i^A(t)} \tag{8}$$

the distributional effect of a tax on good i will shift. For example, if the growth rate of the budget share is smaller for the rich household B compared to A, we move toward a more regressive outcome.

We can formalise this by starting with the case of *no* change in the distributional effect:

$$\frac{w_i^B(t+1) - w_i^B(t)}{w_i^B(t)} = \frac{w_i^A(t+1) - w_i^A(t)}{w_i^A(t)} \tag{9}$$

[2]We can view households A and B as representing the bottom and top half of the income distribution. For an extension to a three-agent model, that incorporates a middle-income group, see Appendix G.

[3]If (Marshallian) own- and cross-price elasticities are invariant across income groups, common price changes affect budget shares proportionally, so our fixed-price assumption is then not needed.

Note that:

$$w(t+1) = w(t) \left(\frac{x(t+1)}{x(t)} \right)^{e_{i,w}} \tag{10}$$

and the left hand side of (9) is thus equivalent to:

$$\frac{w_i^B(t+1) - w_i^B(t)}{w_i^B(t)} = \left(\frac{x^B(t+1)}{x^B(t)} \right)^{e_{i,w}^B} - 1 \tag{11}$$

The growth rate of the budget share is hence determined by two parameters: the growth rate of income and the income elasticity of the budget share

$$g_w^B(t) = (1 + g_x^B(t))^{e_{i,w}^B} - 1 \tag{12}$$

For small growth rates, we can rearrange, take logs, and approximate this relationship as:

$$\ln(1 + g_w^B(t)) = e_{i,w}^B \ln(1 + g_x^B(t)) \approx g_w^B(t) = e_{i,w}^B g_x^B(t) \tag{13}$$

The same applies to the right hand side of (9) and we can thus write (9) as:

$$e_{i,w}^B g_x^B(t) = e_{i,w}^A g_x^A(t) \tag{14}$$

Equation (13) shows that for necessities, $e_i < 1$ (and $e_{i,w} < 0$), the budget share decreases faster the lower the income elasticity of demand is and the larger the growth rate of income is. If the budget share decreases faster for household B relative to the poorer household A:

$$e_{i,w}^B g_x^B(t) < e_{i,w}^A g_x^A(t) \tag{15}$$

a tax on good i will become increasingly regressive over time. Conversely, if the budget share increases faster for B relative to A:

$$e_{i,w}^B g_x^B(t) > e_{i,w}^A g_x^A(t) \tag{16}$$

the tax will become more progressive over time.

Equation (14) shows when changing inequality doesn't change the distributional effect of the tax. This occurs if the ratio of income elasticities for households A and B is equal to the opposite ratio of the growth rates of income[4], or when the income elasticity is unit-elastic for all households: $e_i^A = e_i^B = 1$ (because then $e_{i,w}^A = e_{i,w}^B = 0$).

We can now explore the conditions for a change in the distributional effect, equations (15) and (16), in the case where the elasticities may differ, and when they are uniform across income groups.

[4]If $g_x^A(t) = 0$ and $g_x^B(t) \neq 0$, then we need $e_{i,w}^B = 0$, i.e. the income elasticity of demand for household B need to be unity.

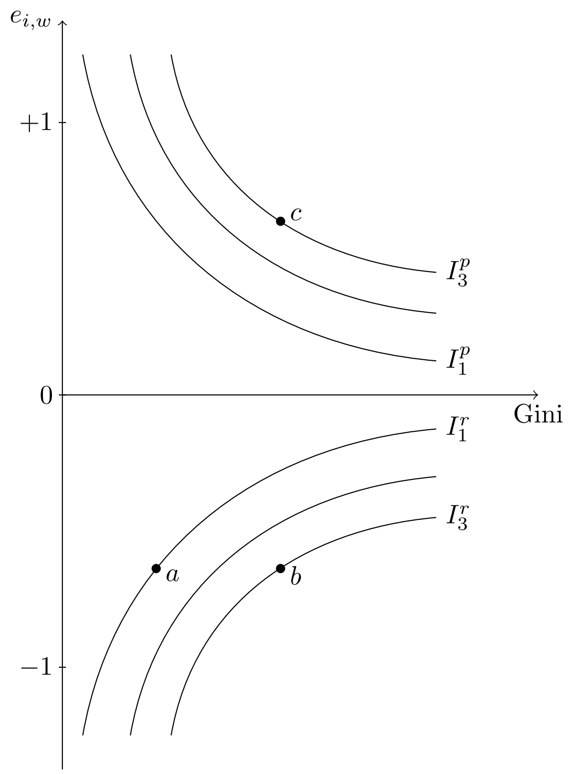


Figure 1: Isoincidence Curves

Note: Income inequality is here exemplified by the Gini coefficient. Gini is a summary statistic of inequality, taking values from 0 (complete equality) to 100 (complete inequality).

Heterogeneous elasticities: $e_i^B \neq e_i^A$

When income elasticities are heterogeneous across households, regressivity increases if the ratio of income elasticities of the budget share, $e_{i,w}^B/e_{i,w}^A$, is smaller than the opposite ratio of the growth rates of income, $g_x^A(t)/g_x^B(t)$. If the ratio is larger, regressivity decreases. With heterogeneous elasticities, the redistributive effect can change even without changes in inequality. For example, if $g_x^A(t) = g_x^B(t)$, regressivity increases if $e_{i,w}^A > e_{i,w}^B$, that is, if the good is a relative necessity for the richer household B compared to A.

Uniform elasticity: $e_i^A = e_i^B = e_i$, (and $e_i \neq 1$)

When income elasticities are equal across households, regressivity increases when income inequality rises, $g_x^B(t) > g_x^A(t)$, and the good is a necessity, $e_i < 1$, or if income inequality decreases and the good is a luxury, $e_i > 1$. Conversely, progressivity increases when income inequality rises and the good is a luxury, or if income inequality decreases and the good is a necessity.

Using a figure, we can illustrate changes in regressivity across countries and time under uniform elasticity. Figure 1 depicts the concept of isoincidence curves, which show combinations of uniform income elasticity and income inequality where the distributional effect of a tax remains constant.[5] Above the x-axis, where $e_{i,w} > 0$, the tax effect is progressive; below it, the effect is regressive. Moreover, along the two axes, the effect is proportional, reflecting either unit-elastic demand or equal income distribution. Lastly, moving further out from the origin, the curves become more regressive or progressive.

The isoincidence curves provide a useful framework. For instance, moving from point a to point b shows increased regressivity due to higher inequality, while the income elasticity remains constant, represented by a shift from I_1^r to curve I_3^r. This shift can occur within a country over time or between countries with different inequality levels but similar income elasticities of demand for the taxed good. Moreover, when moving from b to c the distributional outcome switches from regressive to progressive. This may reflect how gasoline tax progressivity differs between a rich country where gasoline is a necessity and a developing one where it is a luxury good.

Lastly, Figure 1 also demonstrates a broader insight from the model: in countries with relatively equal income distributions, consumption taxes tend to be closer to proportional, regardless of income elasticities. In contrast, in countries with high inequality, such taxes are generally quite regressive for necessities or quite progressive for luxuries.

3 Testing the Model

To empirically test the model's predictions we, first, analyze Sweden's carbon tax on transport fuel. In turn, we explore the distributional impact of changing the income measure, the correlation between changes to inequality and regressivity over time, and the assumption of heterogeneous income elasticities across the income distribution. Second, we analyse previous studies of gasoline tax progressivity across high-income countries.

Our focus is the use-side of income, and we do not include distributive effects of local environmental damages from the taxed good nor tax incidence in the form of how much of the burden that falls on consumers versus firms. Depending on the pass-through rate, a consumption tax could have a separate incidence on the source-side – wages, transfers, and capital income. A simulation by Goulder et al. (2019) finds that a carbon tax in the US would be regressive on the use-side but progressive on the source-side, while Vona (2023) argues that the distributional effect of climate policies on the source-side of income is generally more uncertain. Nevertheless, Andersson (2019) report that changes to Sweden's carbon tax rate are fully passed through to consumers.

We focus on the use-side of income for three reasons. First, our theoretical model is built around budget shares of the taxed consumption good, making use-side effects the natural empirical counterpart. Second, the use-side is the dominant focus in the empirical literature on the distributional effects of transport fuel taxation, allowing us to directly

[5] Isoincidence curves are analogous to indifference curves in consumer theory and isoquants in production theory.

compare our results to existing findings. Third, the political economy of transport fuel and carbon taxation is shaped strongly by the salience of household fuel expenditures. Households directly experience higher pump prices – with fuel tax changes being salient with large effects on households expenditure (Andersson, 2019; Davis and Kilian, 2011; Li, Linn, and Muehlegger, 2014) – which has been a catalyst in mass protests (the French 'Yellow Vests'), policy rollbacks (Sweden), and with possible electoral effects (the US (Gupta, Pierdzioch, and Tiwari, 2024)).[6]

The Swedish Carbon Tax.—The carbon tax in Sweden was implemented in 1991 at US$30 per ton of CO_2 and increased quite rapidly in the early 2000s. Today, in 2025, the rate is above US$130 per ton of CO_2 (1 SEK $\approx$ US$0.10), making it the world's highest carbon tax imposed on households and non-trading sectors. The full tax rate is applied to gasoline, diesel, heating fuels used by households, and fossil fuels used by industries that are not covered by the EU Emissions Trading System. However, due to a limited use of fossil fuels in the heating and non-trading industry sector, around 90 percent of the tax revenue comes from the consumption of transport fuel (Ministry of Finance, 2018). We therefore focus our empirical analysis on households' expenditure on gasoline and diesel.[7]

Data and Methodology.—The relevant data is taken from a Swedish household expenditure survey (HUT) for the years 1999-2012. HUT is a large survey that is carried out since 1958 by Statistics Sweden. The survey was conducted every year between 1999-2001 and again between 2003-2009, with the latest survey in 2012. Our final sample is thus eleven years of data, with around two thousand households surveyed each year.

The HUT survey includes households with at least one person between the age of 0-79, drawn from a representative sample of the larger population. Expenditure data on goods and services is collected with the help of either a journal or, for some categorise like transport fuel, through telephone interviews. The survey also collects information about disposable income, provided by the Swedish Tax Agency. Expenditure on transport fuels, total expenditure on goods and services, and disposable income are the three key variables needed for our analysis.[8]

[6]Our empirical analysis centers on the use-side of income, while recognizing that source-side effects can influence tax progressivity and are important in their own right – particularly in light of the ongoing debate on the 'just transition,' where both consumption and labor market effects are crucial for assessing the full distributional consequences of climate policy (e.g., Bolet, Green, and Gonzalez-Eguino (2024); Vona (2023)).

[7]We do not include indirect expenditure on public transport or goods that use transport fuel as an input in production. Nevertheless, if the ratio of direct to indirect expenditure is rather stable over time, this omission should not affect our empirical test of the model's prediction. Furthermore, Ahola, Carlsson, and Sterner (2009) finds that indirect tax expenditure on transport fuel in Sweden is a very small share of the total transport fuel tax burden.

[8]To enable comparisons across households with different sizes and compositions we make use of an equivalence scale, known as "consumption units". The weights, provided by Statistics Sweden, corrects for economies of scale for large households.

Table 1: Cumulative Income and Carbon Tax Burden

	2005		2009	
Population Decile	Annual Income	Carbon Tax	Annual Income	Carbon Tax
1	4.37	5.86	3.04	6.94
2	11.35	11.29	9.29	12.42
3	19.29	21.42	17.26	19.66
4	28.23	29.77	25.70	30.19
5	37.63	39.75	35.06	40.25
6	47.65	50.15	45.37	52.43
7	58.64	61.45	56.10	63.39
8	69.92	73.74	68.10	75.61
9	82.76	86.84	81.05	88.22
10	100	100	100	100

Note: Columns 2-5 provides the accumulated percentages of annual income and carbon tax burden.
Source: Calculated using HUT data from 2005 and 2009 (Statistics Sweden, 2019).

Carbon tax burden is measured as the share of household income that is spent on the tax. We use two common measures of income: annual income, measured as disposable income in any given year; and lifetime income, where total expenditure in a year is used as a proxy.

While annual income is most commonly used, some researchers advocate for lifetime income (e.g., Poterba 1989, 1991). They argue that annual income misrepresents the financial status of households in the lowest deciles – such as students with low current income but high future potential, or retirees with low pensions but significant savings. Furthermore, according to the permanent income hypothesis, consumers aim to smooth consumption, focusing on lifetime income in their decisions. Since lifetime income can't be directly measured, total expenditure is often used as a proxy, assuming consumption remains a constant fraction of lifetime income.

We do not take a position on which income measure is superior or whether better proxies for lifetime income exist (see Chernick and Reschovsky (1997) for a detailed discussion). Instead, we use both measures to demonstrate that switching from one to the other typically affects the observed level of inequality and, consequently, the tax's progressivity. This holds true regardless of how lifetime income is measured.

If the carbon tax burden decreases (increases) as we move up in the income distribution the tax will be regressive (progressive). To measure changes in tax progressivity over time or across countries we need a summary statistic. A useful starting point to compute such statistic is to analyse concentration curves, which plots the accumulated percentage of tax burden against the accumulated percentage of income.[9]

[9]Concentration curves are similar to the Lorenz curve, used, for instance, to compute the Gini index of inequality. With the Lorenz curve, the accumulated percentage of income is plotted against the

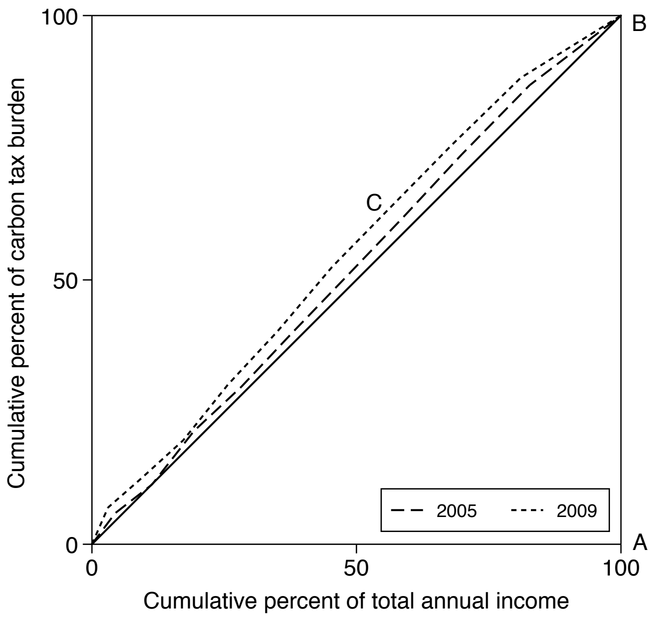


Figure 2: Concentration Curves for Carbon Tax

To illustrate how concentration curves are computed we use data for the years 2005 and 2009. The first column of Table 1 lists households in order of annual income, separated into decile groups, and columns 2 to 5 contain the corresponding accumulated percentages of annual income and carbon tax burden. Figure 2 shows the concentration curves for 2005 and 2009. A proportional tax is illustrated with the solid 45-degree diagonal line *0B*. Along this line, the accumulated percentages of income and tax burden are equal. In 2005 and 2009, the lower income deciles' share of the tax burden exceeds their share of total income, and the curves thus arches above the diagonal line. A regressive tax has a concentration curve above the diagonal, while a progressive tax has one below.[10]

The concentration curve for 2009, *0CB*, lies everywhere above the curve for 2005, and the distributional outcome in 2009 is thus *more* regressive than in 2005. However, instead of plotting and comparing curves it would be helpful to summarize their information with a single number. The two most common summary statistics based on concentration curves are the Suits (1977) and Kakwani (1977) indices. In the main empirical analysis we use the Suits index, but the Kakwani index – and two more measures of progressivity – are used for robustness tests.

The Suits index varies from +1 to -1, with positive values indicating progressivity, negative values regressivity, and zero for a proportional tax. To compute the Suits index we define the area of the triangle *0AB* in Figure 2 as K, and the area below a concentration

cumulative percent of households.

[10]It is less straightforward to judge the overall progressivity when budget shares are not monotonically increasing or decreasing – for instance, goods that are mainly consumed by the middle class. The concentration curve may then cross the diagonal line. However, this is not a concern with our case study.

curve and the horizontal axis as L. The size of the Suits index, S, is then given by the area between the diagonal line and the concentration curve, so that

$$S = \frac{K - L}{K} = 1 - \frac{L}{K} \tag{17}$$

For a regressive tax, the concentration curve is positioned above the diagonal line, L is thus larger than K, and the Suits index is negative: $-1 \leq S < 0$. For example, the concentration curve *0CB* gives a Suits index of -0.103.

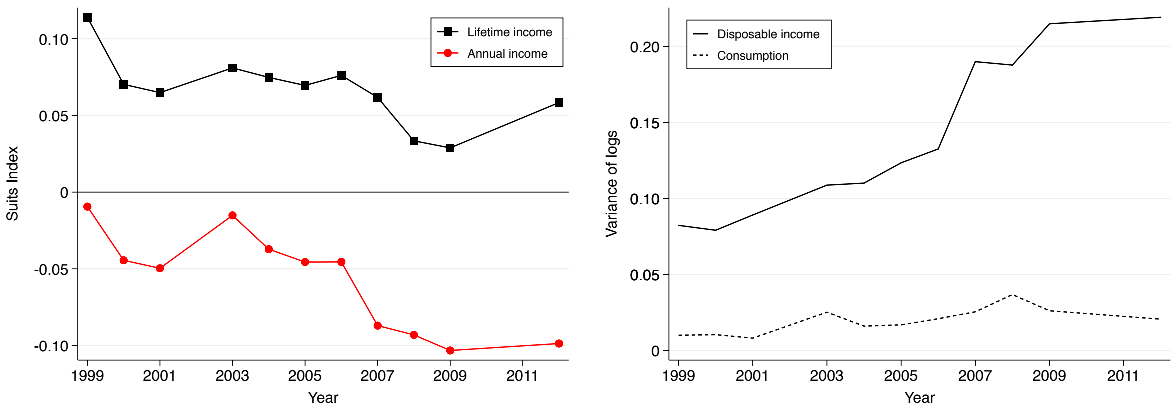
For a progressive tax, the concentration curve is positioned below the diagonal, and the index is positive: $0 < S \leq 1$. Lastly, with a proportional tax, $L = K$, so $S = 0$.

Our model shows how income inequality and the income elasticity of demand determine changes to the degree of progressivity of consumption taxes. Changes to inequality affects the cumulative shares of income and, depending on the size and heterogeneity of income elasticities, the cumulative shares of tax burden. The interaction of the two parameters thus affect the shape and position of the concentration curve, and the Suits index enables us to capture and estimate the resulting change in tax progressivity.

3.1 Annual vs Lifetime Income

We can use our model to explain the common finding that gasoline taxes are less regressive when measured against lifetime income compared to annual income (Poterba, 1989, 1991; Hassett, Mathur, and Metcalf, 2009; Sterner, 2012a). When we use survey data on household expenditure for analyses of tax progressivity, and switch our income measure, we change the level of income for each household but the expenditure on the good in question stays constant. Therefore, the income elasticity of demand is effectively treated as zero, since with $e_i = 0$ a change in income has no effect on the quantity bought. With $e_i = 0$ we have $e_{i,w} = -1$, and equation (16) – the condition for when a tax becomes more progressive – is reduced to $g_x^B < g_x^A$. Hence, a switch to a more equally distributed income measure always reduces regressivity, no matter the *actual* income elasticity of demand for the good.

This result holds true empirically in the case of the Swedish carbon tax. Figure 3(a) shows the overall distributional effect of the Swedish carbon tax on transport fuel between 1999-2012. Against annual income, the tax is regressive in each year, with an average Suits index of -0.057, but against lifetime income the carbon tax is progressive, with an average Suits index of +0.067. The difference in the Suits index across the two income measures is large enough to flip the sign of the index. The effect on the distributional effect from changing the income measure is also robust over time. The results thus indicate that total expenditure is more evenly distributed than annual disposable income in Sweden during this time period. Figure 3(b) shows that this is indeed true, in each



(a) Carbon Tax Progressivity

(b) Variance of Logs

Figure 3: Carbon Tax Progressivity and Income and Consumption Inequality in Sweden, 1999-2012

year the (logarithmic) variance in disposable income across the decile groups is higher than for consumption. Household expenditure surveys in the US show a similar pattern with consumption being more equally distributed than disposable income (Aguiar and Bils, 2015; Attanasio and Pistaferri, 2016).

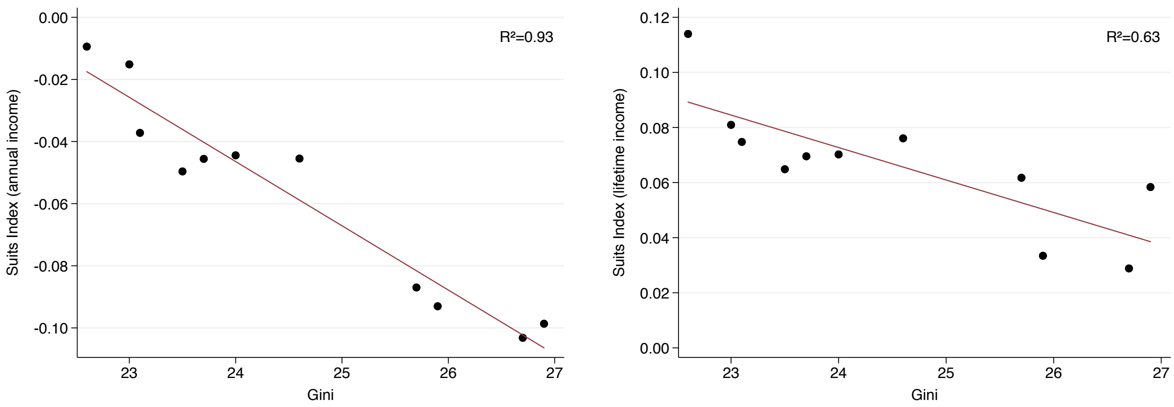
3.2 Across Time

In this section we use equations (15) and (16) to test if rising income inequality in Sweden may account for the trend over time in the distributional effect of the carbon tax. When doing so, we make the simplifying assumption that the average income elasticity of demand for transport fuel is stable during our sample period, but we make no assumption about whether or not elasticities are uniform or variable across income groups.

Figure 3(a) shows that, on both income measures, the trend is toward an increase in regressivity. For the years 1999-2006, the Suits index using annual income is above -0.05, whereas for 2007-2012 the index is around -0.10.

Figure 4 shows that there is a strong negative correlation between this change in carbon tax progressivity and increased inequality. When regressing the estimated Suits index numbers on the Gini coefficients for disposable income for each year the results show a (Pearson) correlation of $r = -0.96$ when using annual income, and $r = -0.79$ when using lifetime income. Extrapolating, these simple linear regressions indicate that at a Gini below 22, the Swedish carbon tax on transport fuel will be progressive on both measures of the Suits index, and that at a Gini above 30, the tax will be regressive. Income inequality was historically low at the time of implementation of the carbon tax in 1991. Sweden had a Gini of 20.8 that year, and the redistributive effect was thus likely progressive (or, at least proportional) using either income measure.

The distributional trends and their strong correlation with inequality are similar on



(a) Annual Income (b) Lifetime Income

Figure 4: Carbon Tax Progressivity and Income Inequality in Sweden

Note: The red line is a fitted trend line with corresponding R^2 in upper-right corner. Source: Gini coefficients for disposable income are provided by Statistics Sweden.

both measures of income, which lends empirical support to the predictions of our model.

3.3 Heterogeneous Income Elasticities

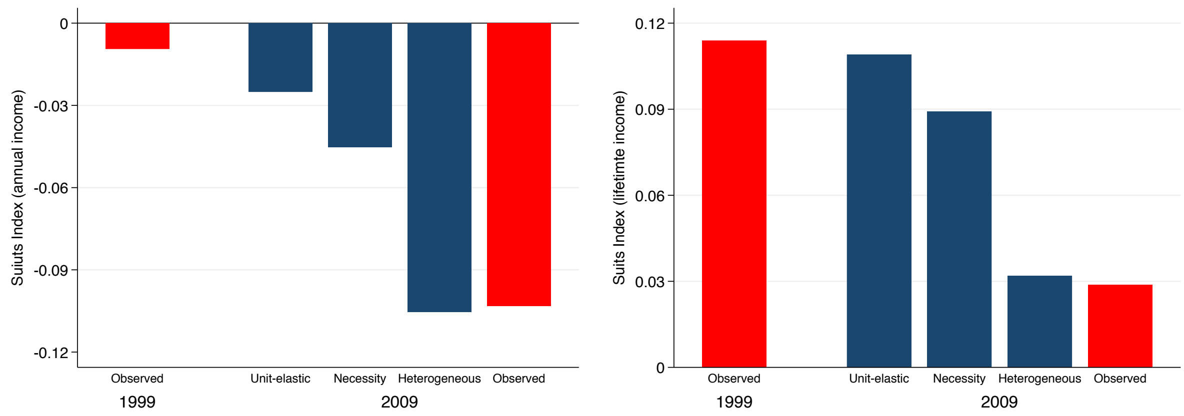
The largest increase in regressivity occurred between 1999 and 2009, with the Suits index dropping by around -0.09 on both income measures. In this section, we aim to explain this drop using a simulation. We assume that transport fuel is either a necessity with uniform elasticities ($e_i = 0.5$) or, alternatively, a relative necessity for high-income households, with heterogeneous elasticities.[11] We also include a base-case scenario with unit-elastic demand across all income groups.

Figure 5 shows that in the unit-elastic case, regressivity increases only slightly, consistent with equation (14), which predicts no change in the distributional effect when income inequality shifts under unit-elastic demand. Assuming uniform elasticities, we observe a regressivity increase of -0.036 on the Suits index with annual income, and -0.025 with lifetime income. However, this is less than half of the actual observed drop of -0.09.[12] Only when heterogeneity is assumed can the simulation replicate the observed change. The case with heterogeneous income elasticities results in a regressivity increase of -0.09 for both income measures, matching the observed Suits index change.

Figure 6(a) shows the average Engel curve for gasoline demand in Sweden between 1999-2012. The Engel curve gradient is positive, and gasoline is thus a normal good. For high-income households the curve bends toward the y-axis, indicating that gasoline is a

[11] In the heterogeneous case, we assign an income elasticity of $e_i = 1.5$ to deciles 1-2, unit-elastic demand for deciles 3-6, $e_i = 0.75$ for decile 7, $e_i = 0.50$ for decile 8, and $e_i = 0.25$ for deciles 9-10. See Appendix D for more information.

[12] Even with an assumed income elasticity as low as 0.2 for transport fuel in Sweden, the regressivity increase is only -0.048 and -0.037, respectively.

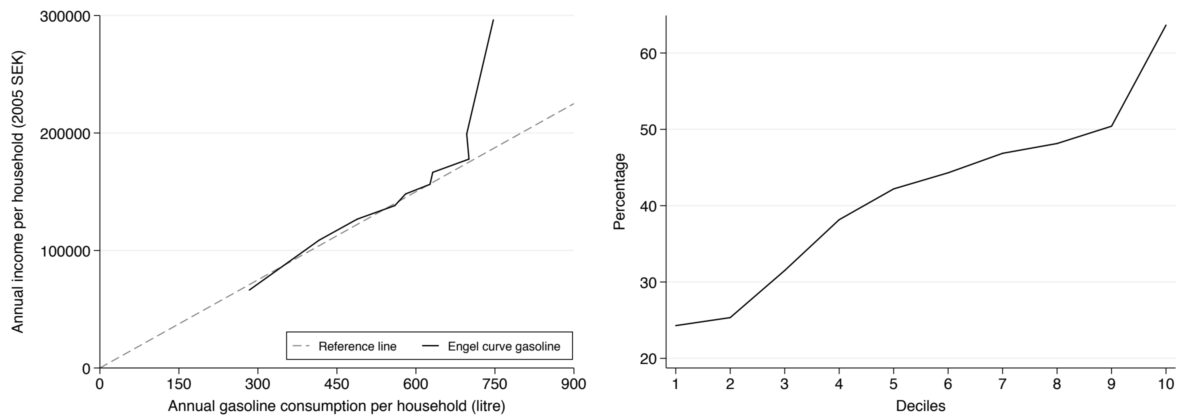


(a) Annual Income

(b) Lifetime Income

Figure 5: Numerical Exercise: Suits Index in 1999 and 2009

Note: The red bars depicts the computed (observed) Suits index numbers in 1999 and 2009, and the blue bars show the simulated Suits index in 2009.



(a) Engel Curve for Gasoline

(b) Growth in Real Disposable Income

Figure 6: Engel Curve for Gasoline and Growth in Real Disposable Income 1999-2012

Note: Source: Data for (b) is provided by Statistics Sweden.

necessity. For low-income households, the curve instead bends slightly downwards toward the x-axis, making gasoline a luxury good. The Engel curve thus indicate that the income elasticity of demand for gasoline in Sweden is indeed heterogeneous – with relatively lower elasticities among high-income households. Furthermore, Figure 6(b) shows that every decile has experienced an increase in real disposable income over the sample period, but the growth rate is considerably higher for richer households, resulting in an increase in inequality.

3.4 Across High-Income Countries

To conclude our empirical part, we analyze the redistributive effects of transport fuel taxes across high-income countries and their correlation with income inequality. We make the

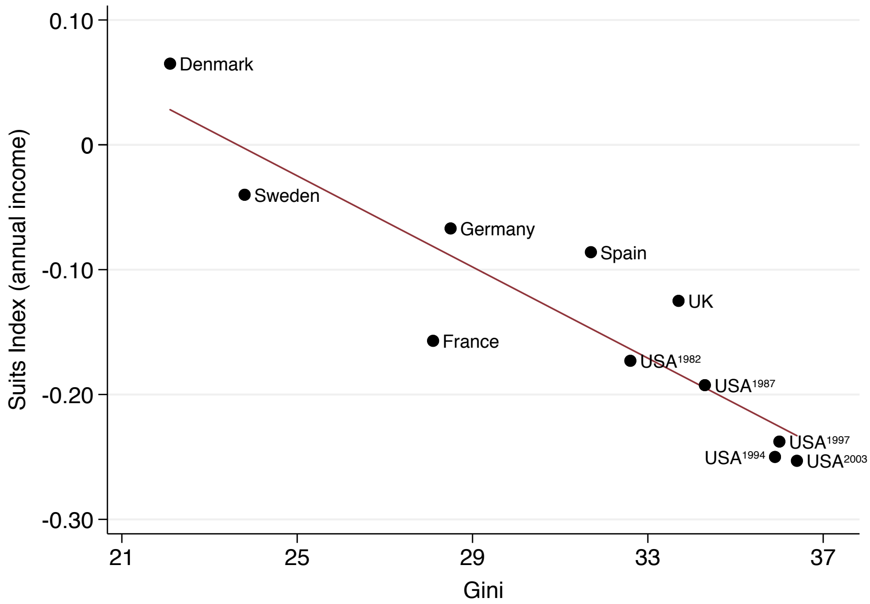


Figure 7: Gasoline Tax Progressivity and Income Inequality in OECD Countries

Note: The figure depicts the correlation between gasoline tax progressivity and income inequality across OECD countries, with $R^2 = 0.82$.
Sources: Suits index numbers in USA in 1982, 1987, 1994, 1997, and 2003 (Chernick and Reschovsky, 1997; Metcalf, 1999; Hassett, Mathur, and Metcalf, 2009); Denmark in 1996 (Wier et al., 2005); other European countries in 2006 (Sterner, 2012a). Gini for disposable income: SWIID database (Solt, 2019).

underlying assumption that income elasticities of demand for transport fuel are similar across developed countries and stable over the sample time period.

In Sterner (2012b), cross-country variation in gasoline tax progressivity is discussed, with Suits indices and Gini coefficients compared across countries. They conclude that "there is no very obvious relation" between the two measures (Sterner, 2012b, p. 319), but their comparison spans countries with vastly different GDP per capita levels, from Ghana and Tanzania to the US and Germany. Income elasticities for transport fuel generally exceed 1 in low-income countries and fall below 1 in high-income countries (Dahl, 2012). Our model predicts that in low-GDP, high-inequality countries, fuel taxes are progressive since fuel is a luxury, while in high-GDP, high-inequality countries, fuel is a necessity, leading to regressive taxes. To test our model's prediction of cross-country variation, we compiled studies on the distributional effects of gasoline taxation in high-income countries. We limited our selection to those that use a comparable empirical approach, namely household expenditure data to calculate Suits indices (Chernick and Reschovsky, 1997; Metcalf, 1999; West and Williams III, 2004; Wier et al., 2005; Hassett, Mathur, and Metcalf, 2009; Sterner, 2012a).[13]

[13] We focus on high-income countries where income elasticities are generally less variable across settings, fuel is consumed by all income groups, data quality is higher, and structural factors such as urbanization, infrastructure, and subsidy regimes are more comparable – together ensuring consistency in the Suits index computations.

Figure 7 shows a strong negative correlation in the cross-country comparison, similar to the pattern observed in Sweden over time.[14] The results suggest that when the Gini coefficient is below 24, a carbon tax on transport fuel is progressive on both Suits index measures, but when the Gini exceeds 29, the tax becomes regressive. This explains why studies using US data consistently find transport fuel taxes to be regressive – the US Gini has been above 30 since the early 1960s. The widespread belief that carbon and gasoline taxes disproportionately burden the poor is thus largely based on studies from a country with relatively high income inequality.

4 Robustness Tests

4.1 Additional Inequality Metrics

As the Gini index is often criticized for being overly sensitive to changes in the middle of the income distribution (Cowell, 2011), we conduct a robustness check. We regress the estimated Suits index for Sweden's carbon tax (using annual income) on five additional inequality measures: the Palma Ratio, the 20:20 share ratio, the P90/P10 ratio, the P99/P50 ratio, and the Atkinson Index.

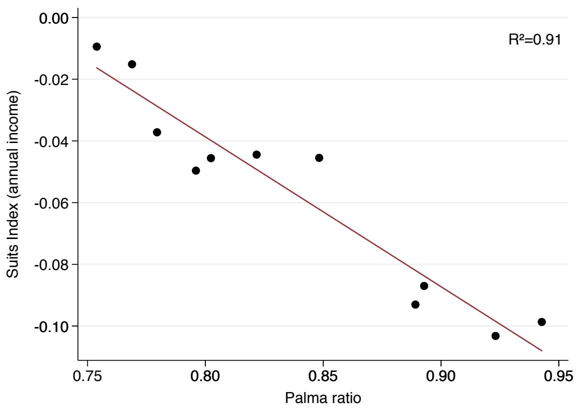
The Palma Ratio is calculated as the ratio of the richest 10 percent of the population's share of national income, divided by the share of the poorest 40 percent. As such, the Palma Ratio is responsive to changes in the top and bottom of the income distribution, and a useful complement to the Gini coefficient. The ratio was introduced based on the finding that, across countries, the income going to deciles 5-9 are often around half of the total. In Sweden, the income share of deciles 5-9 is remarkably stable around 55 percent during 1991-2012.

Like the Palma Ratio, the 20:20 share ratio compares the share of national income between the top and bottom two deciles. The P90/P10 and P99/P50 ratios compare specific percentiles of the income distribution: the ninetieth to the tenth percentile, and the top 1 percent to the fiftieth percentile, respectively.

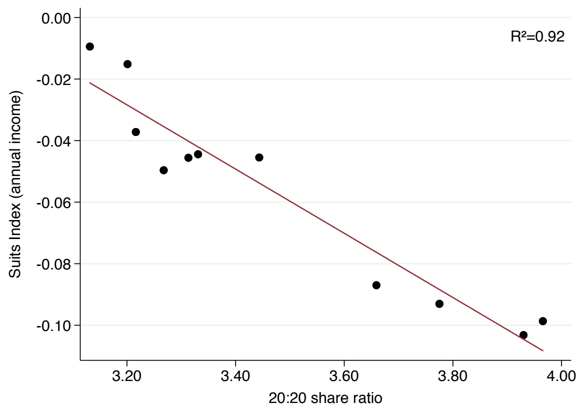
The inequality index in Atkinson (1970) is distinctive because it is explicitly derived from a social welfare function, one with constant relative inequality aversion. In practical terms, the index calculates the *equally distributed equivalent* level of income, i.e., the amount of (mean) income, equally distributed, which would provide the same amount of social well-being as the actual mean income.[15] This tells us what proportion of current average income society would be willing to give up to achieve an equally distributed income level. The larger the inequality aversion, the higher this proportion. Reviews typically place inequality aversion between 0.5 and 2.0 (Arrow et al., 1996; Cowell and

[14] The figure for lifetime income (Figure 12) is in Appendix E.

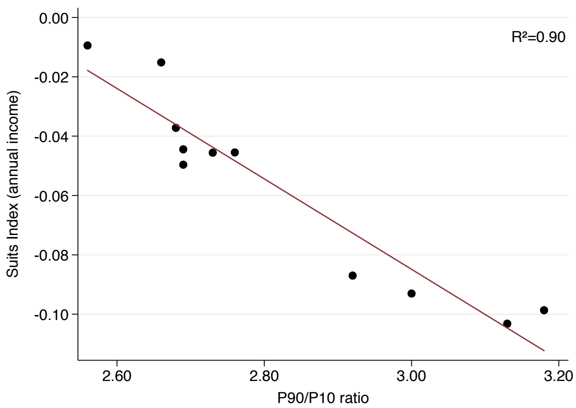
[15] For more details, see Appendix F.



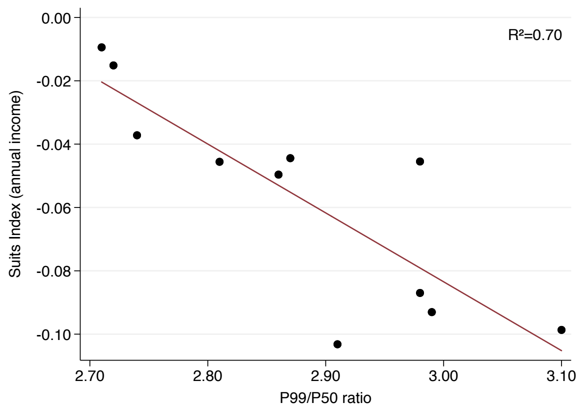
(a) Palma Ratio



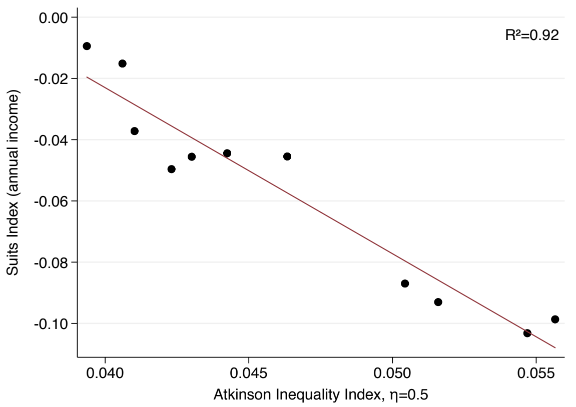
(b) 20:20 share ratio



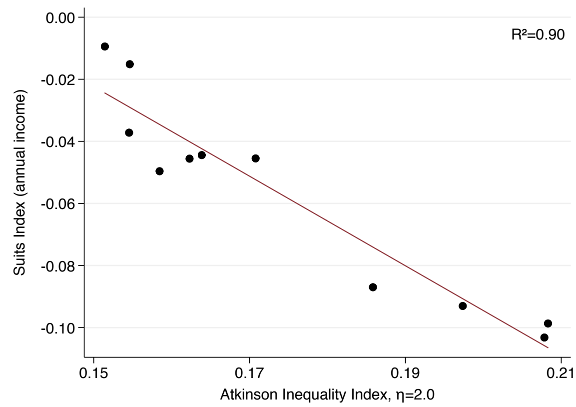
(c) P90/P10 ratio



(d) P99/P50 ratio



(e) Atkinson Index, η=0.5



(f) Atkinson Index, η=2.0

Figure 8: Carbon Tax Progressivity and Income Inequality: Multiple Inequality Measures
Source: (a)-(b), (e)-(f): own calculations using data from Statistics Sweden; (c)-(d): Statistics Sweden.

Gardiner, 1999), and we use this range when computing the Atkinson index for Sweden.

Figure 8 shows a pattern similar to Figure 4(a), with a strong correlation between inequality and regressivity. Only the P99/P50 ratio displays a slightly weaker correlation ($r = -0.83$) than the Gini coefficient. Overall, the strong correlation across all inequality measures suggests that the link between tax progressivity and income distribution changes is robust, regardless of the inequality metric used.

4.2 Additional Tax Progressivity Measures

The empirical evidence supports the model's predictions. However, one may be concerned that the results hinge on the use of the Suits index. We therefore re-estimate the relationship between inequality and tax progressivity using three alternative measures: the well-established Kakwani (1977) and Reynolds and Smolensky (1977) indices, and a simple 20:20 tax budget share ratio.

The Kakwani index is conceptually similar to the Suits index: both are based on concentration curves, independent of the tax rate level, and positive (negative) values indicate progressivity (regressivity).[16] The Reynolds–Smolensky (RS) index, in contrast, is a global progressivity measure that depends on the average tax rate. RS can therefore capture changes to progressivity arising from changes in the Swedish carbon tax rate.[17] In our theoretical model (section 2) the tax rate is fixed over time, as we focus on progressivity effects from changes in income inequality. In the empirical Swedish data, however, the carbon tax rate increased significantly between 2000 and 2004 (Appendix Figure 11). Including RS as a robustness check thus allows us to detect any effects of tax rate changes. As with the other two indices, positive values on the RS index indicate progressivity and negative values regressivity, with a theoretical range from +1 to -1.

We also construct a simpler progressivity measure that is not based on concentration curves. The 20:20 tax budget share ratio is:

$$1 - \frac{(\pi^1 + \pi^2)/2}{(\pi^9 + \pi^{10})/2} \tag{19}$$

where π^j is the carbon tax budget share in decile j. If the average share for the bottom 20 percent of households exceeds that of the top 20 percent, the measure is negative; if the reverse is true, it is positive. This ratio is bounded above at +1 but unbounded below, with positive numbers indicating overall progressivity and negative numbers regressivity.

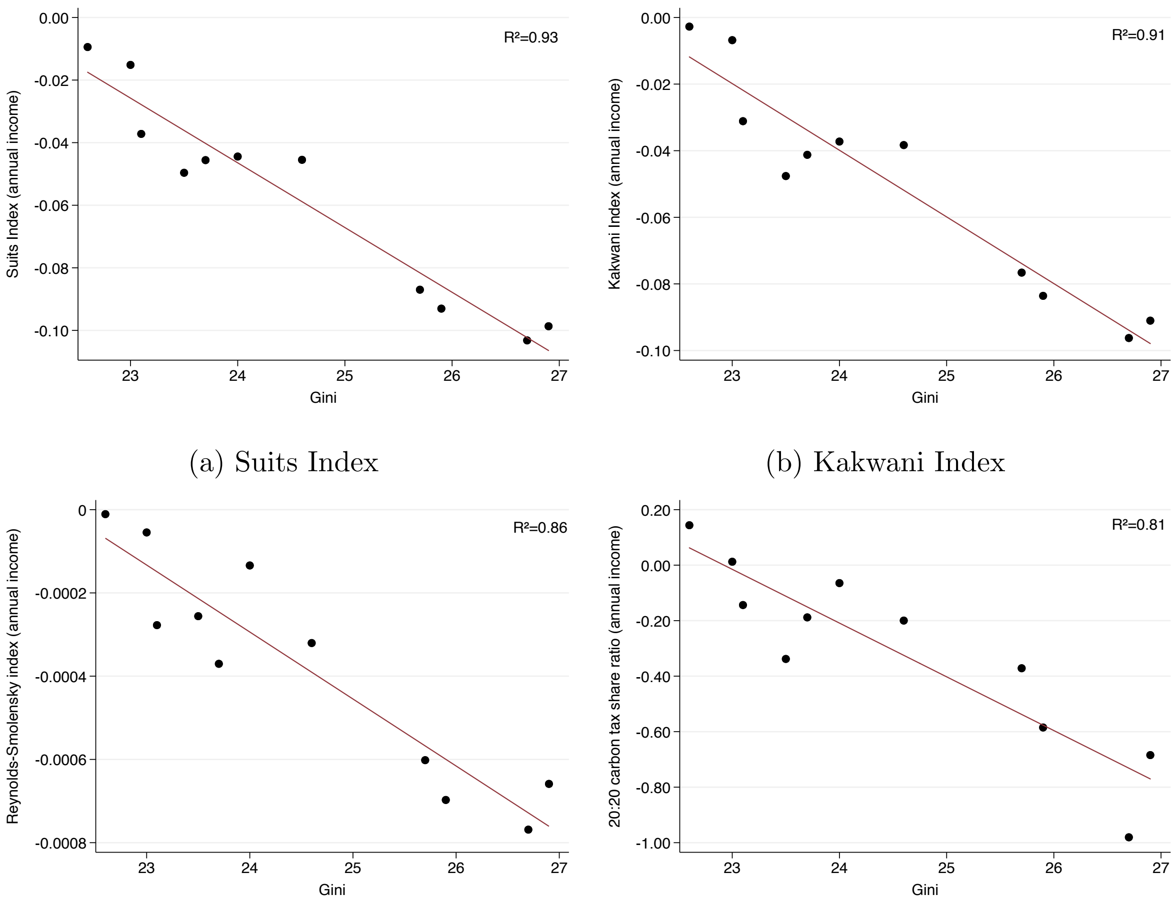
Figure 9 show that the correlation between income inequality and tax progressivity is

[16] For a discussion of similarities and differences between Suits and Kakwani, see Formby, Seaks, and Smith (1981) and Sterner (2012b).

[17] With no re-ranking of indviduals' income positions due to taxation, the RS and Kakwani indices are linked as follows (Kakwani, 1977; Aronson, Johnson, and Lambert, 1994):

$$RS = \frac{g}{(1-g)} KW \tag{18}$$

where g indicates the tax level as tax expenditure as a percentage of disposable income. Since RS is designed for measuring effects from income taxes and transfers, its values will be very small for a single, relatively small consumption tax such as the Swedish carbon tax. In our case, a near-zero RS change does not imply the absence of distributional change – instead it reflects the small share of household income spent on the tax.



(a) Suits Index

(b) Kakwani Index

(c) Reynolds-Smolensky Index

(d) 20:20 carbon tax budget share ratio

Figure 9: Carbon Tax Progressivity and Income Inequality: Multiple Progressivity Measures

Source: (a)-(d): own calculations using data from Statistics Sweden.

robust across all measures. The Kakwani and Suits indices yield nearly identical results, with strong negative correlations with inequality. The RS index produces qualitatively similar results – regressive in all years, and more so as inequality rises – with only slightly weaker correlation. Changes to the carbon tax rate over time in Sweden thus have little effect on the overall empirical finding. One important difference, however, is scale. The Suits index varies from around 0 to –0.10, while RS ranges only from about 0 to –0.0008, reflecting RS's sensitivity to the average tax rate and its design to capture large redistributive effects from income taxes and transfers. The 20:20 tax budget share ratio also shows a strong correlation between inequality and regressivity, with $r = -0.90$. Hence, the main results do not rely on the use of an index based on concentration curves.

5 Discussion

Our model provides policymakers concerned with distributional effects from consumption taxes with a useful framework to assess when complementary redistributive measures may be necessary.

Furthermore, our model and results may explain why carbon taxes were first introduced in the Nordic countries in the early 1990s.[18] Income inequality was historically low in the region at the time – with Gini coefficients in the low 20s – and policymakers thus didn't need to worry about possible regressive effects. However, since then, income inequality in high-income countries has risen, including in the Nordics, in some cases to levels not seen since the late 19th century (Piketty, 2014). Policymakers in high-income countries thus face two formidable long-term challenges: the need to mitigate climate change through emission reductions, and the social and economic effects of rising income inequality. To mitigate climate change with a carbon tax, the tax must target the goods responsible for the majority of emissions: transport fuel, food, heating, and electricity. These goods are, however, typically necessities and carbon taxation will thus likely be regressive in high-income countries, the more so the more unequal the distribution of income.

Implementing a global carbon price is challening, as countries may free-ride on the international public good. And, if growing income inequality increases the regresiveness of carbon taxation, this adds to the difficulties of reaching political cooperation and consensus also *within* countries. This is especially true for high-inequality countries as the equity argument against taxation becomes more salient, providing opportunities for opponents to attack the tax. High inequality also increases the need to offset the regressive impact by revenue recycling, such as lump-sum transfers or reductions of the payroll tax, and thus risk making the carbon tax policy more intricate.

That said, one could argue that high income inequality reflects a low societal preference for equality (Lambert, Millimet, and Slottje, 2003), suggesting that the regressive nature of fuel and carbon taxes may not be as politically contentious in highly unequal countries. Moreover, it's important to recognize that the type of good being taxed also matters. In low-income countries, transport fuel is often a luxury good, making fuel taxes progressive. In these cases, rising inequality would increase the progressivity of the tax.

6 Conclusion

This paper presents a simple model that shows how the two parameters of income inequality and the income elasticity of demand determine changes in the distributional effect of consumption taxes. The model predicts that transport fuel taxes should be progressive in

[18] Finland, Sweden, Norway, and Denmark all introduced carbon taxes between 1990-1992.

low-income, high-inequality countries and regressive in wealthier but unequal countries. Empirical analysis of Sweden's carbon tax on transport fuel and a cross-country study of gasoline taxation in high-income nations support these predictions, showing a strong correlation between inequality and tax progressivity.

Our findings provide a simple framework for policymakers to assess when complementary redistributive measures, such as lump-sum transfers, may be necessary. Furthermore, we highlight that the choice of income measure affects the assessment of tax progressivity by influencing the estimated level of inequality.

In addition to contributing to the debate on carbon and fuel taxation, our model informs broader discussions on the political economy of inequality and taxation. As inequality rises, the need for redistributive policies increases, and regressive consumption taxes become less politically viable. Ultimately, the paper provides a foundation for understanding the determinants of tax progressivity across countries and over time, offering insights for both economists and policymakers.

Future research should further test the model and findings by compiling a panel dataset on the distributional effects of gasoline taxation across countries. Various factors, such as the oil price, GDP per capita, unemployment, and public transport access, may influence tax progressivity. It would be informative to assess the role of income inequality alongside these other factors.

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A Appendix: Data Sources

- Household expenditure in Sweden 1999-2012. Source: Statistics Sweden (2019). The micro-data is only available through agreements with Statistics Sweden.

- Gini coefficients for Sweden. Measured using data on disposable income, excluding capital gains. Source: Statistics Sweden. Available at: statistikdatabasen.scb.se.

- Gini coefficients for OECD countries. Measured using data on disposable income (after tax and transfers). Source: The SWIID Database. Available at: https://fsolt.org/swiid/.

B Appendix: The Gini in Sweden

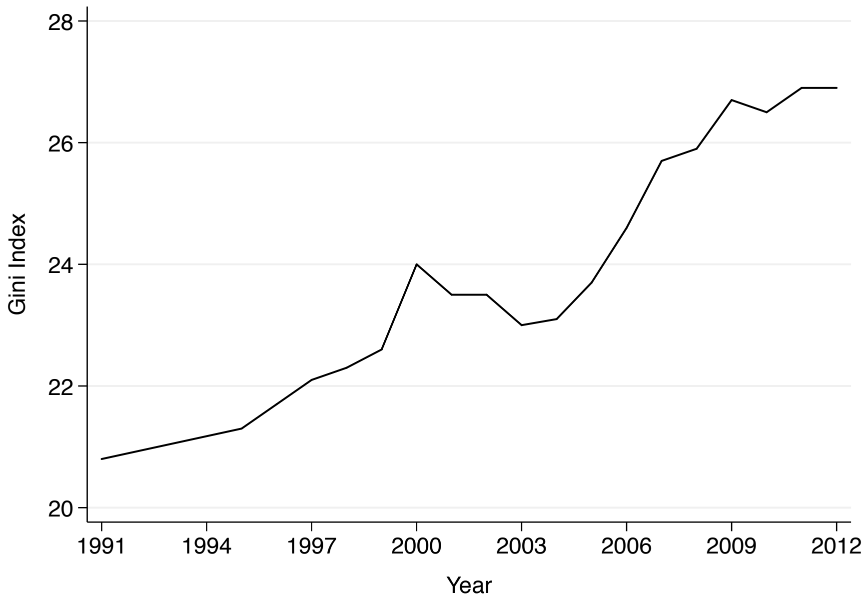
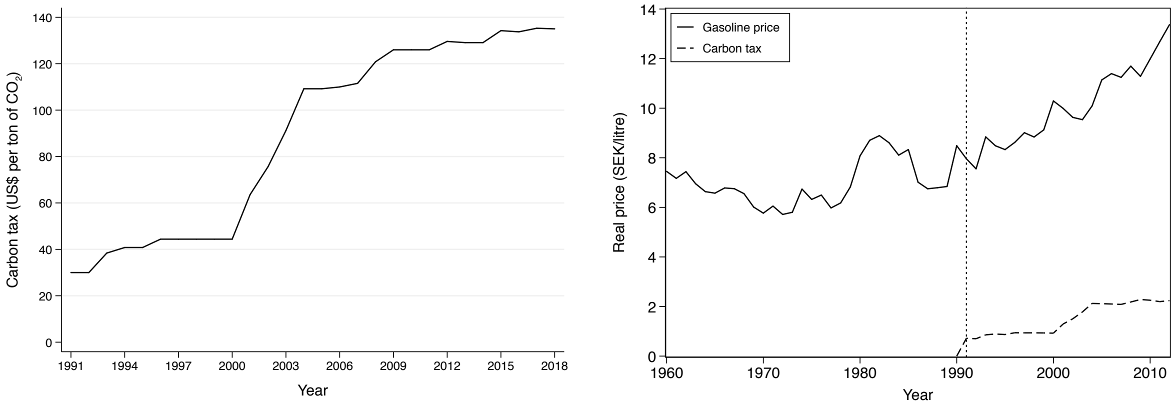


Figure 10: Gini coefficient in Sweden: 1991-2012

Note: The Gini coefficient is calculated using data on disposable income, excluding capital gains. There are missing values for the years 1992-1994. Source: Statistics Sweden.



(a) Carbon Tax Rate 1991-2018 (b) Real Gasoline Price 1960-2012

Figure 11: Carbon Tax Rate and Gasoline Price in Sweden

C Appendix: The Swedish Carbon Tax

In 1990, the Social Democratic government signed the carbon tax into law and implemented it in January of 1991. The tax was introduced at US$30 per ton of CO_2 and later increased quite rapidly in the early 2000s. Today, in 2024, the rate is above US$130 per ton of CO_2, making it the world's highest carbon tax imposed on households and non-trading sectors.

Figure 11 plots the carbon tax rate from 1991-2018 and the real price of gasoline in Sweden from 1960-2012. The real price increased from around 8 SEK per litre in 1991 to more than 13 SEK per litre in 2012. Of this increase, a bit more than 2 SEK is due to the carbon tax. During the same time period, new passenger cars sold in Sweden became increasingly fuel efficient (Swedish Transport Administration, 2017). In 1991, the average fuel efficiency of all cars sold was 9.2 liters per 100 kilometers (9.2 for gasoline and 7.1 for diesel). By 1999, fuel efficiency had improved to 8.3 liters per 100 km, and even further in 2012 to 5.5 liters per 100 km (6.1 for gasoline and 5.2 for diesel). As a result, between 1999-2012, Swedish households spent, on average, about 4 percent of their disposable income on transport fuel. The share is stable around 4 percent during the entire time period, but the variance across income deciles increases from 2008 onwards.

A study in 2003 by the Ministry of Finance (SOU, 2003:2) finds that, overall, the carbon tax is regressive when measured against annual disposable income. The main analysis uses a simulation approach to establish the possible effect of a doubling of the carbon tax rate in 1998, coupled with different forms of revenue recycling. The simulation builds on own- and cross-price elasticities of demand for transport fuel, public transport, heating, and "other goods", estimated using household survey data from the years 1985, 1988 and 1992. A later study, by Ahola, Carlsson, and Sterner (2009), uses empirical data on household expenditure in 2004-2006 and finds that the energy and carbon tax on

Table 2: USA vs. Sweden vs. OECD

			OECD		Ranking	
Variables	USA	Sweden	Mean	Median	USA	Sweden
GDP per capita	59532	50208	43594	41980	5th	11th
Income inequality	38.4	26.1	31.2	30.3	4th	29th
Urban population	82.1	87.4	77.9	80.1	14th	9th
Gasoline tax rate	14.0	114.0	91.5	95.0	1st	26th
Motor vehicles	786	525	528	565	1st	23rd
CO_2 from transport per capita	5.3	2.4	2.1	1.9	1st	10th
CO_2 total per capita	17.0	5.5	8.1	7.3	2nd	26th

Note: GDP per capita is adjusted for purchasing power (2017 data). Income inequality is measured as the Gini coefficient (most recent data available). Urban population is measured as percentage of total population (2017 data). Gasoline tax rate is measured in cents per litre (q4 of 2014). Number of motor vehicles are per 1000 people (2011 data). CO_2 emissions from transport, and the total, are measured in metric tons (2011 data). The last two columns ranks USA and Sweden in comparison to the entire sample of 36 OECD countries, from highest value to lowest. For the gasoline tax rate the ranking is from the lowest to the highest.

gasoline and diesel is regressive when measured against annual income, but progressive when measured against lifetime income.

The results in the studies by the Ministry of Finance (SOU, 2003:2) and Ahola et al. (2009) matches the stylized fact in economics that carbon and gasoline taxes are regressive. This result is found in a number of highly cited studies from the last thirty years. Note, though, that the majority of these studies share the characteristic that they use US data. And most of even older studies of environmental tax incidence, from the 1970s and 1980s, also use US data, and the general result in these studies are that environmental taxes are regressive (SOU, 2003:2). The potential issue, however, is that for variables that are arguably important for the redistributive effects of fuel taxes, US numbers are far from the average OECD country. USA is ranked in the top-5 of countries for the variables listed in Table 2, except for degree of urbanization. Access to public transport is also generally poorer in US cities compared to, for instance, cities in Europe (ITF, 2017), and access to public transport affects tax incidence by providing low-cost substitutes to gasoline and diesel for daily transportation. The results from US studies may thus have low external validity.

D Appendix: Data for Simulation

Table 3: Income Elasticities and Income and Expenditure Data for Simulation

Income decile	1	2	3	4	5	6	7	8	9	10	Average e_i
Unit-elastic	1	1	1	1	1	1	1	1	1	1	1
Necessity	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Heterogeneous	1.5	1.5	1	1	1	1	0.75	0.5	0.25	0.25	0.875
1999											
Disposable income	67	105	127	158	187	228	256	297	349	508	
Total expenditure	122	144	178	176	201	228	266	303	322	397	
Carbon tax expenditure	0.16	0.39	0.61	0.57	0.75	1.04	1.18	1.31	1.42	1.55	
Consumption units	1.28	1.26	1.43	1.56	1.96	2.31	2.31	2.80	2.85	2.93	
2009											
Disposable income	64	137	181	222	262	314	382	458	541	833	
Total expenditure	139	149	177	198	242	272	308	360	413	501	
Consumption units	1.09	1.14	1.17	1.36	1.45	1.58	1.84	1.97	2.16	2.28	

Note: The top part of the table gives the income elasticities of demand for transport fuel, across income deciles, that are used to simulate the distributional effect in 2009. The bottom part of the table gives the annual income and expenditure per household unit across the deciles in 1999 and 2009, measured in nominal Swedish kronor (thousands).

Table 3 lists the income elasticities used in the three simulated scenarios together with the survey data on disposable income and total expenditure in the years 1999 and 2009. There was a noticeable increase in income inequality during the time period: disposable income increased more than 60 percent for the top decile but decreased slightly for the poorest decile. Table 3 also reports the carbon tax expenditure for the year 1999, and using this data – together with the change in disposable income, total expenditure, and the assumed income elasticities – we can compute the carbon tax expenditure in 2009, and thus the simulated Suits index numbers that follow.

E Appendix: Gasoline Tax Progressivity and Lifetime Income

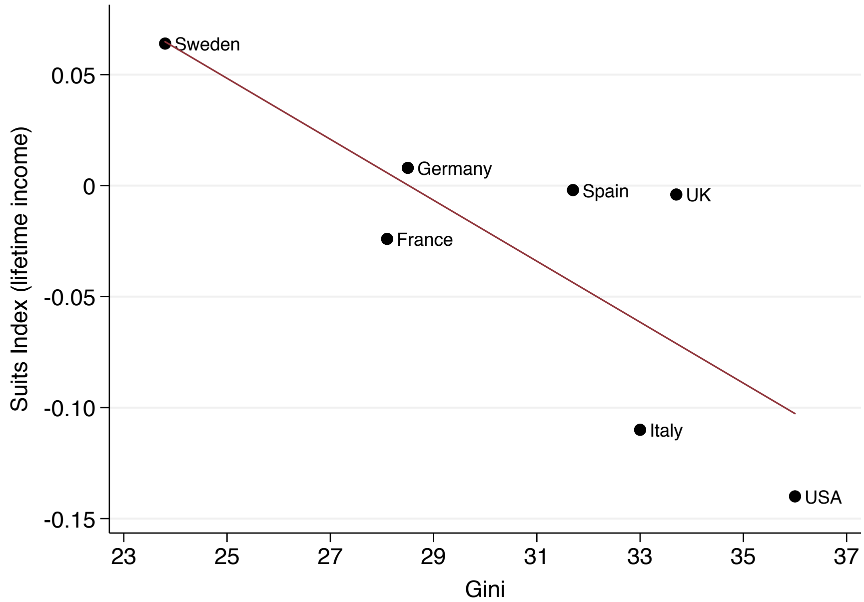


Figure 12: Gasoline Tax Progressivity and Income Inequality: OECD Countries and Lifetime Income

Note: The figure depicts the correlation between gasoline tax progressivity and income inequality across OECD countries, with $R^2 = 0.64$. Gasoline tax progressivity is measured using the Suits index and lifetime income.

Sources: The Suits index number for USA is taken from West and Williams III (2004) and the others are from Sterner (2012a). Gini coefficients: the SWIID database (Solt, 2019).

F Appendix: The Atkinson Index

The social welfare function in Atkinson (1970) is defined as:

$$W = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{x_i^{1-\eta}}{1-\eta} \right) \tag{20}$$

with $\eta \geq 0$ due to concavity. When $\eta = 1$, the function takes a log form.

The Atkinson Inequality Index is then calculated as:

$$AI = \begin{cases} 1 - \frac{1}{\bar{x}} \left(\frac{1}{N} \sum_{i=1}^{N} {x_i}^{1-\eta} \right)^{\frac{1}{1-\eta}} & \text{if } \eta \neq 1 \\ 1 - \frac{1}{\bar{x}} \left(\prod_{i=1}^{N} x_i \right)^{\frac{1}{N}} & \text{if } \eta = 1 \end{cases} \tag{21}$$

G Appendix: Three-Agent Extension

Consider now an economy composed of three types of households, labeled L, M, and H (low, middle, high). Income in time period t is $x^L(t)$, $x^M(t)$, and $x^H(t)$, and we assume that

$$x^L(t) < x^M(t) < x^H(t) \quad \forall\, t, \tag{22}$$

i.e., there is an existing level of inequality in the distribution of income, and the ranking is preserved over time (no re-ranking).[19]

Prices are fixed and p_i is normalized to unity. Both the tax rate and the tax-exclusive price are constant over time.[20] The budget share for good i for household $j \in \{L, M, H\}$ in period t is:

$$w_i^j(t) = \frac{q_i^j(t)}{x^j(t)}. \tag{23}$$

Following the same derivation as in the two-agent case, the growth rate of the budget share is:

$$g_w^j(t) = (1 + g_x^j(t))^{e_{i,w}^j} - 1 \approx e_{i,w}^j g_x^j(t), \tag{24}$$

where $e_{i,w}^j = e_i^j - 1$ is the income elasticity of the budget share, and e_i^j is the income elasticity of demand.

The distributional effect of the tax will remain unchanged if:

$$e_{i,w}^L g_x^L(t) = e_{i,w}^M g_x^M(t) = e_{i,w}^H g_x^H(t). \tag{25}$$

If, for a necessity good ($e_i < 1$), the income of higher-income households grows faster, then:

$$e_{i,w}^H g_x^H(t) < e_{i,w}^M g_x^M(t) < e_{i,w}^L g_x^L(t), \tag{26}$$

the tax will become increasingly regressive over time. Conversely, for a luxury good ($e_i > 1$), faster income growth for richer households will tend to make the tax more progressive.

In other words, with a constant tax rate τ on good i, the burden relative to income for group j is $\tau w_i^j(t)$. The tax becomes more regressive when the burden becomes more concentrated on lower-income groups, i.e. when w_i^L rises relative to w_i^M and w_i^H. Conversely, it becomes more progressive when the burden shifts away from lower-income groups.

[19] Households L, M, and H can be viewed as representing the bottom, middle, and top thirds of the income distribution, respectively. We treat group masses as fixed in the comparative-statics.

[20] If (Marshallian) own- and cross-price elasticities are invariant across income groups, common price changes affect budget shares proportionally, so our fixed-price assumption is then not needed.

Log-ratio analysis.—Now, define log-ratios of budget shares:[21]

$$\begin{aligned} \Delta \ln\left(\frac{w_i^H}{w_i^L}\right) &\approx e_{i,w}^H g_x^H - e_{i,w}^L g_x^L, \qquad \Delta \ln\left(\frac{w_i^M}{w_i^L}\right) \approx e_{i,w}^M g_x^M - e_{i,w}^L g_x^L, \\ \Delta \ln\left(\frac{w_i^H}{w_i^M}\right) &\approx e_{i,w}^H g_x^H - e_{i,w}^M g_x^M. \end{aligned} \tag{27}$$

If all three expressions in (27) are negative, the burden shifts toward the lower-income groups (regressivity increases). If all three are positive, the burden shifts toward the higher-income groups (progressivity increases). Mixed signs across the three ratios imply a polarized shift (burden reallocated toward or away from the middle), and the net change in overall progressivity is theoretically ambiguous without specifying distributional weights (e.g., via a progressivity index).

The first log-ratio in (27) corresponds to the two-agent case discussed in Section 2. The two additional ratios arise from the inclusion of the middle-income group. Their presence opens the possibility of mixed-sign patterns across the three ratios, which do not occur in the two-agent setting, and which underlie the polarization patterns and the resulting ambiguity (discussed further below).

It is convenient to collect the group-specific drivers:

$$\theta^j \equiv e_{i,w}^j \, g_x^j. \tag{28}$$

So that each log-ratio in (27) is a difference of two θ's. The direction of change in tax progressivity is then governed by the ranking of θ^j across income groups.

Heterogeneous elasticities: If e_i^j differ across groups, (27) and (28) gives the general condition:

$$\text{Tax becomes more regressive} \iff \theta^L \geq \theta^M \geq \theta^H \quad \text{(at least one strict)}, \tag{29}$$

and more progressive if the ordering is the reverse. Any non-monotone ordering creates a more ambiguous result, e.g. θ^M largest with θ^L and θ^H relatively smaller, where the middle group's burden increases relatively more.

Uniform elasticity: If $e_i^L = e_i^M = e_i^H = e_i$, (and $e_i \neq 1$), then $e_{i,w}^j = e_i - 1$ is common across groups. With income growth ordered $g_x^L \leq g_x^M \leq g_x^H$ (at least one strict):

- If $e_i < 1$ (the good is a necessity), then $\theta^L \geq \theta^M \geq \theta^H$ (at least one strict), the relative burden shifts more toward low-income groups and regressivity increases.
- If $e_i > 1$ (luxury), the inequalities reverse and the tax becomes more progressive.

[21] For ease of exposition, we hereafter drop the time script t.

Numerical example with uniform elasticity:

Table 4: Income inequality increases

Household	$x(t)$	g_x	e_i	$e_{i,w}$	θ^j
L (low)	20	0.01	0.8	-0.2	-0.002
M (mid)	50	0.02	0.8	-0.2	-0.004
H (high)	100	0.03	0.8	-0.2	-0.006

In the necessity-good case ($e_i < 1$) in Table 4, we have growing income inequality and the budget share falls fastest for the richest group (H), indicating that the tax becomes more regressive as inequality rises. We can use the log-ratios to confirm that this is indeed the case. We have

$$\theta^L = -0.002, \quad \theta^M = -0.004, \quad \theta^H = -0.006,$$

so

$$\Delta \ln\left(\tfrac{w^H}{w^L}\right) = \theta^H - \theta^L = -0.004, \quad \Delta \ln\left(\tfrac{w^M}{w^L}\right) = -0.002, \quad \Delta \ln\left(\tfrac{w^H}{w^M}\right) = -0.002,$$

all negative: regressivity increases.

G.1 Polarization and tax progressivity

We can use the example of income polarization to demonstrate how mixed signs of the log-ratios create ambiguity about the direction of tax progressivity changes.

In line with Esteban and Ray (1994) and Wolfson (1994), we interpret income polarization as a form of bimodalization: the middle group's income grows least relative to both tails ($g_x^H > g_x^M$ and $g_x^L > g_x^M$), so that its income share shrinks while both the top and bottom shares expand ($\Delta s^M < 0$, $\Delta s^L > 0$, $\Delta s^H > 0$).

Table 5: Income polarization

Household	$x(t)$	g_x	e_i	$e_{i,w}$	θ^j	Δs^j
L (low)	20	0.05	0.8	-0.2	-0.010	> 0
M (mid)	50	0.01	0.8	-0.2	-0.002	< 0
H (high)	100	0.06	0.8	-0.2	-0.012	> 0

In Table 5 we have income polarization and uniform elasticity. Here, a tax on a necessity yields $\theta^L < \theta^M$ and $\theta^M > \theta^H$, implying

$$\Delta \ln\left(\frac{w^H}{w^L}\right) = \theta^H - \theta^L = -0.002 < 0, \quad \Delta \ln\left(\frac{w^M}{w^L}\right) > 0, \quad \Delta \ln\left(\frac{w^H}{w^M}\right) < 0,$$

so the relative burden shifts away from L toward M (progressivity increases in the bottom to middle part of the distribution), and from H toward M in the opposite part of the distribution (regressivity increases when measured from the middle to the top). The middle is thus "squeezed" between the tails – i.e., a polarization pattern centered on M.

The net effect on the change in tax progressivity is theoretically ambiguous and depends not only on the relative differences in income growth and income elasticities, but also on any differential weights we give to households in the different parts of the income distribution (our social welfare function). In practice, such distributional weights can be specified by a progressivity index, such as the Suits (1977) and Kakwani (1977) indices. In some cases, however, the two indices may produce conflicting verdicts on the direction of the change in tax progressivity, depending on the different weights they apply to households across income (Formby, Seaks, and Smith, 1981). In other words, polarization redistributes income away from the middle toward both extremes, and with a tax on a necessity the tax burden increases relatively more for the middle compared to the top and bottom, which does not translate into a clear-cut change toward greater regressivity or greater progressivity without specifying which segment of the distribution is emphasized.

Lastly, note that in the three-agent framework, ambiguous effects on tax progressivity measures are more likely to arise when income elasticities differ across groups ($e_i^L \neq e_i^M \neq e_i^H$). Under uniform elasticities, changes in the θ^j terms are driven entirely by differences in income growth rates, which constrains the possible sign patterns in (27). Heterogeneous elasticities relax this restriction, allowing changes to θ^j to stem from differences in both growth rates and elasticities.

H Appendix: Engel Curve Data

Table 6: Average gasoline consumption and disposable income: 1999-2012

Decile	1	2	3	4	5	6	7	8	9	10
Gasoline consumption	284	416	489	560	580	627	632	701	697	747
Real disposable income	66314	108801	126661	138194	148128	156296	166500	177790	199174	296248

Note: Data are averages over the period 1999–2012 and reported per consumption unit in each income decile. Gasoline consumption is measured in liters. Real disposable income is expressed in 2005 Swedish kronor (SEK).